Trident Capacity Use Area
2022 Groundwater Evaluation Report

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S.C. Department of Health and Environmental Control

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Contents

List of Figures

List of Tables

Introduction

The Trident Capacity Use Area (Trident Area), which includes the whole of Berkeley County, Charleston County, and Dorchester County, was the third of six currently designated areas of South Carolina's Coastal Plain to be incorporated into the Capacity Use Program. In the parts of the state designated as a Capacity Use Area, a groundwater withdrawer is defined as, "*a person withdrawing groundwater in excess of three million gallons during any one month from a single well or from multiple wells under common ownership within a one-mile radius from any one existing or proposed well"* (Groundwater Use and Reporting Act, 2000).

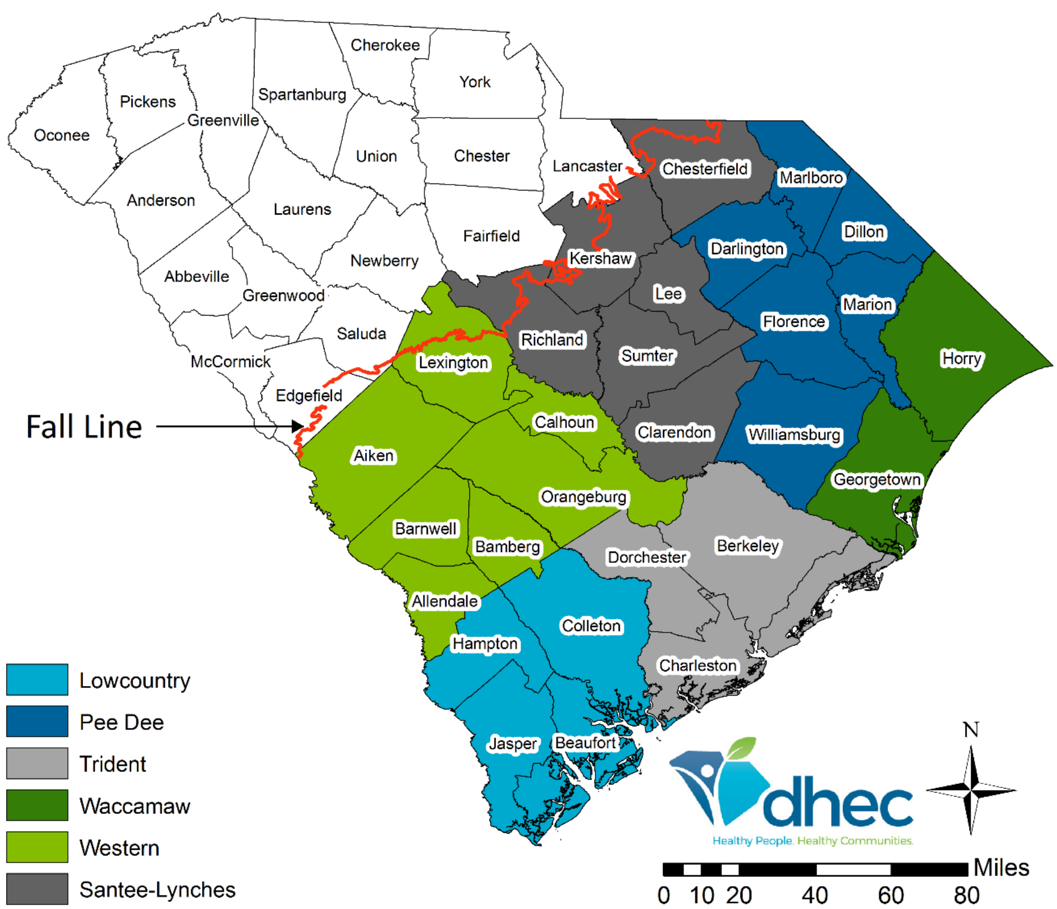

Figure 1. Map of SC DHEC Capacity Use Areas.

Regulatory History

In 1967, the S.C. Water Resources Planning and Coordination Act (Water Resources Act) established the S.C. Water Resources Commission (the Commission), which designated the Waccamaw Area (Horry and Georgetown Counties and the Brittons Neck of Marion County) as the first Capacity Use Area in 1979. In 1993, under the Water Resources Act, the responsibilities of the Commission were distributed so that water permitting tasks went to the S.C. Department of Health and Environmental Control (DHEC) and water planning tasks went to the S.C. Department of Natural Resources (DNR), and the Commission was dissolved. In 2000, the South Carolina Code of Laws (Title 49, Section 5) were revised to include what is now the current Groundwater Use and Reporting Act (Groundwater Use and Reporting Act, 2000). Significant changes enacted by the new law were 1) groundwater assessments to determine the necessity of establishing a Capacity Use Area could be initiated by DHEC as well as requested by local governments or non-governmental organizations within the state; and 2) a Groundwater Management Plan was now required for each Capacity Use Area. The Capacity Use Areas and associated counties were designated in the following order:

- **Waccamaw Area (1979):** Georgetown and Horry Counties, and Brittons Neck of Marion County
- **Lowcountry Area (1981):** Beaufort, Colleton, and Jasper Counties
- **Trident Area (2002):** Berkeley, Charleston, and Dorchester Counties
- **Pee Dee Area (2004):** Darlington, Dillon, Florence, Marion (including Brittons Neck, leaving only Georgetown and Horry Counties in the Waccamaw Area), Marlboro, and Williamsburg Counties
- **Lowcountry Area (2008):** Addition of Hampton County
- **Western Area (2018):** Aiken, Allendale, Bamberg, Barnwell, Calhoun, Lexington, and Orangeburg Counties
- **Santee-Lynches Area (2021):** Chesterfield, Clarendon, Kershaw, Lee, Richland, and Sumter Counties

The initial Trident Groundwater Management Plan (TGMP) (Berezowska & Monroe, 2017) was approved by the DHEC Board of Directors on May 12, 2017. The stated goals of the TGMP are to:

1. Ensure sustainable development of the groundwater resource by management of groundwater withdrawals.
2. Protect groundwater quality from salt-water intrusion.
3. Monitor groundwater quality and quantity to evaluate conditions.

The TGMP addressed achieving these goals by evaluating the following aspects of groundwater use in the Trident Area:

- Groundwater sources currently utilized.
- Current water demand by type and amount used.
- Current aquifer storage and recovery, and water reuse.
- Population and growth projections.
- Water demand projections.
- Projected opportunities for aquifer storage and recovery, as well as water reuse.
- Projected groundwater and surface water options.
- Water conservation measures.

Following the guidelines set forth in the TGMP, this document provides an evaluation of current groundwater use and recommendations for its management.

Hydrogeologic Framework

Physiographic Provinces

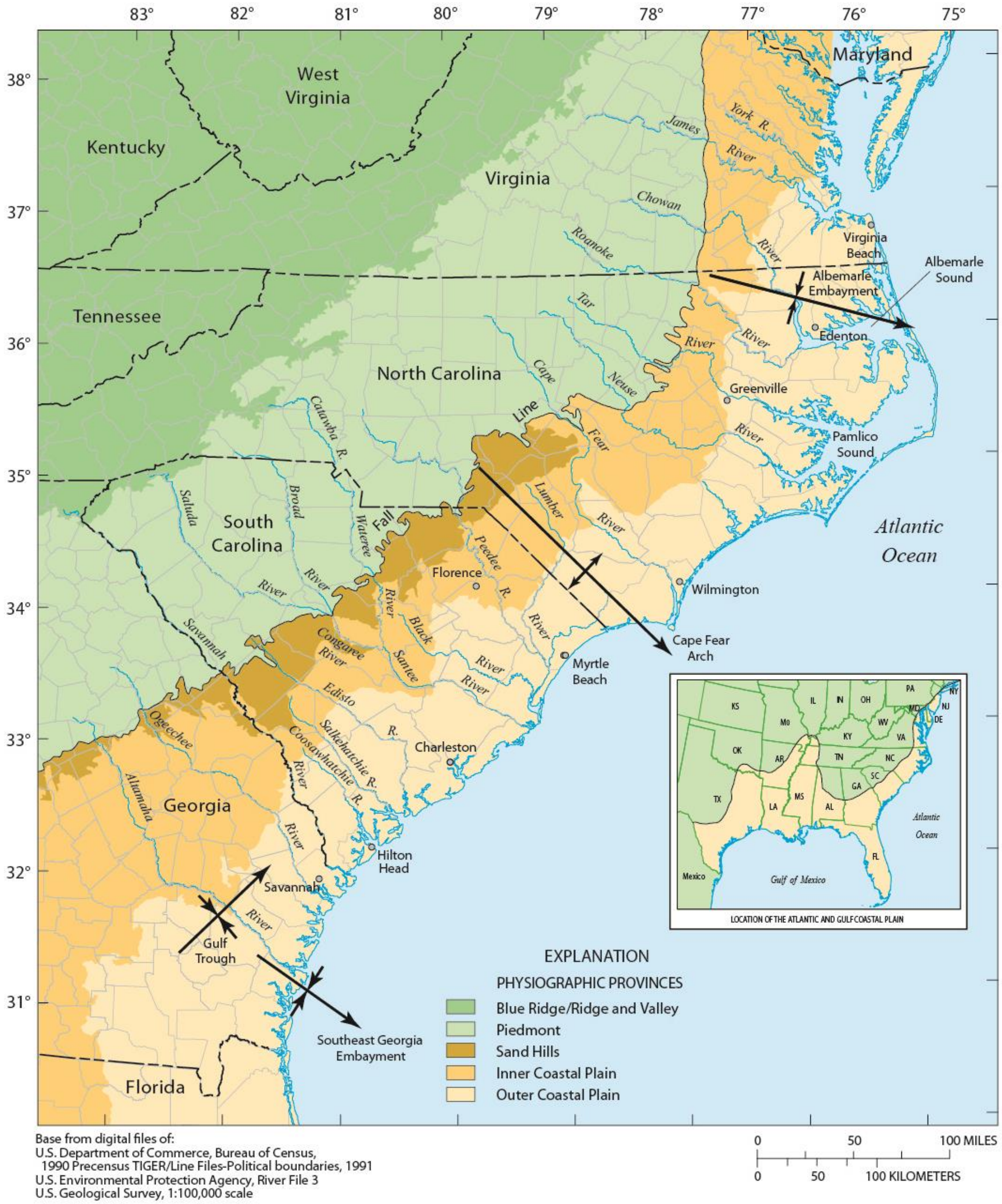

Figure 2. Map of the Atlantic Coastal Plain from North Carolina to Georgia. Inset map indicates the extent of the entire Atlantic and Gulf Coastal Plain. U.S. Geological Survey (usgs.gov/media/images/atlantic-coastal-plain-maryland-florida); accessed May 20, 2022.

The Coastal Plain of South Carolina (CPSC) is part of the larger Atlantic Coastal Plain (ACP). The ACP's northern boundary is in New Jersey and the southern boundary is in Florida. From east to west, the ACP extends from the Fall Line to the coastline with three regions that run roughly parallel to the Atlantic Coastline (Fig. 2).

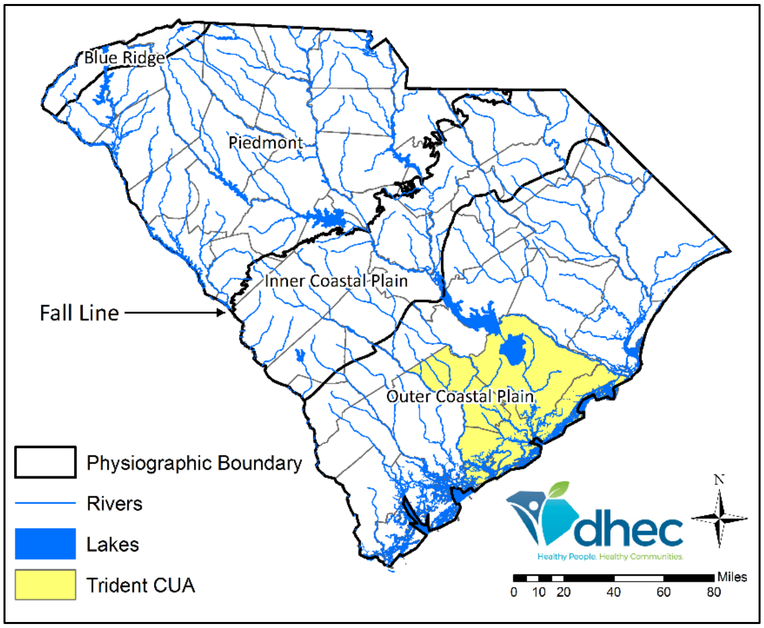

Figure 3. Map of the South Carolina physiographic provinces with the Trident Area highlighted yellow.

