Hydrogeologic Framework and Ground Water Resources of the North Albemarle Region, North Carolina

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EXECUTIVE SUMMARY

The North Albemarle region lies north of the Albemarle Sound and east of the Chowan River, including Camden, Chowan, Currituck, Gates, Pasquotank, and Perquimans Counties (figure i). This area is in great need of additional water sources in order to accommodate a growing population spilling into northeastern North Carolina from rapid growth of the Hampton Roads, Virginia area. Currituck, Camden, and Pasquotank Counties have the most serious water supply problems, inasmuch as they are operating at or near their maximum water production rates.

Development of surface water supplies throughout much of northeastern North Carolina is limited due to such factors as fluctuating chloride concentrations, high levels of organic matter, water color, algal blooms, and low hydraulic gradients. Consequently, the population of the North Albemarle region is exclusively dependent on ground water as a water supply source. Potable ground water in the North Albemarle region is limited to relatively shallow aquifers, except for Gates County, in the northwestern part of the area. Over much of the region, the deeper aquifers contain brackish or saline ground water.

As indicated by monitoring well measurements, ground water levels in the northwestern part of the North Albemarle area have been declining for many years. In southeastern Virginia, withdrawals of ground water have increased dramatically since about 1940. Much of this increase is due to withdrawals by Union Camp Corporation located in Franklin, Virginia. Withdrawals by Union Camp of approximately one million gallons per day (MGD) began in 1940 (Peek, 1977). By 1992, ground water withdrawals by Union Camp were approximately 38 MGD (USGS data). Other pumping centers affecting flow in southeastern Virginia are located near the towns of West Point and Smithfield, and the Cities of Williamsburg, Newport News, and Suffolk. Along with Union Camp Corporation at Franklin, these pumping centers accounted for about 71 MGD (81 percent) of the total 1983 ground water pumpage in southeastern Virginia. As a direct result, ground water levels in the lower Cape Fear aquifer system have been declining at a rate of approximately 2 feet per year as observed at the Sunbury, Como, and Parkville research stations in Gates, Hertford and Perquimans Counties, North Carolina.

The purpose of the North Albemarle Ground Water Study is to construct an up-to-date hydrogeologic framework of the area of concern, which includes the following North Carolina counties: Camden, Chowan, Currituck, Gates, Pasquotank, Perquimans, eastern Bertie and Hertford, and the following southeastern Virginia counties: the southern areas of Southampton, Isle of Wight, Suffolk and Chesapeake (figure i). Southeastern Virginia counties were included in the framework in order to establish, for ground water modeling purposes, the continuity of the aquifer system from North Carolina into the Franklin pumping center. The hydrogeologic framework study was accomplished by correlation and interpretation of borehole geophysical and lithologic logs, water level and chloride measurements taken from observation wells, aquifer test data, and Time Domain Electromagnetic Soundings. Three deep wells were constructed by the Division of Water Resources in 1994-95 in order to provide subsurface information where little was available.

In addition to defining the aquifer framework and pumping impacts, this study seeks to assist the water deficient counties in the region in their efforts to locate additional ground water