The CPSC is typically divided into two regions: the Inner Coastal Plain and the Outer Coastal Plain. The Inner Coastal Plain includes the Sandhills Region, and the Outer Coastal Plain is identical to that of the ACP. The Trident Area is located entirely within the Outer Coastal Plain which is characterized by a series of terraces dissected by numerous streams (Fig. 3). The topography of the Trident Area is low relief with elevations ranging from sea level to about 130 feet. Due to the low relief, Charleston County experiences frequent inundation from tidal storm surges and river flooding (Park, 1985). Both groundwater and surface water sources are available and utilized by water withdrawers, but the majority of the surface water intakes in the Trident Area are located in Berkeley and Dorchester Counties as the surface water sources in Charleston County are heavily influenced by the tides and are therefore too salty for most uses.

Aquifers

The hydrogeologic framework of the CPSC consists of wedge-shaped stratigraphy divided into alternating layers of water-bearing, permeable sand, or carbonate deposits (aquifers) with layers of fine-grained clays, silts, or low-permeability carbonate deposits (confining units) (Fig. 4) (Gellici & Lautier, 2010). The hydrogeologic units underlying the CPSC were deposited during the late Cretaceous to Tertiary Periods. From oldest to youngest, the Cretaceous units are the Gramling, Charleston, McQueen Branch, and Crouch Branch (Gellici & Lautier, 2010). The Tertiary units, in the same chronological order, are the Gordon, Floridan (further divided into the Middle Floridan and Upper Floridan), and Surficial (Fig. 4).

The Cretaceous units are present below all three Trident Area counties, except for the McQueen Branch Aquifer which is not present below a small portion of southern Charleston County. Of the Tertiary Units, the Gordon Aquifer is present below all three counties in the Trident Area, but the Middle Floridan Aquifer only exists below northern Dorchester County and a small portion of southwestern Berkeley County; the Upper Floridan Aquifer is not present below the Trident Area (Wachob, Gellici, & Czwartacki, 2017).

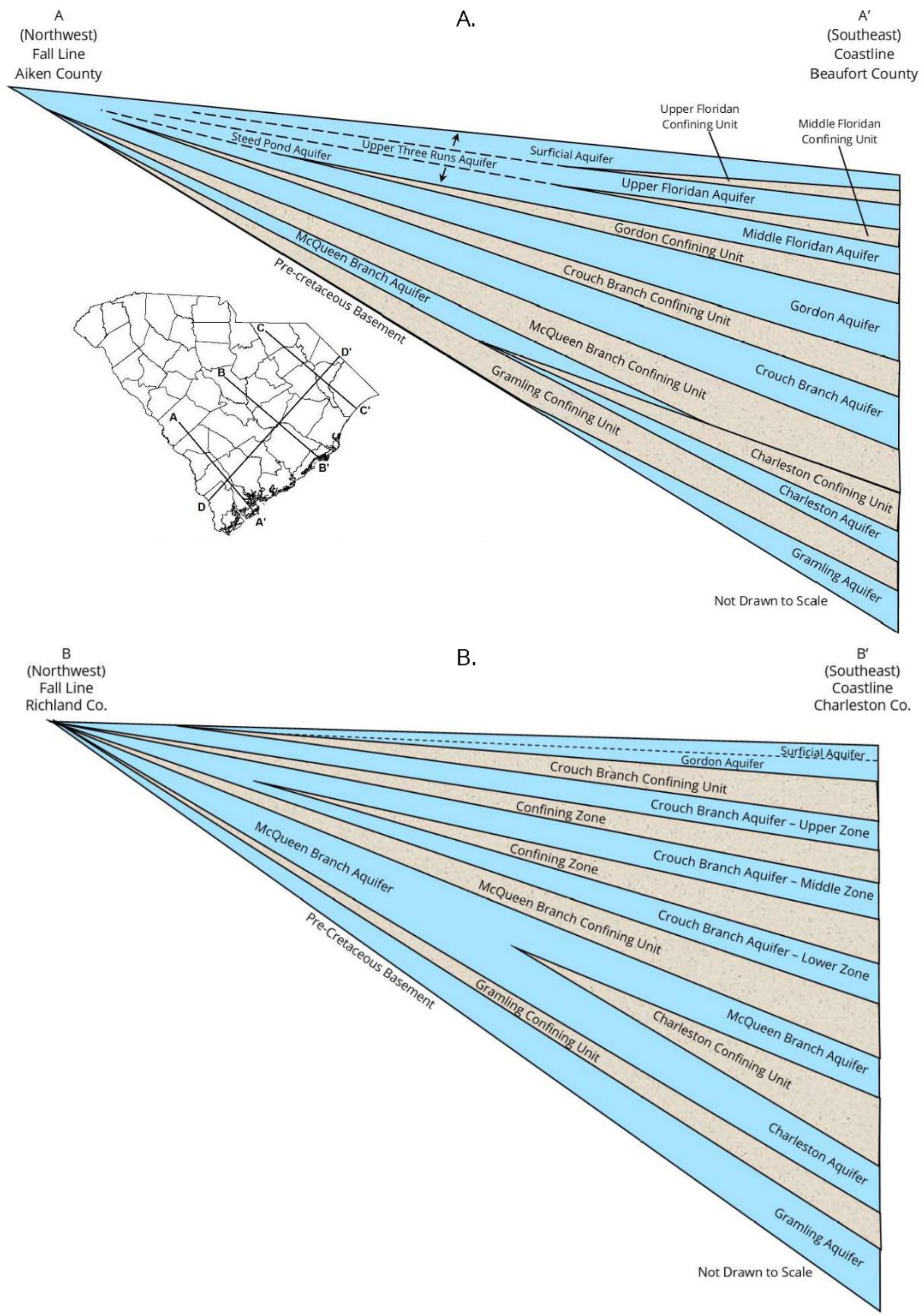

Figure 4. Generalized cross-sections of CPSC stratigraphy. Inset map shows the locations of the four (4) cross-sections. A. The A to A' line; B. The B to B' line; C. The C to C' line; and D. The D to D' line (Campbell & Coes, 2010).

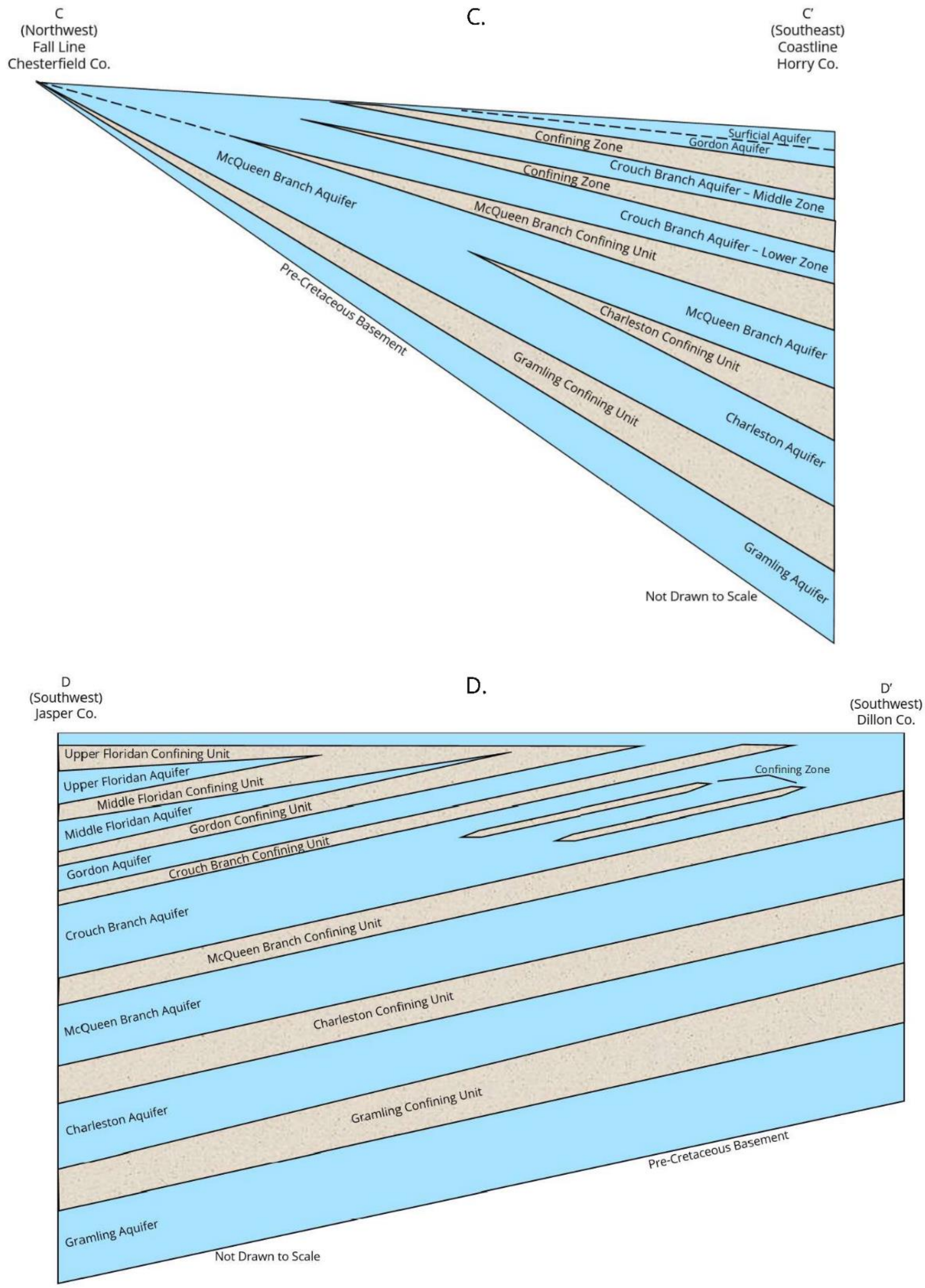

Figure 4, continued.

Recharge Areas

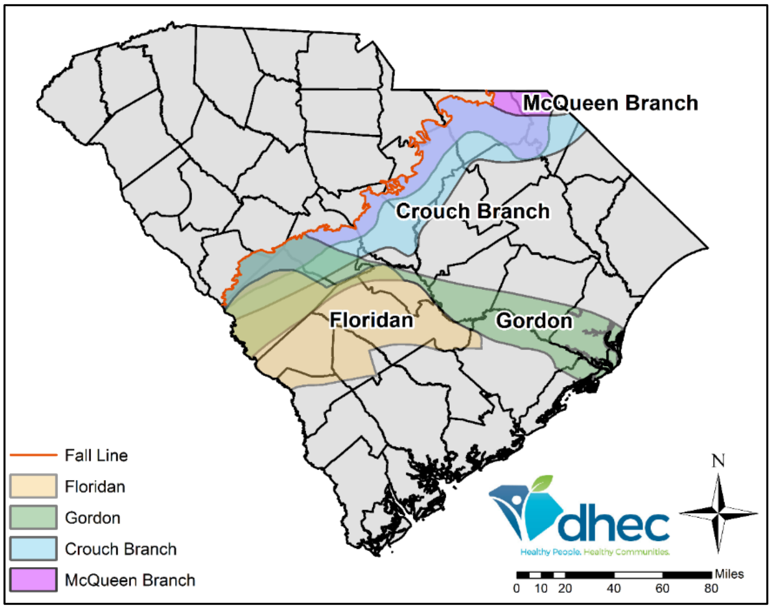

Figure 5. Map indicating the location and extent of the CPSC aquifer recharge areas.

The recharge areas for South Carolina's aquifers are primarily located within the Inner Coastal Plain (Fig. 5). The surficial aquifer receives direct recharge through infiltration of local precipitation and surface water bodies. Groundwater in the deeper aquifers is primarily replenished by precipitation and surface water infiltration in the recharge areas. Water enters the system in the recharge areas, then moves slowly 'down-dip' through the hydrogeologic framework towards the Atlantic Ocean. Consequently, the rate at which groundwater is replenished in the deeper aquifers of the Trident Area is largely controlled by the rate at which groundwater travels from the recharge zones near the Fall Line and the transmissivity of the aquifer. Typical groundwater flow rates for silts to well-sorted sands range from 0.003 to 300 feet per day (Fetter, 2001). This means that once the precipitation becomes part of the groundwater system, it may take anywhere from a few years to tens of thousands of years to reach some locations below the Trident Area.

Surface Water

The Trident Area spans portions of the Santee and Edisto River Basins in South Carolina (Fig. 6). Surface water sources are primarily rivers and streams, but locally impounded waters are used for irrigation as well. The Edisto and the Santee rivers flow through this area, defining the boundaries to the northeast (Santee) and the southwest (Edisto) (Fig. 7).

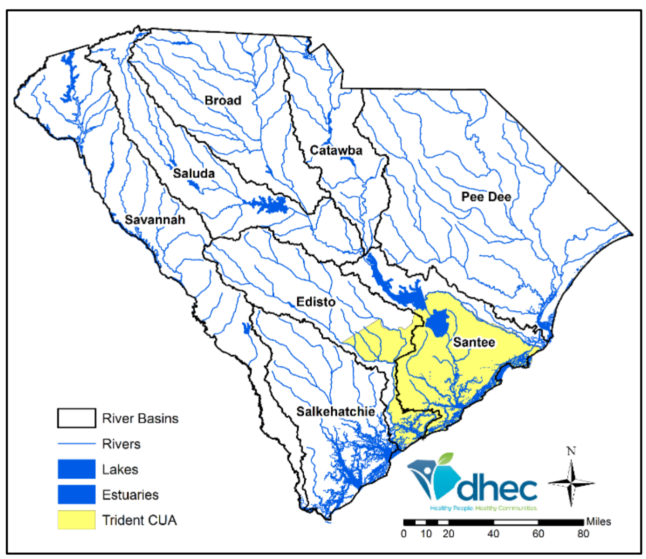

Figure 6. Surface water map of South Carolina with the Trident Area highlighted yellow.

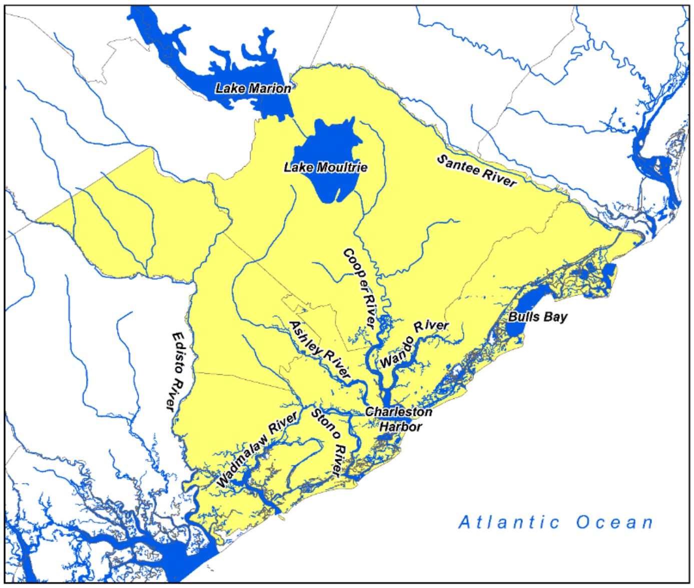

Figure 7. Detailed map of the surface water available within the Trident Area.

Other major rivers that originate or flow through the Trident Area are the Ashley, Cooper, Stono, Wadmalaw, and Wando Rivers. Although rivers and streams are abundant in the Trident Area, majority of the surface water intakes are located upstream in Berkeley and Dorchester Counties, out of the tidally influenced portions of the rivers.

Current Groundwater Demand

In 2021 there were 50 facilities that reported water use from 100 wells in the Trident Area counties. Of the permitted wells, 30 are permitted for water supply (30%), followed by industry and irrigation with 23 permitted wells each (23% each), golf course (20%), and thermopower (4%). No wells were permitted for aquaculture, mining, hydropower, nuclear power, or other. More than half of the permitted wells are in Dorchester County (55%), followed by Charleston County (25%), and Berkeley County (20%) (Table 1, Fig. 8).

Table 1. Trident Area Capacity Use Wells by County and Use Category

Use Category	Berkeley	Charleston	Dorchester	Total (%)
Aquaculture (AQ)	0	0	0	0 (0%)
Golf Course (GC)	5	12	3	20 (20%)
Industry (IN)	10	3	10	23 (23%)
Irrigation (IR)	1	1	21	23 (23%)
Mining (MI)	0	0	0	0 (0%)
Other (OT)	0	0	0	0 (0%)
Hydropower (PH)	0	0	0	0 (0%)
Nuclear Power (PN)	0	0	0	0 (0%)
Thermopower (PT)	0	0	4	4 (4%)
Water Supply (WS)	4	9	17	30 (30%)
Total (%)	20 (20%)	25 (25%)	55 (55%)	100 (100%)

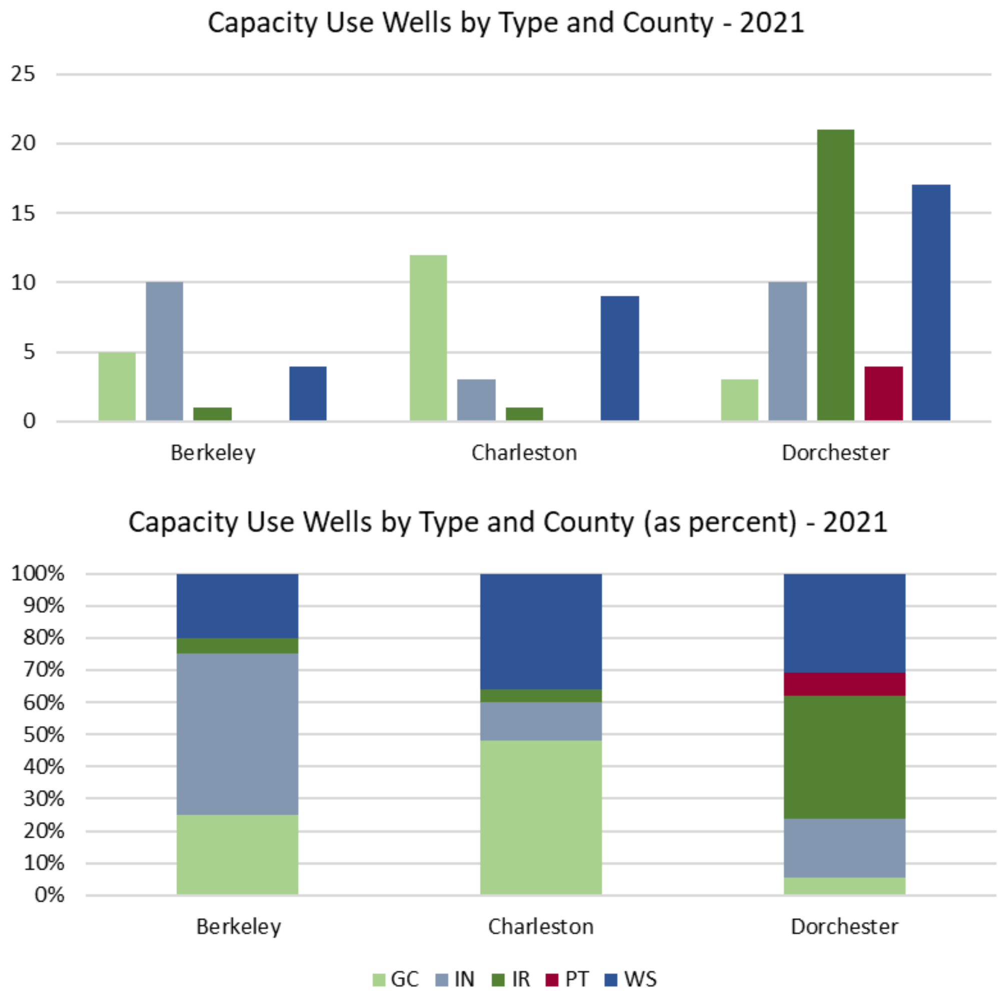

Figure 8. Graphs of Trident Area Permitted Wells by Type and County – 2021. A. Number of each well type by county, and B. Each well type presented as a percent of the total by county.

A total of 4,566.89 million gallons (MG) (or 4.567 billion gallons) was reported for groundwater use during 2021 for the Trident Area (Table 2, Fig. 9). The largest volume of groundwater use reported was for public water supply at 42% of the total. Industry was the next largest reported water use category at 35%, followed by golf course (11%), irrigation (10%), and thermopower (2%).

Table 2. Reported Water Use (MG) by County and Use Category

Use Category	Berkeley	Charleston	Dorchester	Total (%)
Aquaculture (AQ)	0	0	0	0 (0%)
Golf Course (GC)	16.22	441.77	22.67	480.66 (11%)
Industry (IN)	1,200.56	46.39	349.27	1,596.22 (35%)
Irrigation (IR)	10.00	3.50	448.66	462.16 (10%)
Mining (MI)	0	0	0	0 (0%)
Other (OT)	0	0	0	0 (0%)
Hydropower (PH)	0	0	0	0 (0%)
Nuclear Power (PN)	0	0	0	0 (0%)
Thermopower (PT)	0.00	0.00	107.50	107.50 (2%)
Water Supply (WS)	37.42	1,529.43	353.51	1,920.36 (42%)
Total (%)	1,264.20 (28%)	2,021.08 (44%)	1,281.61 (28%)	4,566.89 (100%)

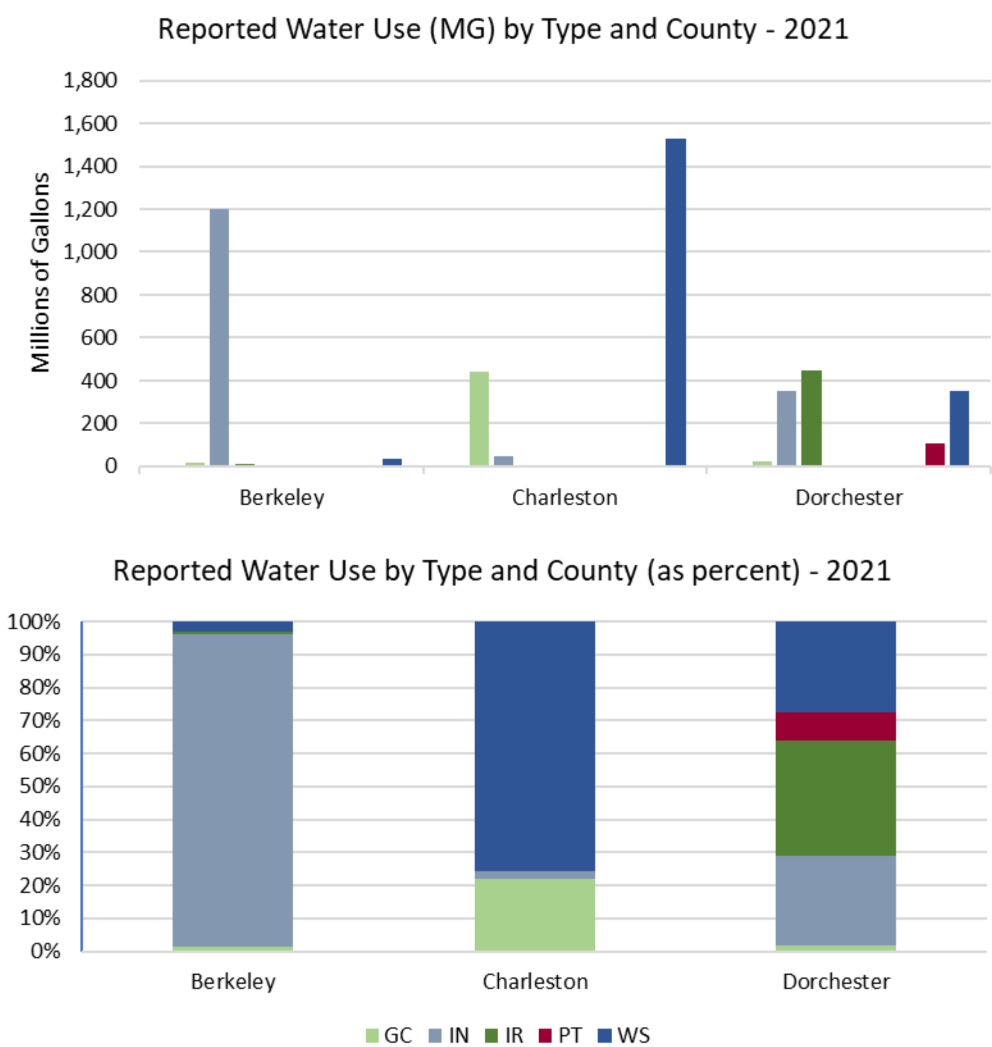

Figure 9. Graphs of 2021 Reported Water Use by County and Use Type. A. Reported water use for each county in millions of gallons. B. Reported water use as a percent of the total for each county.

Industry is the category with the largest demand on groundwater in Berkeley County, and water supply and irrigation are the leading categories on groundwater demand in Charleston and Dorchester counties, respectively (Table 2, Fig. 9). Water supply accounts for 42% of current demand for the entire region. Of the three Trident Area counties, Charleston has the largest demand on groundwater at 44%, and Berkeley and Dorchester account for 28% each (Table 2).

Berkeley County Details

Berkeley County has 13 permitted facilities with a total of 20 capacity use wells. Note that each permitted facility is owned or operated by a groundwater withdrawer and there are groundwater withdrawers that own or operate more than one permitted facility, some of which have the same name. The total reported withdrawals for 2021 were 33% of the total permitted annual withdrawal limits for the county. The largest source of groundwater for Berkeley County is the Charleston Aquifer supplying 88% (1,120.85 MG) of the total reported water use for 2021 (Table 3).