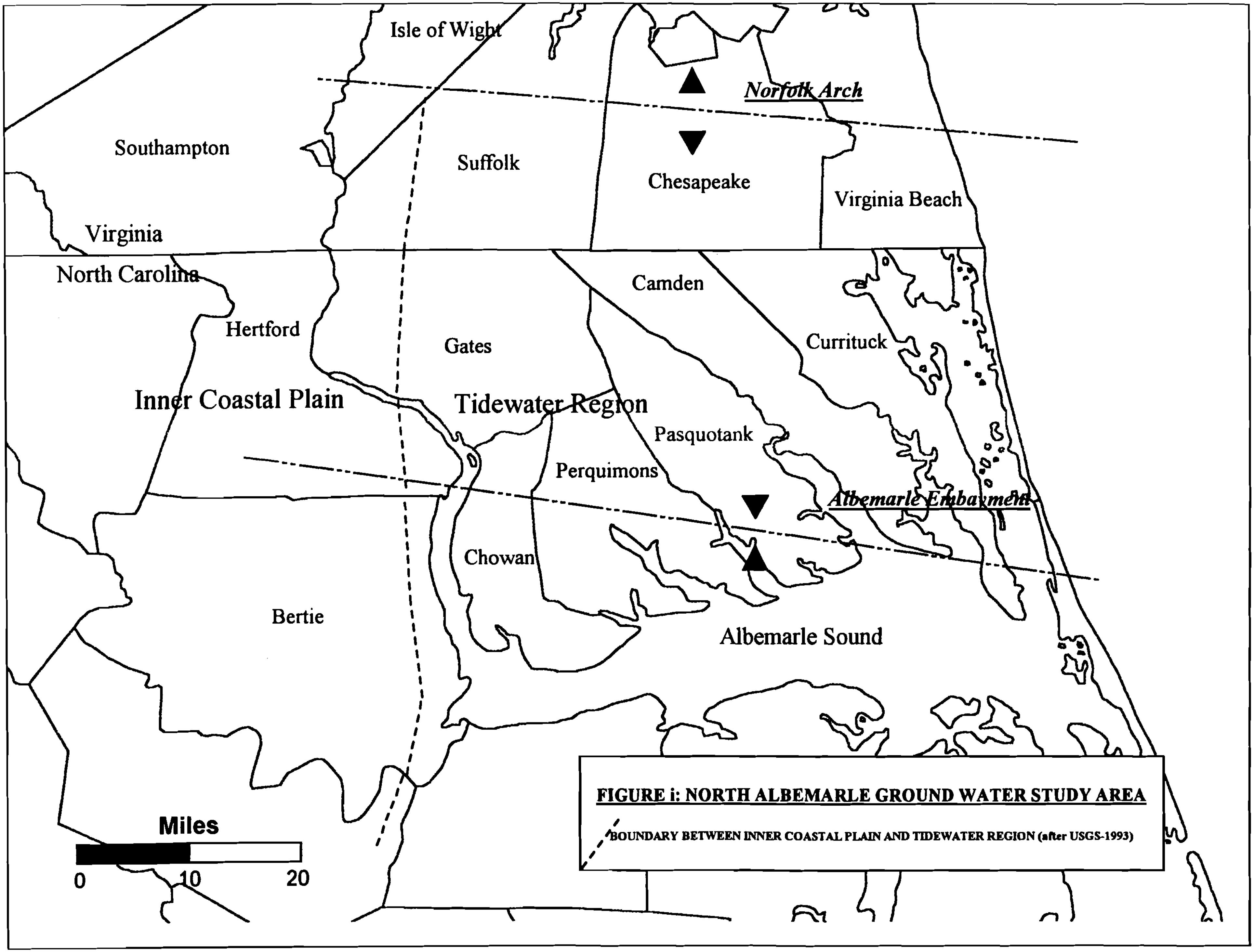

FIGURE i: NORTH ALBEMARLE GROUND WATER STUDY AREA

supplies, either fresh or economically treatable by reverse osmosis technology. In this regard, general target areas within the aquifer system are recommended for future ground water supply.

The area covered by this report is situated primarily within the tidewater region of the North Carolina and Virginia coastal plain physiographic province. The western fringe of the study area is part of the inner coastal plain of North Carolina and Virginia (figure i). The topography of the region is comprised predominantly of an en echelon series of dissected Quaternary age terraces and intervening, seaward facing escarpments which are in parallel orientation with the Atlantic coastline. The North Carolina and Virginia coastal plains are comprised of sedimentary deposits which were laid down in a cyclic fashion during alternating transgressions and regressions of the Atlantic Ocean (Brown, Miller and Swain, 1972, Harsh and Meng, 1988). The coastal plain is made up of a wedge shaped mass of Cenozoic through Mesozoic age sedimentary deposits which range in thickness from zero at the fall line to 10,000 feet at Cape Hatteras. Sediments are principally comprised of sand, gravel, conglomerate, limestone, silt, clay, shell material and combinations thereof which were deposited in alternating marine to nonmarine environments.

The sedimentary deposits of the study area have been differentiated into geologic formations and formation members based on lithologic and paleontologic consistencies. Differentiation of the sediment wedge into component aquifers and confining units is based upon the mapping of hydraulically connected permeable beds, the boundaries of which do not necessarily correspond to formation boundaries. The relationship between geologic formations in the northeastern North Carolina and southeastern Virginia coastal plains and hydrogeologic units designated in this study is shown in figure 2.

Six major regional aquifers were identified in the study, as well as the intervening confining layers that separate them. They include the surficial, Yorktown, Castle Hayne, Beaufort, upper and lower Cape Fear aquifers . Each aquifer unit was mapped and described in as much detail as available data would allow in order to define them in terms of regional elevation, thickness and lateral distribution, hydraulic properties, relationship to stratigraphic units, ground water flow, and chloride distribution. The approximate positions of the 250, 500, and 10,000 parts per million chloride interfaces were plotted for each aquifer in order to identify where potable water supplies may be found, and where reverse osmosis treatment would be necessary in order to produce potable water.

Potable ground water supplies can be found over the entire region in the surficial and Yorktown aquifers, with the exception of the Outer Banks of Currituck County, where fresh water has not been identified to date in the Yorktown aquifer. Due to the shallow position (39 to 180 feet below land surface) of the 250 ppm chloride interface in the Yorktown aquifer in mainland Currituck, Camden, Pasquotank, and eastern Perquimans Counties, the thickness of the fresh water zone is very limited in some areas (Appendix: plates A-2 through A-10).

In the North Albemarle region, potable ground water in the Castle Hayne aquifer can be found to the west of the 250 ppm chloride interface (Appendix: figures A-6 and A-7) in southeastern Hertford, eastern Bertie, western Gates, and central Chowan Counties, and possibly in the northwestern tip of Camden County. West of the position of the 250 ppm interface, reverse osmosis treatment would be necessary in order to produce potable water from this aquifer. Water supply wells positioned between the 250 and 500 ppm chloride interfaces as delineated in this study would provide the most economically treatable concentrations. Very little pump test data is available in the eastern North Albemarle counties to delineate areas where the productive ability of the Castle Hayne aquifer is suitable for municipal supply.

The Beaufort aquifer contains potable ground water to the west of the position of the 250 ppm chloride interface (Appendix: figure A-8 and A-9) in Bertie, Hertford, western Gates and west central Chowan Counties. East of the position of this interface, reverse osmosis treatment would be required. Specific capacity data from a few tests (Appendix: table A-1) in the eastern North Albemarle Counties indicate that the productive ability of this aquifer is generally poor.

Potable water supplies in the upper Cape Fear aquifer are found to the west of the 250 ppm chloride interface (Appendix: figure A-10) in Hertford, Bertie, and Gates Counties and may possibly be found in the northwestern tips of Pasquotank and Camden Counties. Development of the aquifer in northwestern Pasquotank and Camden Counties would, however, be inhibited by the presence of the Dismal Swamp National Wildlife Refuge. Economically treatable supplies of lower chloride range salt water (250-1000 ppm) may be found in Chowan, northern Perquimans, northwestern Pasquotank, northwestern Camden, and northwestern Currituck Counties in the upper Cape Fear aquifer. A Jacobs Distance drawdown test performed on the upper and lower Cape Fear aquifers (Appendix: figure A-21) indicates that the transmissivity and hydraulic conductivity of this aquifer is very high in the area covered by the Como, Sunbury, and Parkville research stations. It is possible that highly transmissive zones are present further to the east in the counties where future ground water supply is a concern.

The lower Cape Fear aquifer contains fresh water in Gates, Hertford, Bertie and possibly the northwestern tip of Pasquotank County as indicated by the 250 ppm chloride interface plotted on regional cross-sections (Appendix: plates A-2 through A-10). East of this interface, lower chloride range salt water may be found in northwestern Camden, northwestern Pasquotank, and possibly in Chowan County.

The best option for the water concerned counties in the eastern North Albemarle region for expansion of existing municipal water supplies is to further develop the potable water supply in the Yorktown aquifer. This could be prudently accomplished by locating new well fields where transmissivity and hydraulic conductivity values are highest, in conjunction with areas of maximum depth to the fresh water-salt water interface. Proper well field design is also an important consideration, in order to maximize aquifer productivity, and minimize the possibility of salt water upconing. Findings in the main body of the report will provide guidance with regard to identifying optimal target areas for well field placement in the Yorktown aquifer.

INTRODUCTION

The North Albemarle region of northeastern North Carolina lies north of the Albemarle Sound and east of the Chowan River, including Camden, Chowan, Currituck, Gates, Pasquotank, and Perquimans Counties (figure i). This area is in great need of additional water sources in order to accommodate a growing population spilling into northeastern North Carolina from rapid growth of the Hampton Roads, Virginia area. Currituck, Camden, and Pasquotank Counties have the most serious water supply problems, inasmuch as they are operating at or near their maximum water production rates.

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PURPOSE AND SCOPE

The purpose of the study is to construct an up-to-date hydrogeologic framework of the area of concern, which includes the following North Carolina counties: Camden, Chowan, Currituck, Gates, Pasquotank, Perquimans, eastern Bertie and Hertford, and the following southeastern Virginia counties: the southern areas of Southampton, Isle of Wight, Suffolk and Chesapeake (figure i). Southeastern Virginia counties were included in the framework in order to establish, for ground water modeling purposes, the continuity of the aquifer system from North Carolina into the Franklin pumping center. The hydrogeologic framework study was accomplished by correlation and interpretation of borehole geophysical and lithologic logs, water level and chloride measurements taken from observation wells, aquifer test data, and Time Domain Electromagnetic soundings. Three deep wells were constructed by the Division of Water Resources in 1994-95 in order to provide subsurface information where little was available.

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PREVIOUS STUDIES

Numerous local geologic and hydrogeologic reports on the North Albemarle region and southeastern Virginia have been published in previous years, as well as a few regional reports. The reports that most relate to this study are mentioned as follows:

Wilson (1991) conducted a hydrogeologic framework, ground water modeling, and water supply study of the Currituck County Outer Banks.

Harsh and Laczniak (1990) published a study of the regional ground water flow system and digital flow modeling in the Virginia, northeastern North Carolina, and southeastern Maryland coastal plains.

Winner and Coble (1989) presented a regional hydrogeologic framework study of the North Carolina Coastal Plain in which they described the major aquifers and confining units in terms of their regional extent and thickness, lithology, and hydraulic properties.

A sequence stratigraphic and foraminiferal biostratigraphic study of the Albemarle embayment in North Carolina was presented by Zarra (1989). Twenty six depositional sequences and twenty six sequence boundaries were defined for the lower Cretaceous to Quaternary section of the Albemarle embayment.

Meng and Harsh (1988) published as part of the USGS Regional Aquifer System Analysis Program (RASA) a hydrogeologic framework study of the Virginia coastal plain.

Hamilton and Larson (1987) presented the results of a study of the hydrogeology of the southeastern Virginia coastal plain, including the development and refinement of a digital, ground water flow model. The model was used to predict the future effects of increased pumping on the aquifer system.

A regional study of the stratigraphy, structure, and phosphate deposits of the Pungo River Formation of the North Carolina coastal plain was published in 1982 by J.A. Miller.

The results of a ground water modeling study of the lower Cretaceous aquifer in the Franklin, Virginia area were presented in a 1974 report by O.J. Cosner. Predictive model simulations were presented to show the future effects of heavy pumping from the Franklin, Virginia area. The model predicted that if pumpage continued to increase in the Franklin area, over time, serious dewatering of the lower Cretaceous aquifer would occur.

Brown, Miller, and Swain (1972) provided a regional structural and stratigraphic framework study of the Atlantic Coastal Plain from North Carolina to New York. They identified and mapped seventeen chronostratigraphic units and developed a structural model based on depositional alignments and thickening trends.

Lloyd (1968) presented a ground water resources study of Chowan County, North Carolina in which he identified and traced the extent, thickness, lithology, hydraulic properties, and water quality of each of the aquifers, as determined from a network of well information.

Harris, (1966) conducted a study of the geology and ground water resources of the Hertford-Elizabeth City area.