Table 3. Permit Limits and 2021 Reported Water Use – Berkeley County

Facility	Permit No.	Permitted Limit per Year (MGY)	Reported Water Use in 2021 (MGY)	Aquifer(s)
Berkeley Country Club	08GC001	24	3.3 0	Surficial Crouch Branch
Joint Base Charleston/ Red Bank Plantation GC	08GC005	48	2.10	Crouch Branch
City of Goose Creek/ Crowfield Golf and Country Club	08GC006	25	10.82	Gordon
Albany International Corporation, Press Fabrics	08IN002	48	32.55	Charleston
CR Bard, Inc.	08IN007	103	70.29	Gordon
NUCOR STEEL BERKELEY PLANT	08IN011	1,300	0.76 1,085.56	Crouch Branch Charleston
Maguro Enterprises, LLC	08IN015	549	2.74	Charleston
United States Air Force, NNPTC - B.2409 Utility Plant	08IN016	30	8.67	Gordon
Titan Farms	08IR004	31	10.00	Gordon
Moncks Corner Water Works	08WS003	288	4.55	Gordon
NUCOR STEEL BERKELEY PLANT	08WS058	1,300	0.00	Crouch Branch
SC Dept of Corrections Division of Facilities Management	08WS064	50	37.42	Gordon
Berkeley County Water and Sanitation	08WS066	36	0.03	Gordon
	TOTALS	**3,832**	**1,268.77**	

Charleston County Details

Charleston County has 13 permitted facilities with a total of 25 capacity use wells. The total reported withdrawals for 2021 were 49% of the total permitted annual withdrawal limits for the county. The largest source of groundwater for Charleston County is the Charleston Aquifer supplying 96% (1,945.48 MG) of the county's total reported water use for 2021 (Table 4).

Table 4. Permit Limits and 2021 Reported Water Use – Charleston County

Facility	Permit No.	Permitted Limit per Year (MGY)	Reported Water Use in 2021 (MGY)	Aquifer(s)
Kiawah Island Utility Inc.	10GC002	175	69.48	Charleston
LRA Charleston PP Golf, LLC	10GC003	23	10.22	Charleston
Kiawah Resort/Osprey Point GC	10GC015	100	66.50	Charleston
Kiawah Island Inn Company, LLC/The Ocean Course	10GC020	113	110.44	Charleston
Kiawah Resort Associates, LP/Cassique GC	10GC021	275	150.13	Charleston
Briar's Creek Holdings, LLC/The Golf Club at Briar's Creek	10GC052	140	0.00	Gramling
LINKS THE @ STONO FERRY	10GC053	50	3.5 31.5	Gordon Crouch Branch
Ingevity South Carolina, LLC/Charleston Chemical Plant	10IN010	71	17.74 28.65	Gordon Crouch Branch
Carolina Park Riverside Association, LLC	10IR061	259	3.50	Crouch Branch
Seabrook Island Utility Commission	10WS003	220	142.01	Charleston
Mt Pleasant Waterworks	10WS006	2,409	1277.26	Charleston
Town of Sullivan Island Water & Sewer Department	10WS007	108	1.66	Gramling
Isle of Palms Water & Sewer Commission	10WS010	200	119.45	Charleston
	TOTALS	**4,143**	**2,032.03**	

Dorchester County Details

Dorchester County has 24 permitted facilities with a total of 55 capacity use wells. The total reported withdrawals for 2021 were 31% of the total permitted annual withdrawal limits for the county. The largest source of groundwater for Dorchester County is the Crouch Branch Aquifer supplying 67% (947.52 MG) of the total reported water use for 2021 (Table 5).

Table 5. Permit Limits and 2021 Reported Water Use – Dorchester County

Facility	Permit No.	Permitted Limit per Year (MGY)	Reported Water Use in 2021 (MGY)	Aquifer(s)
Legend Oaks Golf Operations, LLC	18GC004	20	10.00	Gordon
City of North Charleston/ The Golf Club at Wescott Plantation	18GC051	50	12.67	Gordon
Giant Cement Company/ Harleyville Plant	18IN001	308	2.57 185.48	Gordon Crouch Branch
SHOWA DENKO INC	18IN002	190	111.41	Gordon
ARGOS Cement LLC/Harleyville Plant	18IN040	250	26.62 23.18	Surficial Gordon
Ham Bone Farm, LLC	18IR002	36	5.8 21.5	Gordon Crouch Branch
Infinger Farms Partnership	18IR003	235	228.20	Crouch Branch
J & C Farms	18IR004	98	19.30	Gordon
J. H. Westbury and Sons	18IR007	182	50.20	Crouch Branch
Gunter Farms	18IR008	120	22.50	Gordon
Pendarvis Farms	18IR009	328	52.86	Crouch Branch
Fender Farms	18IR010	79.5	10.30	Gordon
Weathers Farms	18IR011	150	38.00	Crouch Branch
Dorchester Biomass, LLC	18PT001	198	0.08 107.42	Gordon Crouch Branch
Summerville CPW	18WS001	1210	8.06	Charleston
St. George Water Department	18WS002	168	115.13	Crouch Branch
Town of Harleyville	18WS003	36	28.40	Gordon
DCWA/KNIGHTSVILLE	18WS005	650	140.7 59.6	Crouch Branch Gramling
DCWA/Reevesville	18WS006	15	8.67	Gordon
DCWA/Conoflow	18WS008	175	8.03	Crouch Branch
DCPW/EDISTO TRIBAL COUNCIL	18WS010	30	29.29	Gordon
SC Depart of Corrections Division of Facilities Management	18WS011	97	68.47	Gordon
Giant Cement Company/ Harleyville Plant	18WS014	15	1.53	Gordon
Dorchester County Water & Sewer	18WS016	33	23.90	Gordon
	TOTALS	**4,653.50**	**1,419.86**	

Aquifer Demand Details

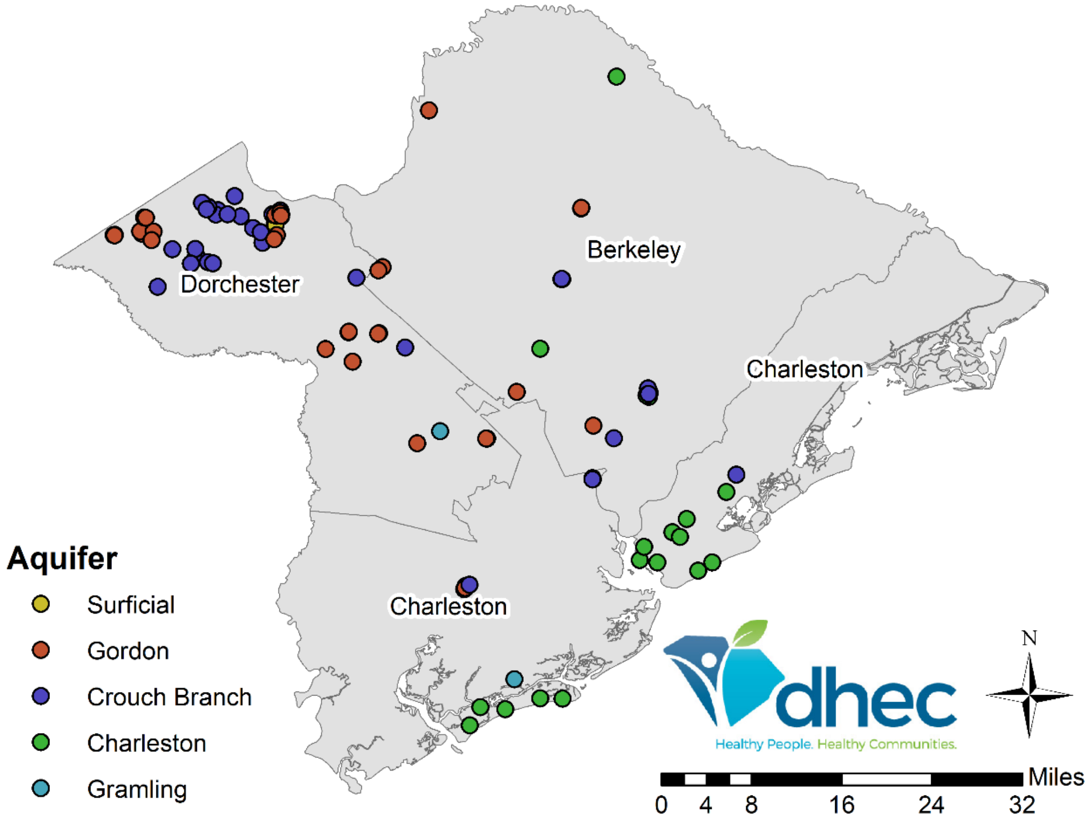

Figure 10. Trident Area map showing the locations of capacity use wells with reported water use for 2021. Different symbol colors represent the aquifer into which each well is screened.

In terms of number of wells, the Gordon Aquifer is the most heavily accessed aquifer in the Trident Area (41, 41%) followed by the Crouch Branch (34, 34%), Charleston (19, 19%), Surficial (4, 4%), and the Gramling Aquifer (2, 2%). The most heavily used aquifer in terms of groundwater demand as reported for 2021 is the Charleston Aquifer (67%) followed by the Crouch Branch (20%), Gordon (11%), and the Gramling and Surficial Aquifers (~1% each). The Charleston Aquifer wells are primarily located in Charleston County, and the Surficial, Gordon, and Crouch Branch Aquifer wells are primarily in Dorchester County (Figure 10, Table 6).

Table 6. Number of Wells and 2021 Reported Water Use by Aquifer – Trident Area

Aquifer	Number of Wells (%)	2021 Water Use MG (%)
Surficial	4 (4%)	29.92 (0.66%)
Gordon	41 (41%)	512.61 (11.22%)
Crouch Branch	34 (34%)	907.72 (19.88%)
Charleston	19 (19%)	3,057.04 (66.94%)
Gramling	2 (2%)	59.6 (1.31%)
TOTAL	**100 (100%)**	**4,566.89 (100%)**

Historic Reported Water Use: 2001 – 2021

Water use within the Trident Area has remained relatively constant over the past 20 years (2001 through 2021). From 2002 through 2005, there was an increase in water supply withdrawals. These increases correspond to the longest duration of drought in the Trident Area since 2000 (National Integrated Drought Information System, 2022). Reported water use increased slightly in 2014 and has remained relatively constant ever since. The initial increases in reporting were due to the addition of thermopower and irrigation wells in the Trident Area in 2013. Reported use from these sectors has remained relatively constant ever since, with the exception of a slight increase in reported use for irrigation in 2019, which corresponds with a dry year in the Trident Area (Appendix A, Fig. A1). Reported use from industry and golf course capacity use wells have remained comparatively unchanged from 2001 through 2021 (Fig. 11).

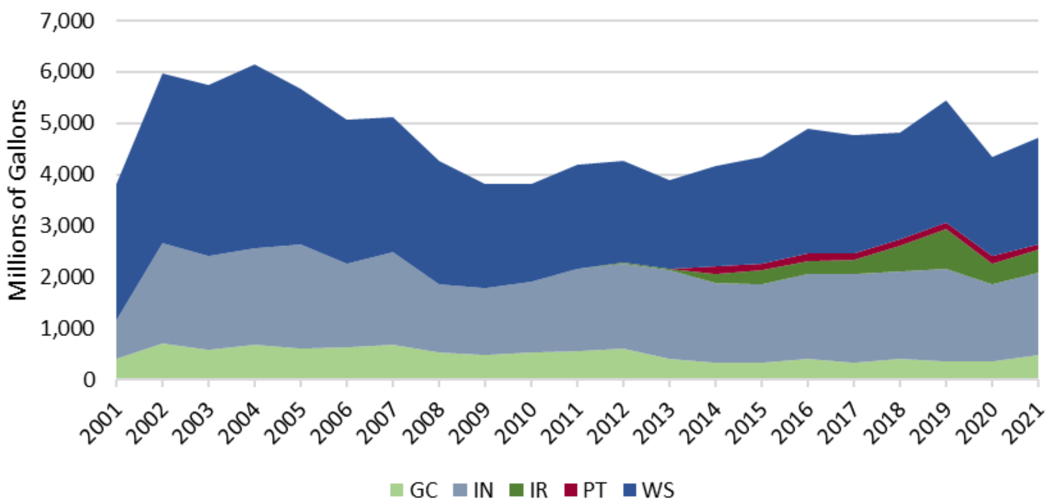

Figure 11. Trident Area reported water use by category from 2001 to 2021.

Comparing historic (2001 to 2021) reported groundwater use across the Trident Area counties shows that Charleston County consistently reported larger groundwater use volumes than the other counties. Charleston County's reported use decreased in 2008 and has remained relatively constant ever since. This decrease corresponds with the end of the dry period that was previously discussed, resulting in a reduction of water supply demand. Berkeley and Dorchester Counties have consistently reported similar volumes of groundwater use. These trends among use types (Fig. 11) and distribution among the Trident Area counties (Fig. 12) were also observed in the most recent reported water use (2021).

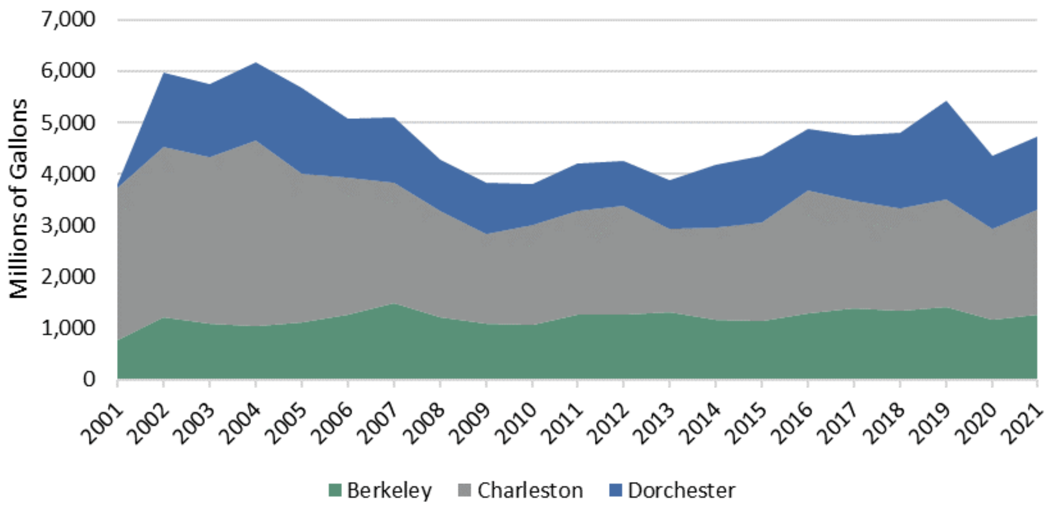

Figure 12. Trident Area reported water use by county from 2001 to 2021.

The total population in the Trident Area has increased by 250,000 people over the past 20 years, primarily the result of population growth in Charleston County. Berkeley and Dorchester Counties have also experienced growth in population, but to a lesser degree (Fig. 13). Reported groundwater use in the Trident Area did not reflect a similar increase as seen in the population growth (Fig. 12).

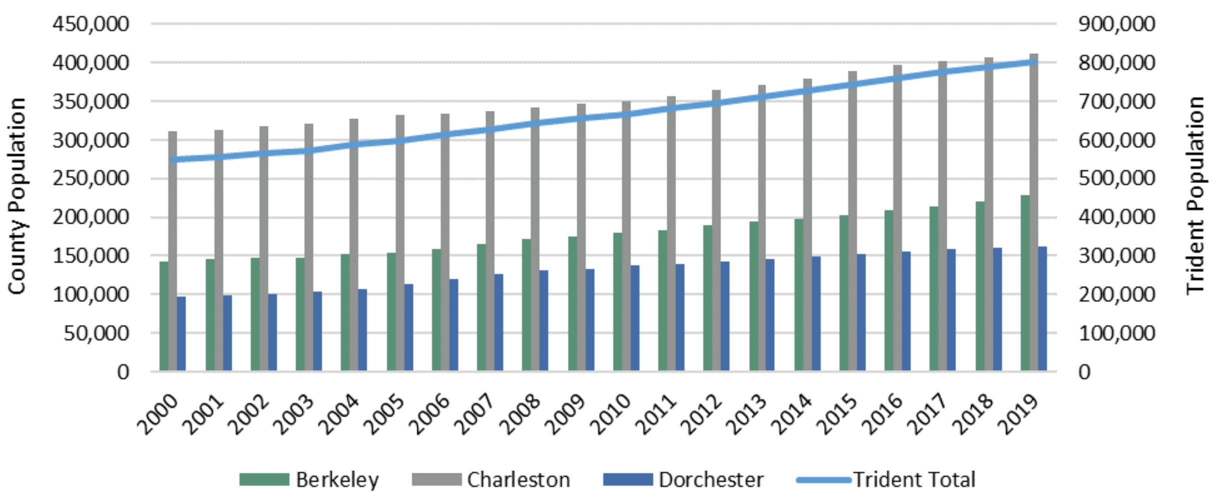

Figure 13. Population estimates and census data for the Trident Area (blue line) and each county (vertical bars). www.census.gov; accessed April 15, 2022.

Groundwater Impacts

In order to assess the ongoing conditions of the aquifers in South Carolina, water levels are measured manually or by using automatic data recorders (pressure transducers) in wells screened in each of the CPSC aquifers. The groundwater monitoring network used for these measurements is maintained by DNR and the U.S. Geological Survey (USGS). These water level measurements are used to understand the impact of groundwater withdrawal over time, as well as provide an areal snapshot of groundwater conditions at a specific time. The extent of the DNR Monitoring Well Network may be seen in the map in Appendix B.

Groundwater Trends

There are currently 12 public monitoring wells located in Trident Area counties (Table 7). The majority of these wells are screened in the Gordon Aquifer and are located in Charleston County. The length of time for which there are groundwater level measurements ranges from 5.7 years to 43.2 years. All of the wells are maintained by DNR as part of their groundwater monitoring network with the exception of BRK-0431 and CHN-0014, which are maintained by the USGS.

Table 7. List of monitoring wells in Trident Area counties with aquifer and length of well record.

Well ID	Agency	County	Aquifer	Record Length (years)
BRK-0431	USGS	Berkeley	McQueen Branch	15.4
BRK-0644	SCDNR	Berkeley	Gordon	23
CHN-0014	USGS	Charleston	McQueen Branch	15.4
CHN-0044	SCDNR	Charleston	Gordon	43.2
CHN-0101	SCDNR	Charleston	Gordon	43.2
CHN-0163	SCDNR	Charleston	Charleston	6.9
CHN-0484	SCDNR	Charleston	Gordon	22.8
CHN-0803	SCDNR	Charleston	Gordon	21.3
CHN-0989	SCDNR	Charleston	Gordon	5.7
CHN-0990	SCDNR	Charleston	Gordon	8.9
CHN-0991	SCDNR	Charleston	Surficial	8.9
DOR-0228	SCDNR	Dorchester	Charleston	6.2

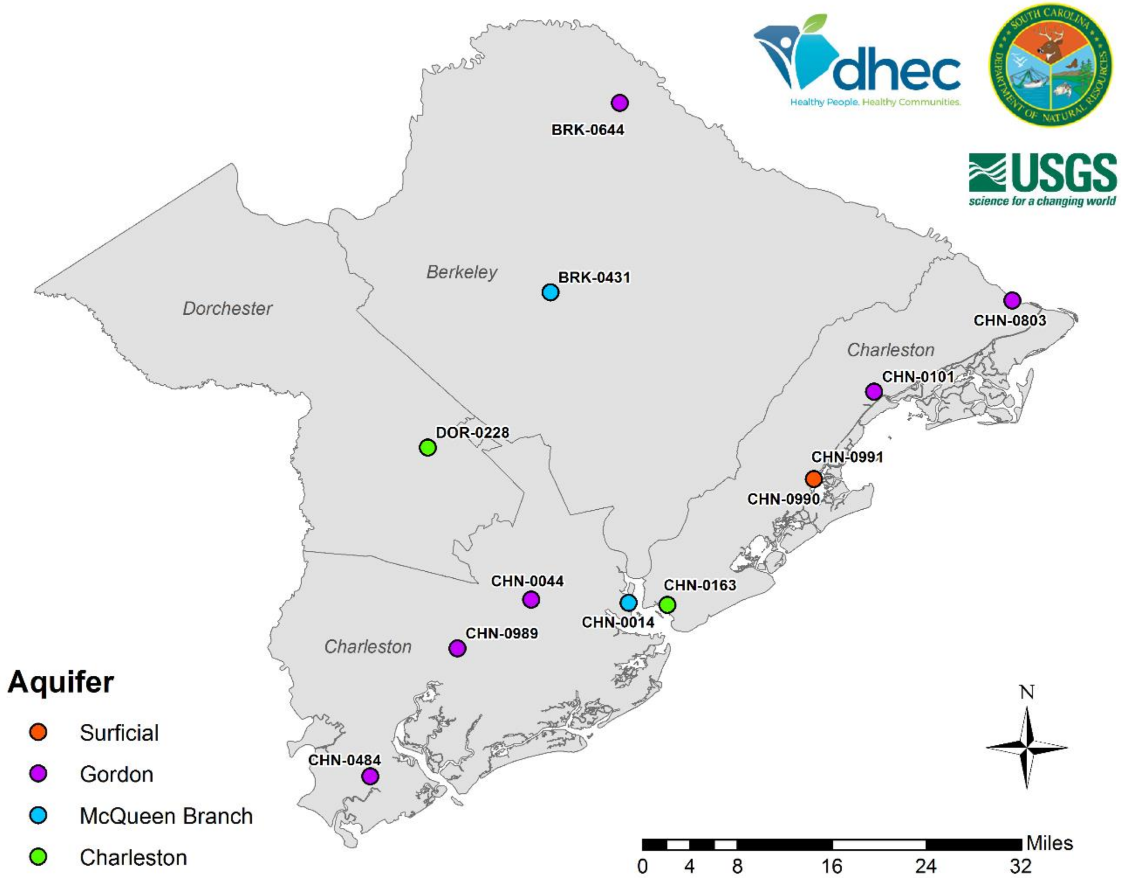

Figure 14. Map of DNR and USGS monitoring wells in the Trident Area. Different symbol colors represent the aquifer into which each well is screened. The water levels for each are presented below.

Surficial Aquifer

The Surficial Aquifer is the aquifer that is utilized the least in the Trident Area, providing <1% of all reported water use in 2021 (Fig. 10, Table 6). Monitoring well CHN-0991 (Fig. 15, K) is the only monitoring well screened in the Surficial Aquifer in the Trident Area and has records dating back to 2014. Water levels at this location have remained stable overall, but the data indicates that levels decline in the spring and summer months and rebound in the fall and winter. These declines and rebounds are due to the local recharge the Surficial Aquifer receives through precipitation which causes the water level profile to reflect the local climate.

Gordon Aquifer

While the Gordon Aquifer provides groundwater to more wells in the Trident Area than any of the other aquifers (41%), withdrawal from the Gordon Aquifer only accounted for 11.22% of total reported groundwater withdrawals from capacity use wells in the Trident Area in 2021 (Fig. 10, Table 6). Majority of the monitoring wells in the Trident Area are screened in the Gordon Aquifer including BRK-0644, CHN-0044, CHN-0101, CHN-0484, CHN-0803, CHN-0989, and CHN-0990 (Fig. 15, B, D-E, and G-J, respectively). Water levels at the BRK-0644, CHN-0101, CHN-0803, and CHN-0990 monitoring locations have slightly increased over time. Conversely, water levels at the CHN-0044, CHN-0484, and CHN-0989 monitoring locations have decreased over time.

McQueen Branch Aquifer

Two of the monitoring wells in the Trident Area, BRK-0431 and CHN-0014 (Fig. 15, A and C), are screened in the McQueen Branch Aquifer. Monitoring well BRK-0431's water level record has decreased over time, while CHN-0014's water level record has remained relatively stable over the same time interval. The McQueen Branch Aquifer does not supply groundwater to any of the permitted capacity use wells in the Trident Area.

Charleston Aquifer

The Charleston Aquifer is the most utilized aquifer in the Trident Area, providing approximately 67% of all reported withdrawals for 2021. Although it is the most heavily relied upon aquifer, only two monitoring wells in the Trident Area are screened in the Charleston Aquifer: CHN-0163 and DOR-0228 (Fig. 15, F and L). Both monitoring wells indicate declines in groundwater levels over the past several years (-5.5 ft, DOR-0228; -19.9 ft, CHN-0163).