ACKNOWLEDGMENTS

Appreciation is extended to numerous individuals and organizations who helped to make this study possible.

Gale Johnson oversaw the drilling and testing operations on the Division of Water Resources Moyock, Hertford, and Gates County tests, and was instrumental in other planning, data gathering and analysis efforts in the beginning phase of the study.

John Nickerson and Kenny Gay of the North Carolina Geological Survey provided very beneficial litho- and bio-stratigraphic analyses of well cuttings from the DWR Moyock, Hertford, and Gates County Prison tests.

The Groundwater Section of the NC-ENR Division of Water Quality provided personnel, drilling, and testing equipment for the installation and testing of DWR boreholes

The U.S. Geological Survey Water Supply Branch, Virginia Water Control Board, NC-DWQ Groundwater Section and the North Carolina Geological Survey provided well logs, geologist and drillers logs, and pump test data.

The Virginia Water Control Board allowed DWR personnel to measure water levels in monitoring wells in southeastern Virginia.

Randolph McFarland and Barry Smith of the U.S. Geological Survey, Richmond, Virginia office provided ground water withdrawal data, and current water level data for southeastern Virginia.

Several people helped to improve the manuscript of the report by their technical reviews. They included Nat Wilson and Stuart Strum of the North Carolina Division of Water Resources, Bill Hoffman, Kenny Gay, and John Nickerson of the North Carolina Geologic Survey, and Ralph Heath, consulting hydrogeologist.

GEOLOGIC SETTING

The area covered by this report is situated primarily within the tidewater region of the North Carolina and Virginia coastal plain physiographic province. The western fringe of the study area is part of the inner coastal plain of North Carolina and Virginia (figure i). The topography of the region is comprised predominantly of an en echelon series of dissected Quaternary age terraces and intervening, seaward facing escarpments which are in parallel orientation with the Atlantic coastline. The North Carolina and Virginia coastal plains are comprised of sedimentary deposits which were laid down in a cyclic fashion during alternating transgressions and regressions of the Atlantic Ocean (Brown, Miller and Swain, 1972, Meng and Harsh, 1988). The coastal plain is made up of a wedge-shaped mass of Cenozoic through Mesozoic age sedimentary deposits which range in thickness from zero at the fall line, to 10,000 feet at Cape Hatteras. Sediments are principally comprised of sand, gravel, conglomerate, limestone, silt, clay, shell material and combinations thereof which were deposited in alternating marine to nonmarine environments. The sedimentary wedge is situated on a basement complex of Paleozoic age rocks. Sediment deposition in the study area was affected by two major structural features, the Norfolk Arch and the Albemarle Embayment. The Norfolk Arch, one of several east, southeast trending basement structural highs of the Atlantic coastal plain, is situated in the northern part of the study area (figure i). The Albemarle Embayment is a broad, open ended sedimentary basin that dips gently toward the southeast and is flanked on the north by the Norfolk Arch. The Norfolk Arch modified the depositional environment to the south, and inhibited the northward progression of southern limestone depositing seas across the arch (Meng and Harsh, 1988).

The sedimentary deposits of the study area have been differentiated into geologic formations and formation members based on lithologic and paleontologic consistencies. Differentiation of the sediment wedge into component aquifers and confining units is based upon the mapping of hydraulically connected permeable beds, the boundaries of which do not necessarily correspond to formation boundaries. In most instances, aquifers and confining units are made up regionally of more than one geologic formation. Traditionally in the North Carolina Coastal Plain, aquifers are named after the formation of which they are primarily comprised, although this system of nomenclature can create confusion especially in places where the principal component formation dies out and the aquifer is then made up of a formation or formations for which it is not named. The relationship between geologic formations in the northeastern North Carolina and southeastern Virginia coastal plains and hydrogeologic units designated in this study is shown in figure 2. The hydrogeologic system in the study region, from basement to land surface, consists of the lower Cape Fear and upper Cape Fear aquifers and confining units, which correspond primarily to the Cretaceous Cape Fear Formation and Cretaceous Black Creek Formation, the Beaufort aquifer and confining unit, which are comprised of the Paleocene Beaufort Formation, the Castle Hayne aquifer and confining unit, which are made up of the upper part of the Beaufort, the Eocene Castle Hayne and Miocene Pungo River Formations, the Yorktown aquifer and confining unit, which are comprised of the upper part of the Pungo River, Pliocene Yorktown and Pliocene Chowan River Formations, and the surficial aquifer, which is made up primarily of Quaternary age surficial deposits. Where confining beds are missing, the Yorktown Formation can be part of the surficial aquifer.

GENERAL DESCRIPTION OF THE GROUND WATER SYSTEM

Ground water flows in a rather complex three-dimensional pattern through the subsurface in the North Albemarle region, as is typical in a multi-layered system. Ground water flows laterally through aquifers from recharge to discharge areas along flowlines which parallel directions of steepest hydraulic gradient, as well as vertically downward or upward in response to differences in total hydraulic head between aquifers. The complexity of ground water flow patterns is illustrated along a typical hydrogeologic cross section through northeastern North Carolina (figure 3).