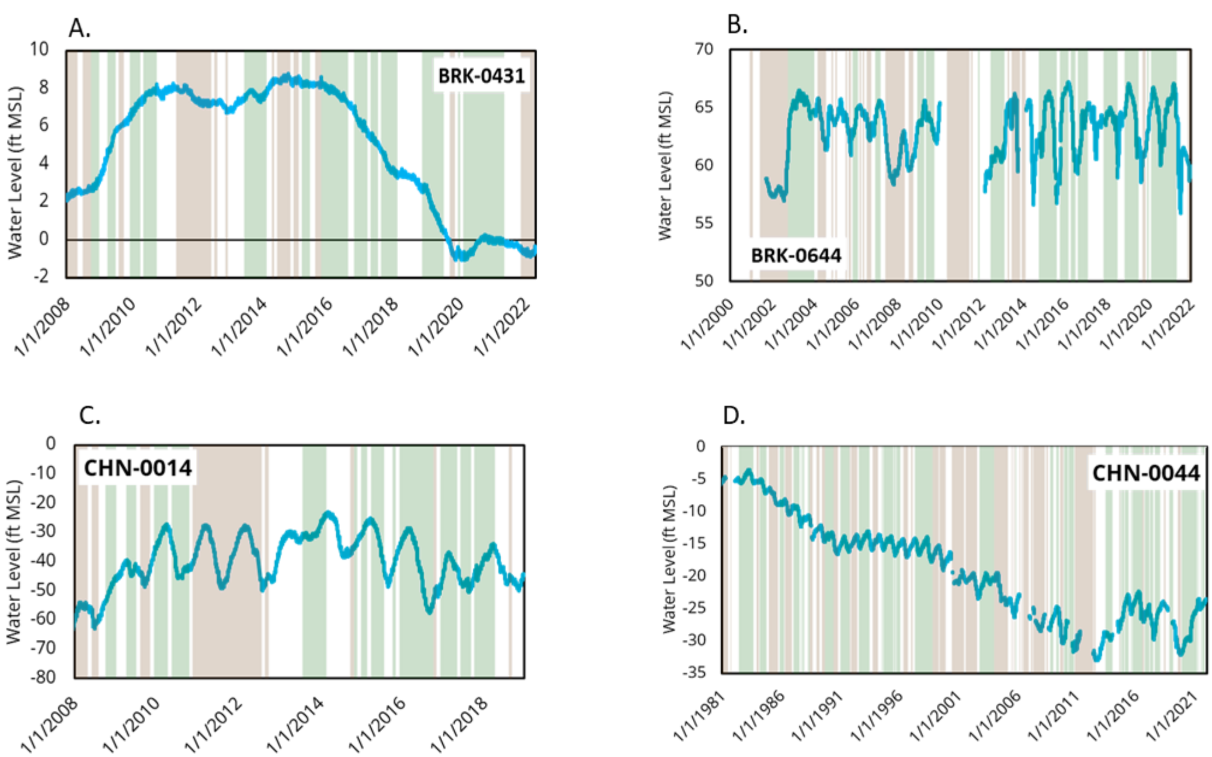

Figure 15. Water level plots from DNR and USGS monitoring wells in the Trident Area. Water levels are in feet relative to sea level (MSL). Blue lines represent automatic data recordings and red dots represent manual water level measurements. The green background indicates wet periods, and the brown background indicates dry periods. http://hydrology.dnr.sc.gov/groundwater-data/ and http://waterdata.usgs.gov/; accessed April 22, 2022.

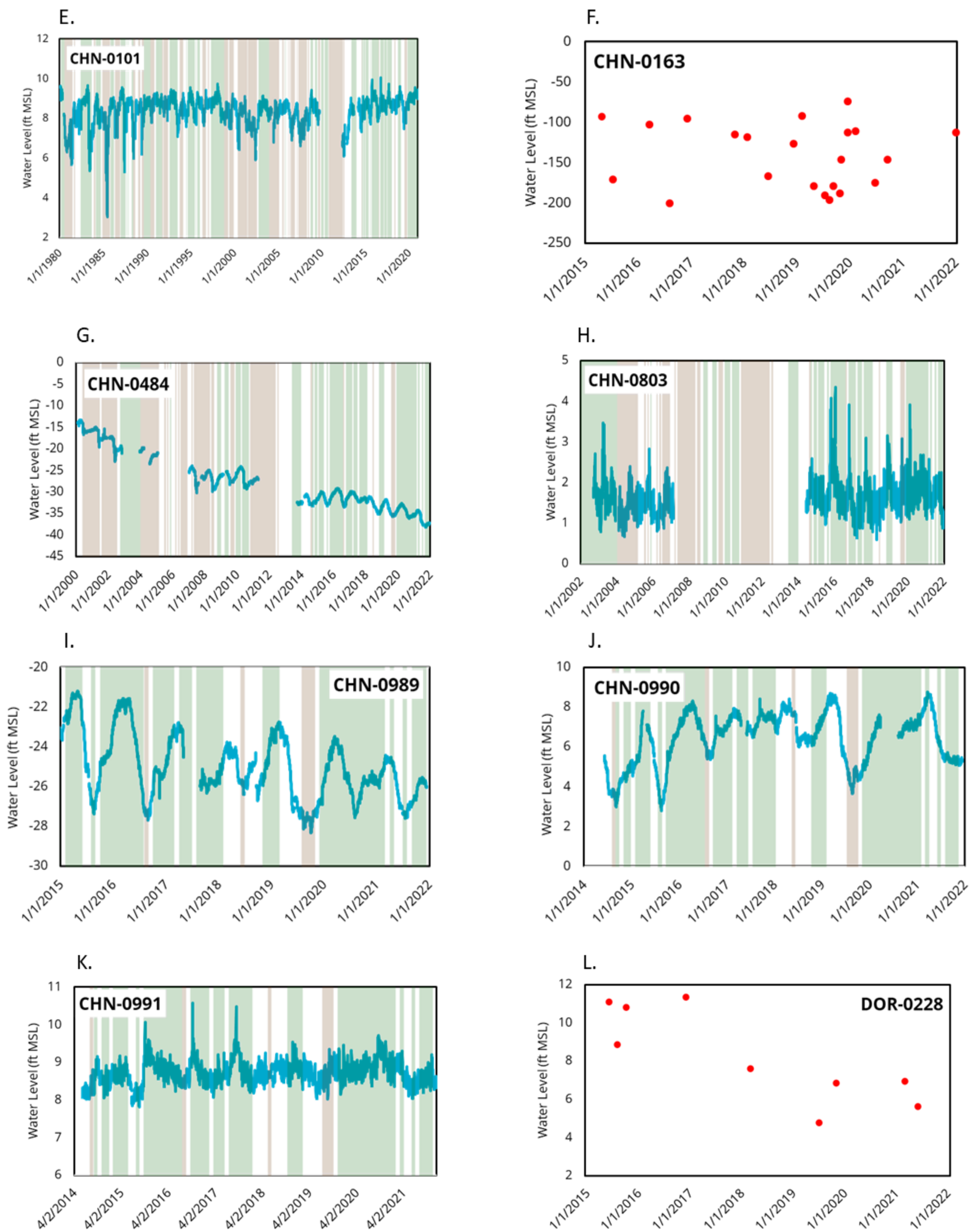

Figure 15, continued.

Potentiometric Maps

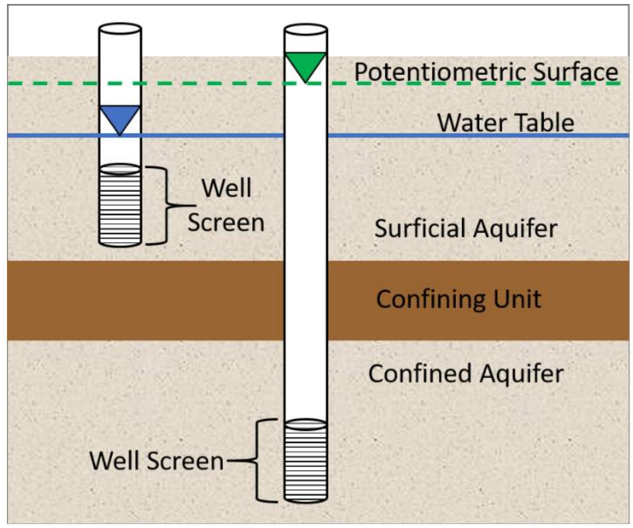

Figure 16. Illustration of a water table and potentiometric surface. Water levels in the wells are indicated by the blue (water table) and green (potentiometric surface) triangles.

Water level measurements also indicate the surface of the water table or the potentiometric surface at the well location (Fig. 16). The water table is the free surface of the groundwater in the surficial aquifer that receives recharge directly from precipitation. The potentiometric surface is the water level measured in a confined aquifer and represents the pressure of the overlying water and sediment at that location (the pressure surface). Concurrent water level measurements at several locations within a single aquifer can be combined to create a water table (surficial aquifer) or potentiometric (confined aquifer) map. Just as contour maps are made of the land surface by connecting points of equal elevation, water table and potentiometric maps are created by connecting points of equal water elevation or pressure.

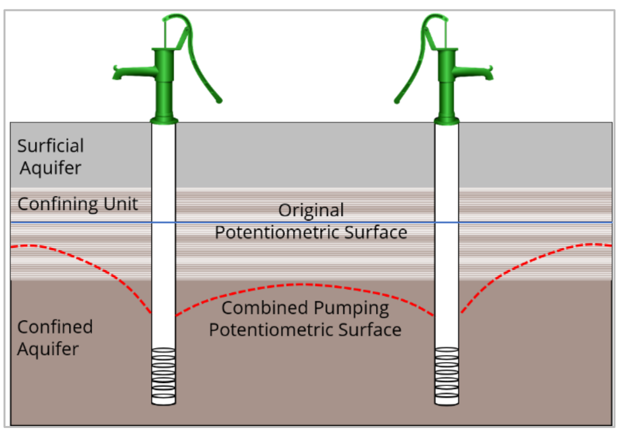

Figure 17. Illustration of the effect of combined pumping on a potentiometric surface.

These maps are used to evaluate groundwater conditions within an aquifer because groundwater withdrawal results in changes to these contour lines. Changes to the contour lines are especially important to note in confined aquifers in areas that take much longer to recharge. Groundwater withdrawal creates a greater impact in confined aquifers when large capacity wells are pumping in close proximity. The combined effect can create pumping cones (or cones of depression) that alter the potentiometric surface for miles from the pumping center (Figs. 17 and 18).

The contours of a potentiometric surface or water table map also point to changes in the direction of groundwater flow because groundwater flows perpendicular to (at right angles to) the contour lines from high to low water elevation (or pressure). Pumping cones change inland flow paths which can introduce contaminants to wells from any nearby source(s), cause other wells to experience reduced flow, and reduce the discharge to local streams and rivers. Coastal pumping cones reverse the normal offshore direction of net groundwater flow (Fig. 18). This reversal of groundwater flow at the coast can cause saltwater to infiltrate coastal wells.

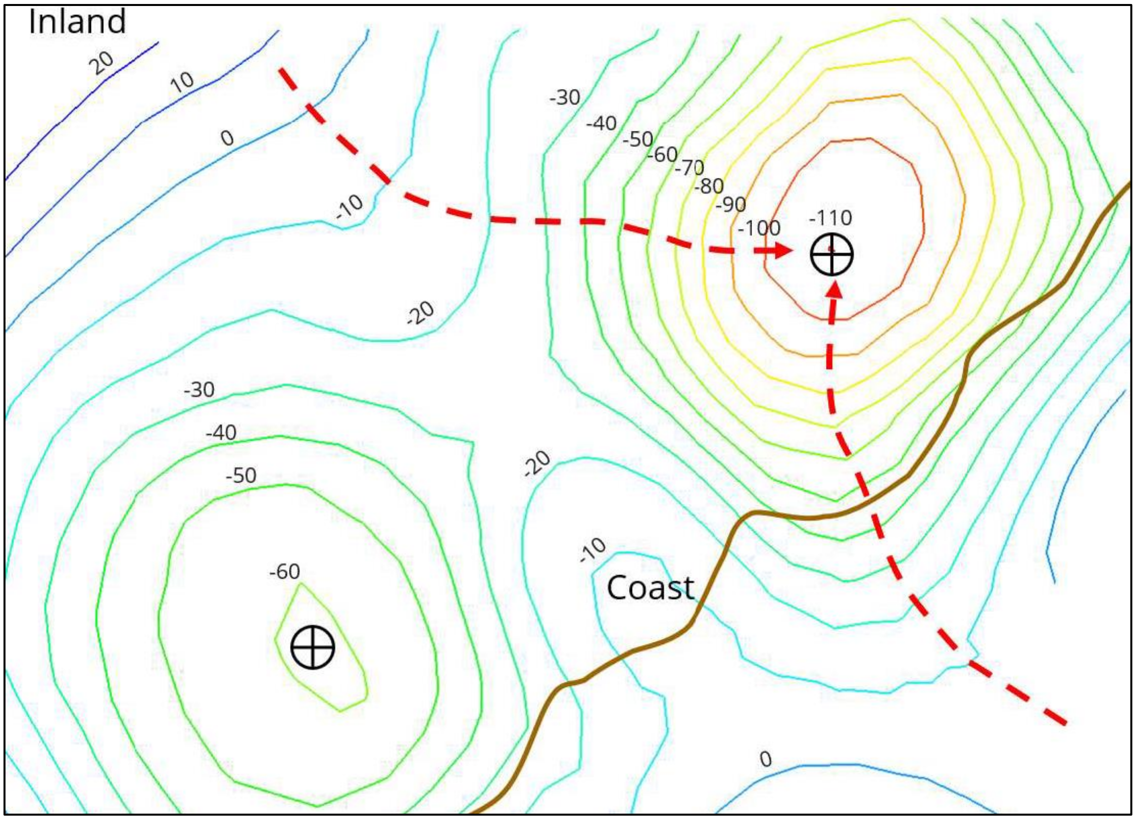

Figure 18. Illustration of a potentiometric map where contour lines show water level elevations from measurements in a confined, coastal aquifer. The numbers in this illustration are elevations in feet relative to mean sea level (the zero-contour line). Negative values are feet below mean sea level, and the dashed red arrows indicate the direction of groundwater flow.