Within the surficial aquifer, the shape of the water table roughly follows the shape of the surface topography. Ground water moves from areas of recharge in the interstream areas, where water levels are highest, to discharge areas such as the Dismal swamp, the Chowan, Perquimans, Pasquotank and Little River valleys, the Albemarle and Currituck Sounds, and other smaller creeks, swamps and estuaries. Over the wide extent of the report region, recharge rates to the surficial aquifer may be predicted to vary within a range of 5 to 20 inches per year. This is based on evapotranspiration rates, variations in infiltration capacities of soils, varying water table conditions, and 40 to 60 inches of rainfall per year. In the deeper confined aquifers, including the Yorktown, Castle Hayne, Beaufort, upper and lower Cape Fear, the effects of localized recharge and discharge lessens with increasing depth. According to a generalized water budget model of the coastal plain (Wilder and others, 1978) approximately one inch of ground water per year moves from the surficial to deeper confined aquifers. Within the Yorktown through lower Cape Fear aquifer recharge areas, water leaks downward from the surficial aquifer through the confining beds. In these recharge areas, the water table in the surficial aquifer is above the potentiometric surfaces of the Yorktown through lower Cape Fear aquifers. The rate of recharge depends on the difference in head values between the surficial aquifer and the deeper, confined aquifers, and on

Figure 2. -Relationship of Stratigraphic and Hydrogeologic Units in the Study Region

North Albemarle Geologic Units			North Albemarle Hydrogeologic Units	SE Virginia Hydrogeologic Units
System	**Series**	**Formation**	**Aquifers and Confining Units**	
Quaternary	Holocene	Undifferentiated	Surficial Aquifer	Columbia Aquifer
Quaternary	Pleistocene	Undifferentiated	Surficial Aquifer	Columbia Aquifer
Tertiary	Pliocene	Chowan River Fm.	Yorktown Confining Unit	Yorktown Confining Unit
Tertiary	Pliocene	Yorktown Formation	Yorktown Aquifer	Yorktown-Eastover Aquifer St. Marys Confining Unit
Tertiary	Middle Miocene	Pungo River Formation	Castle Hayne Conf. Un.	St. Marys-Choptank Aquifer Calvert Confining Unit
Tertiary	Middle Eocene	Castle Hayne Formation	Castle Hayne Aquifer	Chickahominy-Piney Point Aquifer
Tertiary	Upper Paleocene	Beaufort Formation	Beaufort Conf. Unit Beaufort Aquifer	Nanjemoy-Marlboro CU Aquia Aquifer
Cretaceous	Upper Cretaceous	Peedee Fm.[1] Black Creek Formation	Upper Cape Fear Confining Unit	Upper Potomac Confining Unit
Cretaceous	Upper Cretaceous	Cape Fear Formation	Upper Cape Fear Aquifer	Upper Potomac Aquifer
Cretaceous	Upper Cretaceous	Cape Fear Formation	Lower Cape Fear Confining Unit	Middle Potomac Confining Unit
Cretaceous	Upper Cretaceous	Cape Fear Formation	Lower Cape Fear Aquifer	Middle Potomac Aquifer Lower Potomac Confining Unit Lower Potomac Aquifer
Cretaceous	Lower Cretaceous	Unnamed Units		

1. Present only in southern part of study area

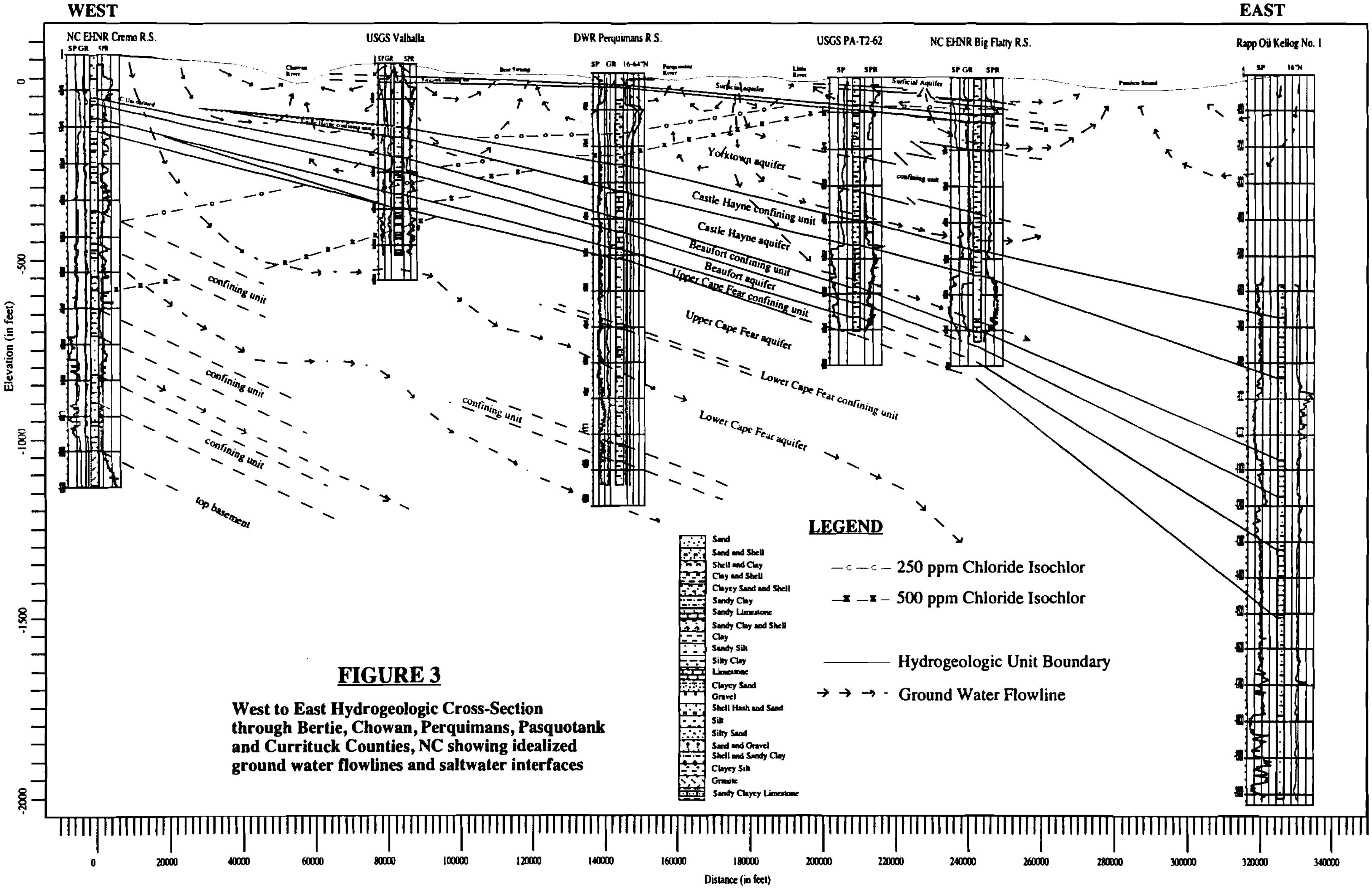


FIGURE 3

West to East Hydrogeologic Cross-Section through Bertie, Chowan, Perquimans, Pasquotank and Currituck Counties, NC showing idealized ground water flowlines and saltwater interfaces

the thickness and permeability of the confining beds. Recharge rates are proportional to head difference and confining bed permeability and are inversely proportional to confining bed thickness. In the ground water discharge areas, water levels are successively higher from shallow to deep aquifers, allowing ground water to flow upward through the system. Discharge rates are governed by the same principles as recharge rates.

The natural ground water flow regime in the North Albemarle region has been disturbed by large scale pumping from the upper and lower Cape Fear aquifers in the Franklin, Virginia area. As indicated by hydrographs and potentiometric surface maps (figures 4, 5, 6, and 7), an extensive cone of depression has developed in these aquifers over much of the northwestern part of the study area. The shallower aquifers are being slightly affected as well. This is indicative of three things:

1. Water is being withdrawn from these aquifers at a higher rate than they are being recharged.

2. In the northwestern part of the study area, ground water in the upper and lower Cape Fear aquifers is flowing toward the Franklin, Virginia pumping center instead of toward the Atlantic Coast, as it would under normal conditions.

3. The gradual decline of water levels in the deep aquifers in the northwestern part of the study area has probably caused a significant reduction in the amount of upward movement of ground water in discharge areas due to lowering of hydraulic head differentials between deeper and shallower aquifers.

A major limitation on ground water supply development in the eastern most counties of the North Albemarle region is the presence of shallow salt water in the aquifer system. Chloride concentrations generally increase with increasing depth in the aquifer system, except in the case of the upper and lower Cape Fear aquifers, where concentrations fluctuate. Salt water is defined for the purposes of this study as water containing greater than 250 ppm (parts per million) chloride. As recognized by Winner and Coble (1989), the position of the fresh water-salt water interface has a very complicated pattern in the coastal plain. Sediments were deposited during cyclic fluctuations of sea level over geologic time. The seaward limit of fresh water is unique for each aquifer as governed by variations in hydraulic properties, position and rates of recharge, thickness and hydraulic conductivity of overlying confining beds, and hydraulic gradients. Over much of the eastern section of the North Albemarle region, salt water is encountered at 39 to 180 feet below land surface. Meisler (1989), attributed the shallow occurrence of salt water in the North Albemarle region, Delaware and Chesapeake Bay area, and lower Cape Fear River Basin to coincide with areas of major ground water discharge. Moreover, he related this condition to generally higher sea levels and more prevalent marine conditions during the late Tertiary and Quaternary Periods.

Analysis of data collected for this study indicates that in much of the eastern part of the study area hydraulic head values are higher at depth (Appendix: plates A-2 to A-10). In places where head gradients indicate downward components of flow, head differentials are not great enough to facilitate a high rate of recharge. Lower heads in the shallow aquifer system relative to deeper aquifers maintain the shallow presence of salt water. Low transmissivity and hydraulic conductivity of the aquifers (appendix: table A-1), and the presence of thick Pliocene and Miocene age clay and silt beds in the eastern counties have also played a major role in impeding fresh water recharge and flushing of salt water bearing strata over geologic time.