Beginning in 1987, DNR began publishing potentiometric maps from water level measurements in the aquifers of the CPSC. In addition to the wells presented above, others are used belonging to a variety of water suppliers, irrigators, and industry. The following figures are a combination of these contour lines with water use data reported to DHEC. Groundwater withdrawal density maps were created using the annual reported groundwater withdrawal amounts from wells in the Trident Area. Clusters with more intense shading represent higher concentrations of groundwater withdrawal and areas with lighter or no shading represent lower amounts of groundwater withdrawal. Each density map was overlain with the corresponding potentiometric map for each year of withdrawal to show how the potentiometric surface has changed over time.

Floridan Aquifer System

The Floridan Aquifer System, formerly known as the Tertiary Aquifer System and Black Mingo Aquifer System, contains what are now known as the Upper and Middle Floridan Aquifers and the Gordon Aquifer (Gellici & Lautier, 2010). The pre-development map was made using historic water level data from wells screened in the Upper and Middle Floridan Aquifers and the Gordon Aquifer. The most recent measurements were published in 2018 as separate maps of the Upper and Middle Floridan Aquifers and the Gordon Aquifer. Because no Trident Area capacity use wells are screened in the Upper and Middle Floridan Aquifers, only the 2018 Gordon Aquifer potentiometric map has been included below.

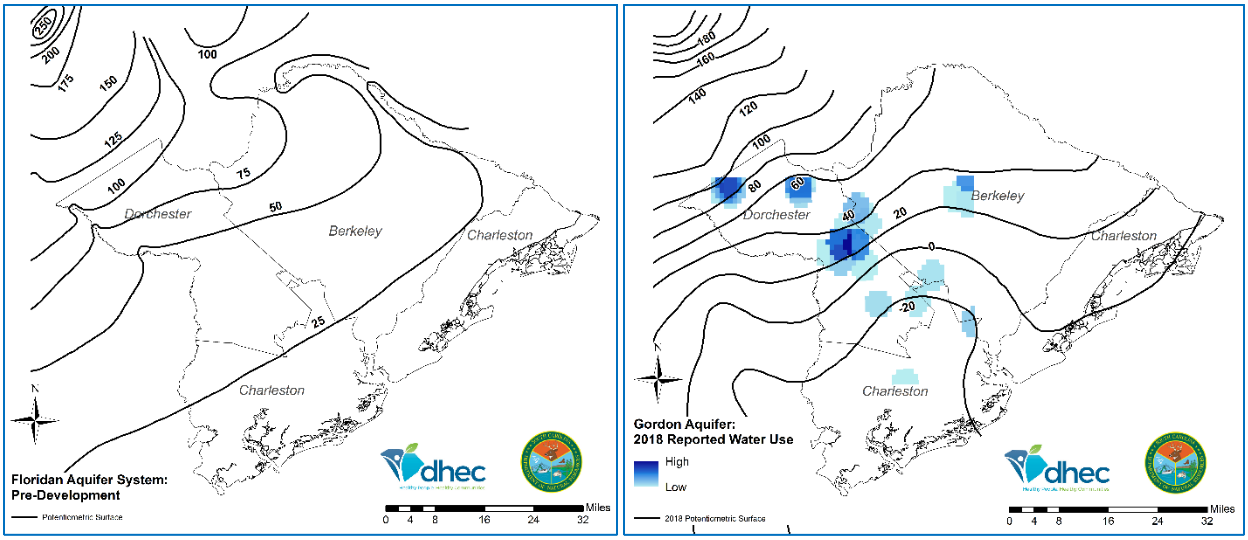

Figure 19. A. Pre-development potentiometric map of the Floridan Aquifer System in the Trident Area (Aucott & Speiran, 1985). B. 2018 potentiometric map of the Gordon Aquifer (Czwartacki, Wachob, & Gellici, 2019). Contour lines are in feet relative to mean sea level.

The pre-development potentiometric surface map indicates that the water level nears zero (mean sea level) at the coast and that the flow of groundwater is in a southeasterly direction. The pre-development potentiometric maps were digitized by DNR from the maps in a 1985 USGS report (Aucott & Speiran, 1985), and are considered to be the potentiometric surfaces of the aquifers in the year 1900 (Fig. 19, A).

High-density groundwater withdrawal from the Gordon Aquifer in central Dorchester County has resulted in the zero-contour line of the potentiometric surface to move nearly 32 miles inland, resulting in a water level drop of more than 20 feet in southeastern Dorchester County and southern Berkeley and Charleston Counties. The direction of groundwater flow has shifted from a southeasterly direction to a southerly direction in southeastern Dorchester County and southern Berkeley and Charleston Counties. The zero-contour line remains near the coast in northern Charleston County (Fig. 19, B).

Crouch Branch Aquifer

The pre-development potentiometric surface of the Crouch Branch Aquifer indicates that groundwater flowed in a northeasterly direction and water levels ranged from 150 feet above mean sea level below northwestern Dorchester County to 50 feet above mean sea level below northeastern Charleston County (Fig. 20, A). By 2016 the pressure surface had lowered by 25 feet in northern Dorchester County and had lowered by nearly 100 feet in eastern Berkeley and northern Charleston Counties. The groundwater flow shifted from an easterly direction to a southeasterly direction in Dorchester and western Berkeley Counties to a northeasterly direction in Charleston and eastern Berkeley Counties (Fig. 20, B). The Crouch Branch Aquifer is heavily influenced by the pumping cone that has developed below Georgetown County.

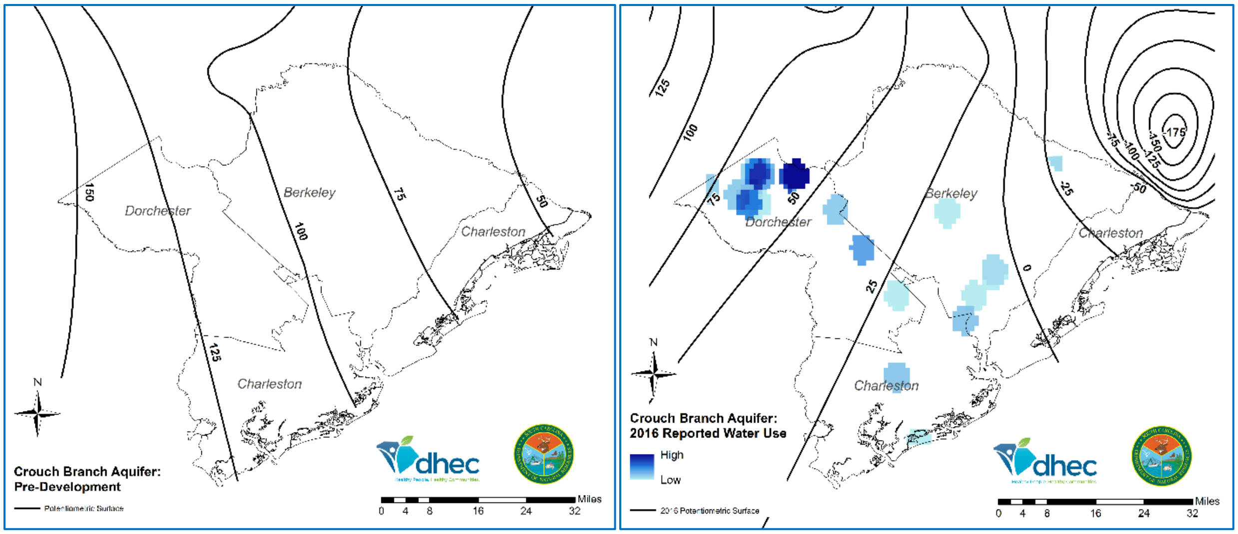

Figure 20. A. Pre-development potentiometric map of the Crouch Branch Aquifer in the Trident Area (Aucott & Speiran, 1985). B. 2016 potentiometric map of the Crouch Branch Aquifer (Wachob, Gellici, & Czwartacki 2017). Contour lines are in feet relative to mean sea level.

Middendorf Aquifer System

The McQueen Branch, Charleston, and Gramling Aquifers are collectively known as the Middendorf Aquifer System in South Carolina. They are now referenced individually as the McQueen Branch, Charleston, and Gramling Aquifers. The pre-development potentiometric map was created for the Middendorf Aquifer System, and DNR continues to publish potentiometric maps by combining data from all three of the Middendorf aquifers; therefore, it is not possible to determine the pressure surface changes unique to each aquifer.

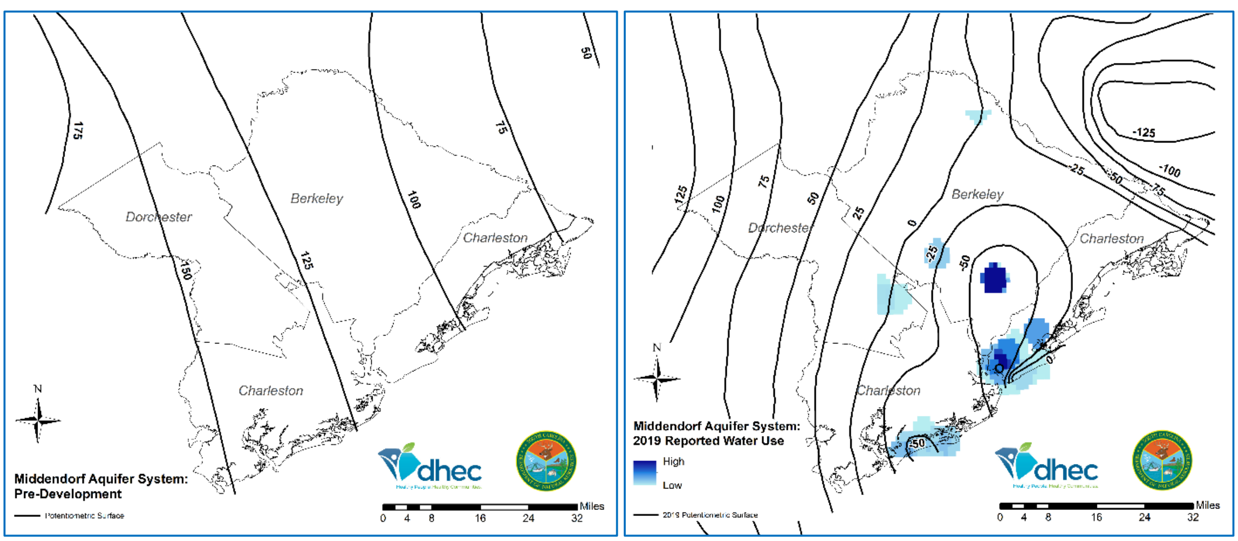

Figure 21. A. Pre-development potentiometric map of the Middendorf Aquifer System in the Trident Area (Aucott & Speiran, 1985). B. 2019 potentiometric map of the Middendorf Aquifer System (Czwartacki & Wachob, 2020). Contour lines are in feet relative to mean sea level.

The pre-development potentiometric surface of the Middendorf Aquifer System indicates that groundwater flowed in a northeasterly direction and water levels ranged from 175 feet above mean sea level below northwestern Dorchester County to 75 feet above mean sea level below northeastern Charleston County (Fig. 21, A). High-density groundwater pumping in southern Berkeley and central Charleston Counties have caused the pressure surface to decline by 175 feet. The groundwater flow shifted from a northeasterly direction to an easterly direction in much of the Trident Area with the exception of northeastern Berkeley and Charleston Counties which shifted to a northerly flow direction (Fig. 21, B). In addition to the concentrated pumping in southern Berkeley and central Charleston Counties, the Middendorf Aquifer System is also heavily influenced by the pumping cone that has formed below Georgetown County.

Groundwater Evaluation

Although water levels have declined since 1900 in all of the aquifers below the Trident Area counties, the primary area of concern is the pumping cone that has formed in the Middendorf Aquifer System below the Mount Pleasant area of Charleston County as a result of the locally intense pumping in the area. Monitoring well CHN-0163 (Fig. 15, F) shows that water levels in this area range from 74 to 200 feet below mean sea level. This pumping has also altered the potentiometric surface, causing the pressure surface to decline from 125 feet above mean sea level to 50 feet below mean sea level since 1900 (Fig. 21). This lowering of the pressure surface at the coast in conjunction with a growing population (Fig. 13) and continued concentrated, high-capacity groundwater pumping can reduce the freshwater flow toward coastal discharge areas and cause saltwater to infiltrate the freshwater zones of the aquifer (Fig. 18). Saltwater intrusion decreases freshwater storage in the aquifers, and, in extreme cases, can result in the abandonment of public water supply wells.