FIGURE 4 Hydrograph of NCDENR Sunbury Research Station

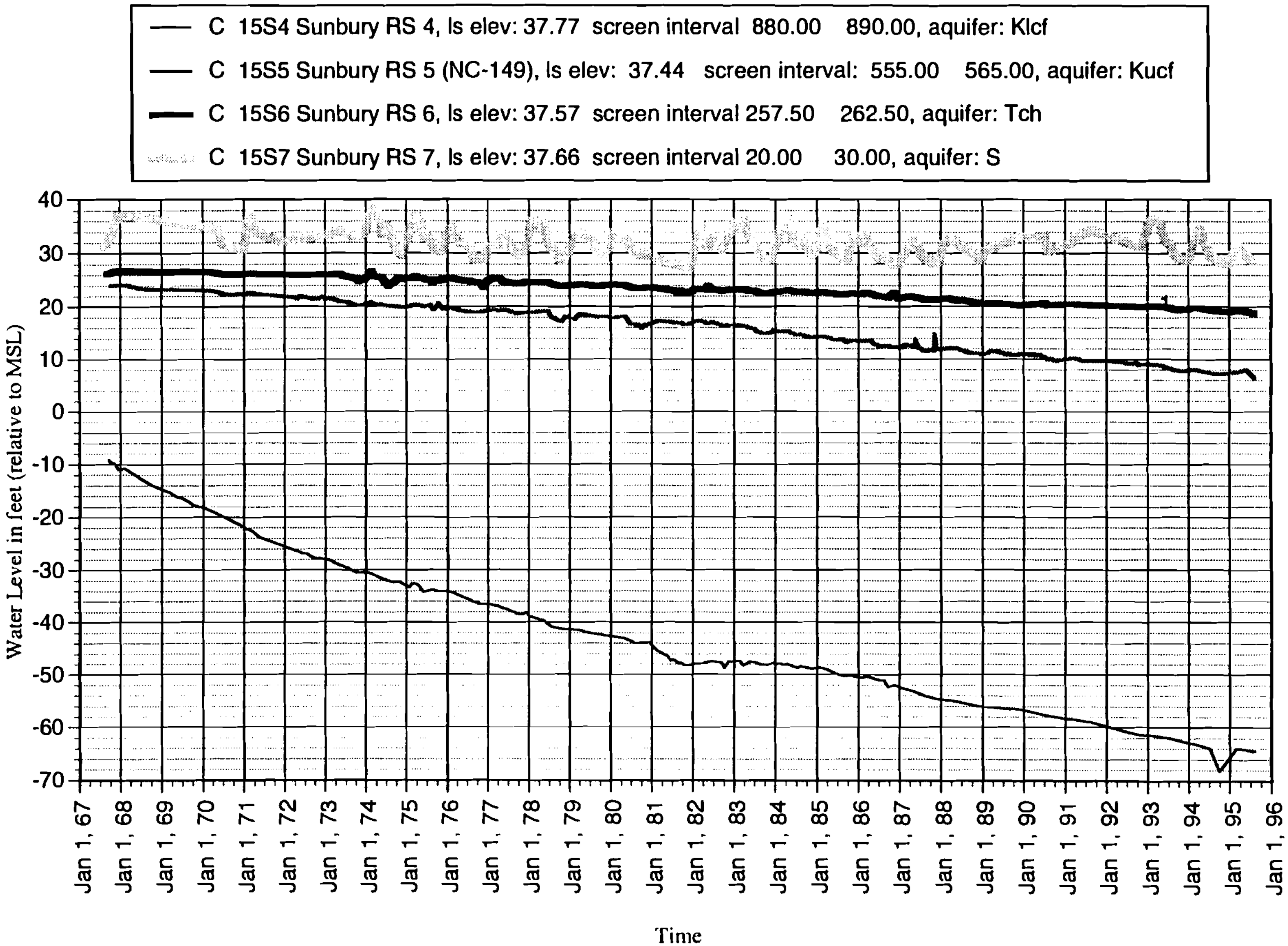