The Crouch Branch Aquifer has been most greatly impacted below northwestern Dorchester County as a result of locally intense pumping in the area, and eastern Berkeley and northern Charleston Counties due to the pumping cone below Georgetown County. The potentiometric surface has declined by approximately 75 feet across the board below Trident Area counties with the exception of a portion of eastern Berkeley County and northern Charleston County where the pressure surface has declined by 100 feet since 1900 (Fig. 20).

The Gordon Aquifer shows signs of a lowering of the potentiometric surface and the net groundwater flow direction has changed from an easterly direction to a southerly direction in Dorchester County and southern Charleston County, but there is not evidence of a pumping cone below the Trident Area counties at this time (Fig. 19).

Recommendations

All aquifers below Trident Area counties have experienced water level declines and therefore the ongoing pressure on these groundwater sources should be carefully monitored, but the primary area of concern is the pumping cone that has developed in the Mount Pleasant area of Charleston County.

Gordon Aquifer

- Staff evaluations of applications for withdrawal increases to existing permits and new groundwater withdrawal permits should include a groundwater model assessment to determine the potential for the development of pumping cones, increased saltwater intrusion in southern Charleston County, and potential interference on any neighboring wells.

Crouch Branch Aquifer

- Staff evaluations of applications for withdrawal increases to existing permits and new groundwater withdrawal permits should include a groundwater model assessment to determine the potential for the development of pumping cones, increased saltwater intrusion in northern Charleston County, and potential interference on any neighboring wells.

Charleston and Gramling Aquifers

- Staff evaluations of applications for withdrawal increases to existing permits and new groundwater withdrawal permits should include a groundwater model assessment to determine the potential for the development of pumping cones, increased saltwater intrusion in central Charleston County, and potential interference on any neighboring wells.
- Further groundwater pumping reductions in and around the Mount Pleasant pumping cone are needed to raise groundwater levels above sea level and to minimize the risk of saltwater intrusion and land subsidence in the region.
- Increase the use of Aquifer Storage and Recovery (ASR) wells and increase the use of Artificial Recharge (AR) to help in the recovery of the pumping cone below Mount Pleasant, Charleston County.
- Public water supply facilities should undergo an in-depth analysis of infrastructure to ensure there are no underlying issues contributing to groundwater loss. Conservation efforts should also be encouraged to the public through education and incentives.

Trident Capacity Use Area

- Cooperative work with DNR should continue in preparing the potentiometric surface maps, and future maps should be based on data from individual aquifers to the greatest extent possible to better aid in evaluation of how groundwater withdrawals from capacity use wells (which must be screened into single aquifers) are impacting the local groundwater conditions.
- Work toward educating all South Carolinians on best practices for water conservation must continue in cooperation with all stakeholders.
- Work in conjunction with local, state, and federal partners to expand the groundwater monitoring network in Trident Area aquifers, specifically the Crouch Branch and Charleston Aquifers, by identifying wells scheduled for abandonment that may be incorporated and of benefit to the well network.

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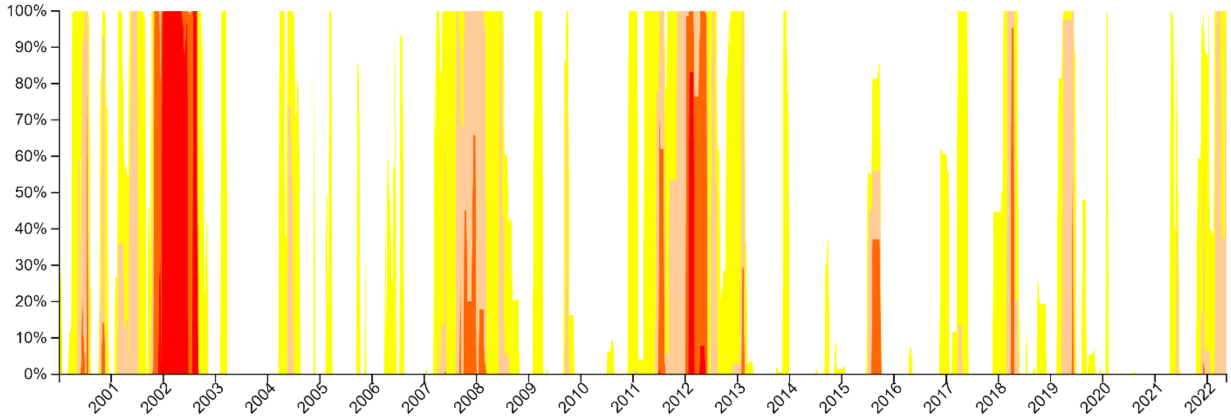
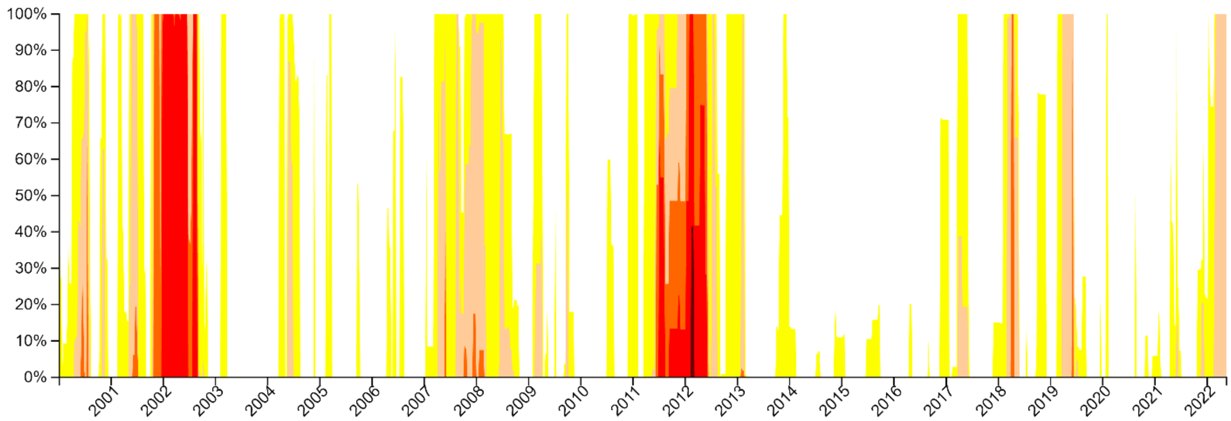
Appendix A: Historic Drought Conditions

A. Berkeley County (SC) Percent Area in U.S. Drought Monitor Categories



B. Charleston County (SC) Percent Area in U.S. Drought Monitor Categories



C. Dorchester County (SC) Percent Area in U.S. Drought Monitor Categories

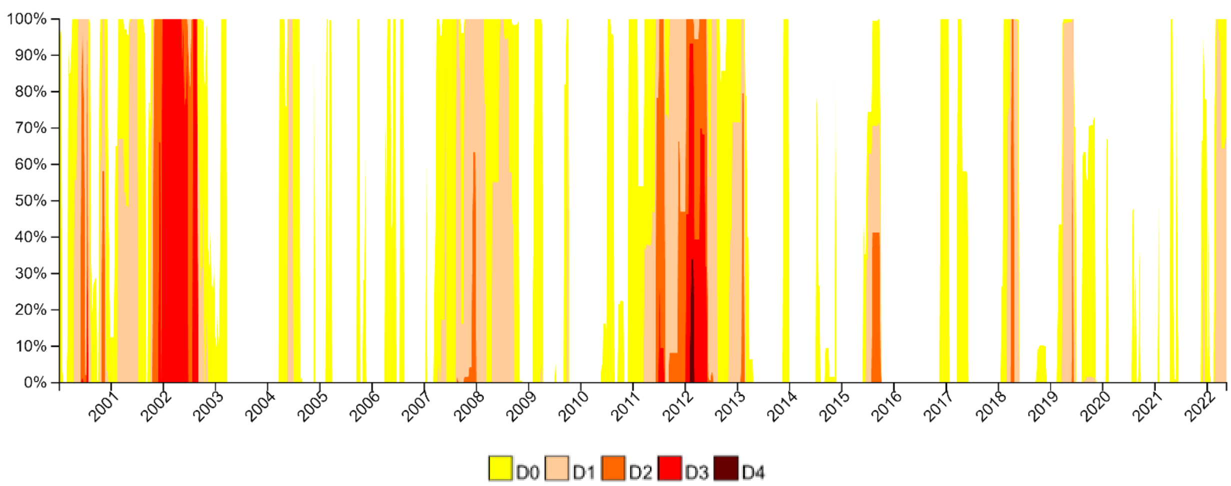


Figure A1, A-C. Severity and percent drought coverage for Trident Area counties. D0 represents abnormally dry periods and D4 represents periods of exceptional drought. https://www.drought.gov/; accessed May 20, 2022.

Appendix B: SC DNR Groundwater Monitoring Network

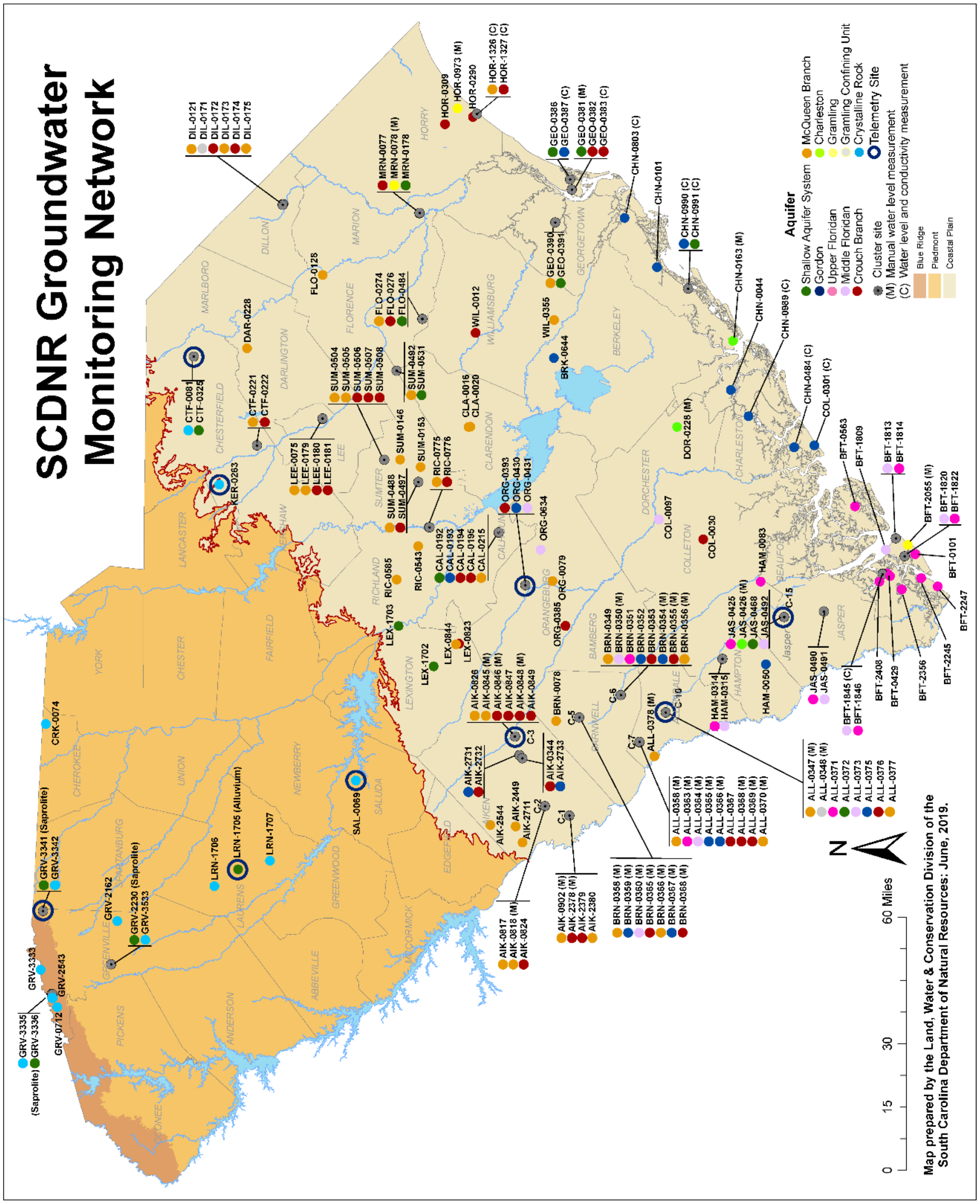


Figure B1. Map of wells included in the SC DNR Groundwater Monitoring Network. https://hydrology.dnr.sc.gov/; accessed May 20, 2022.