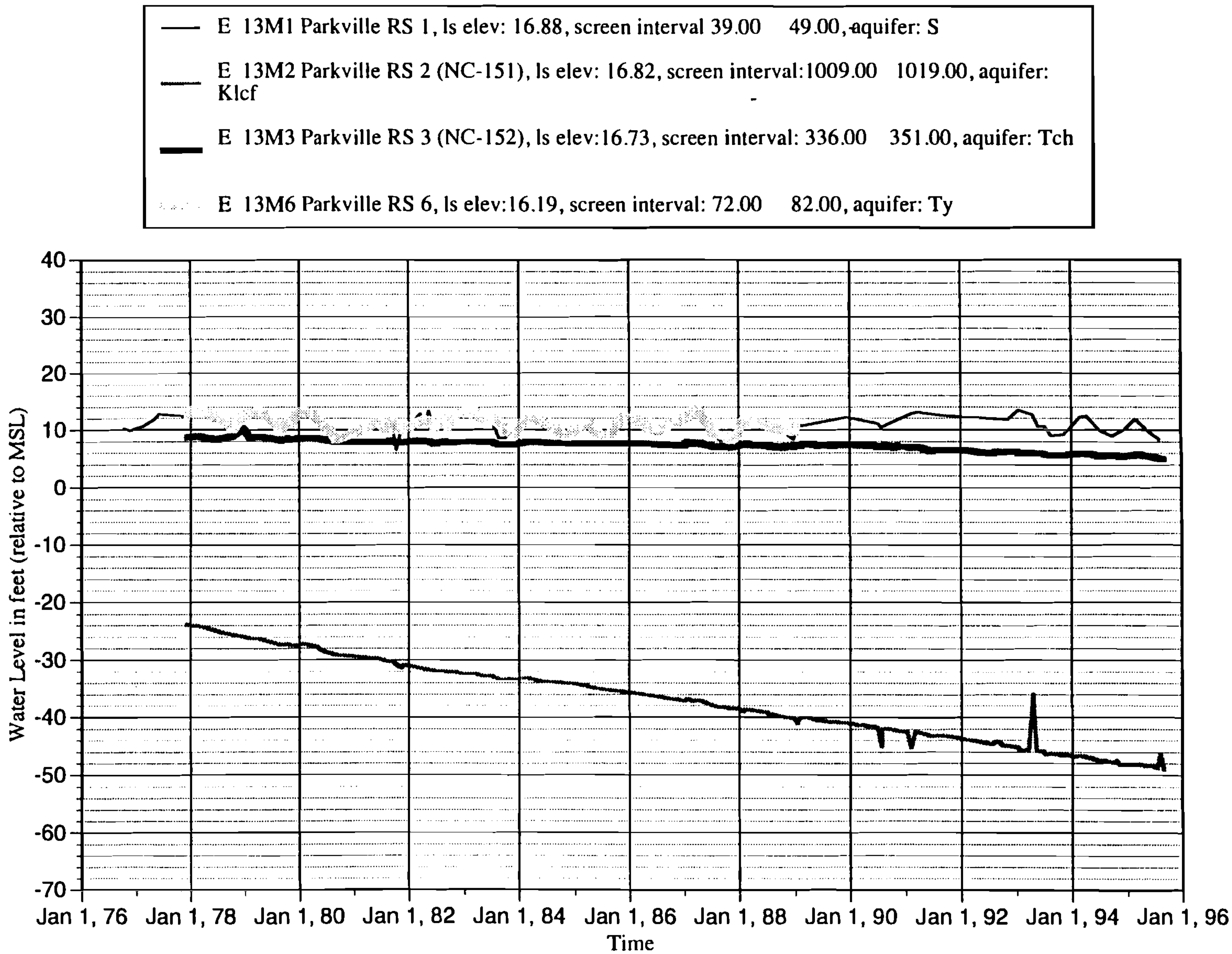
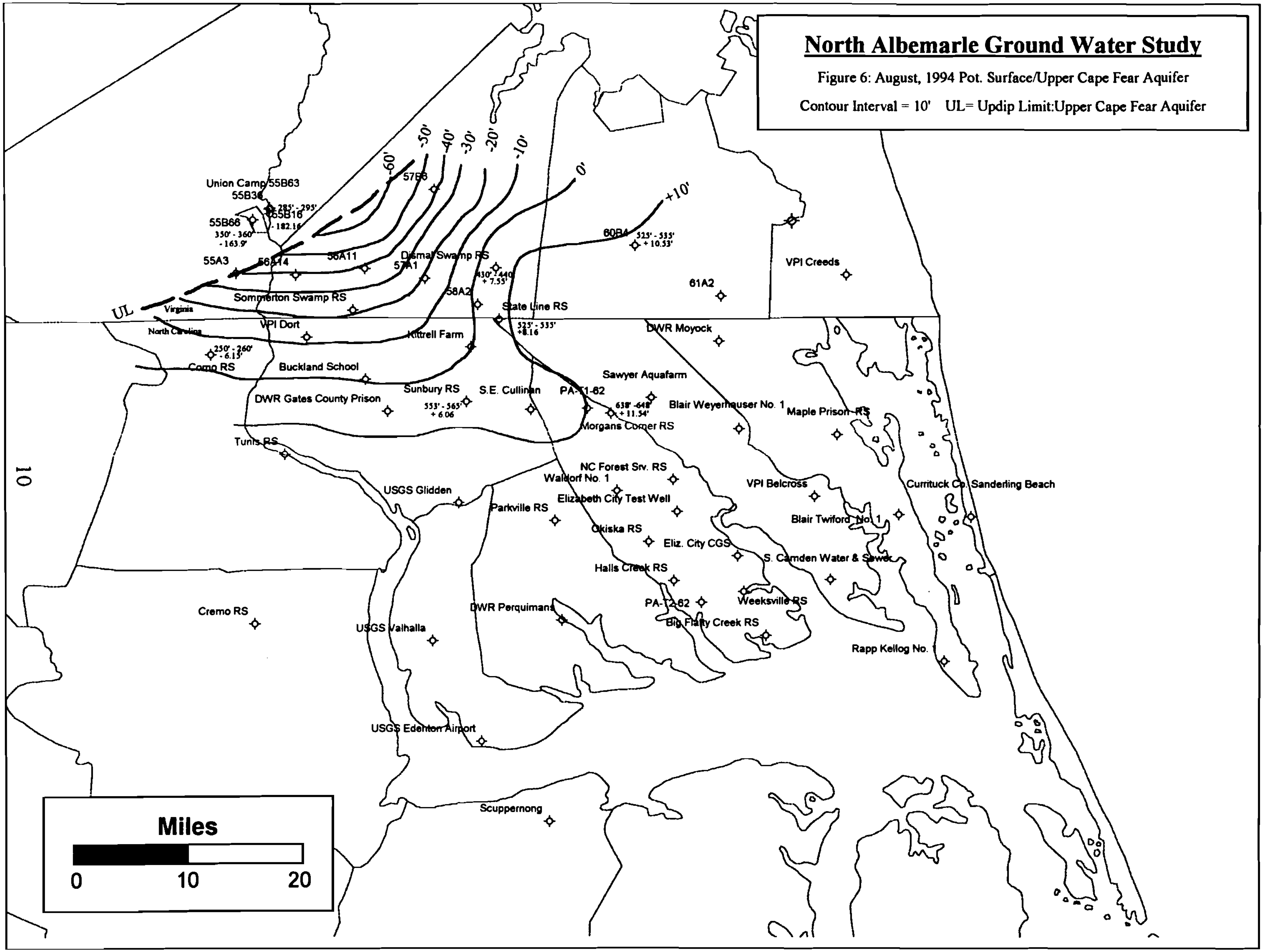
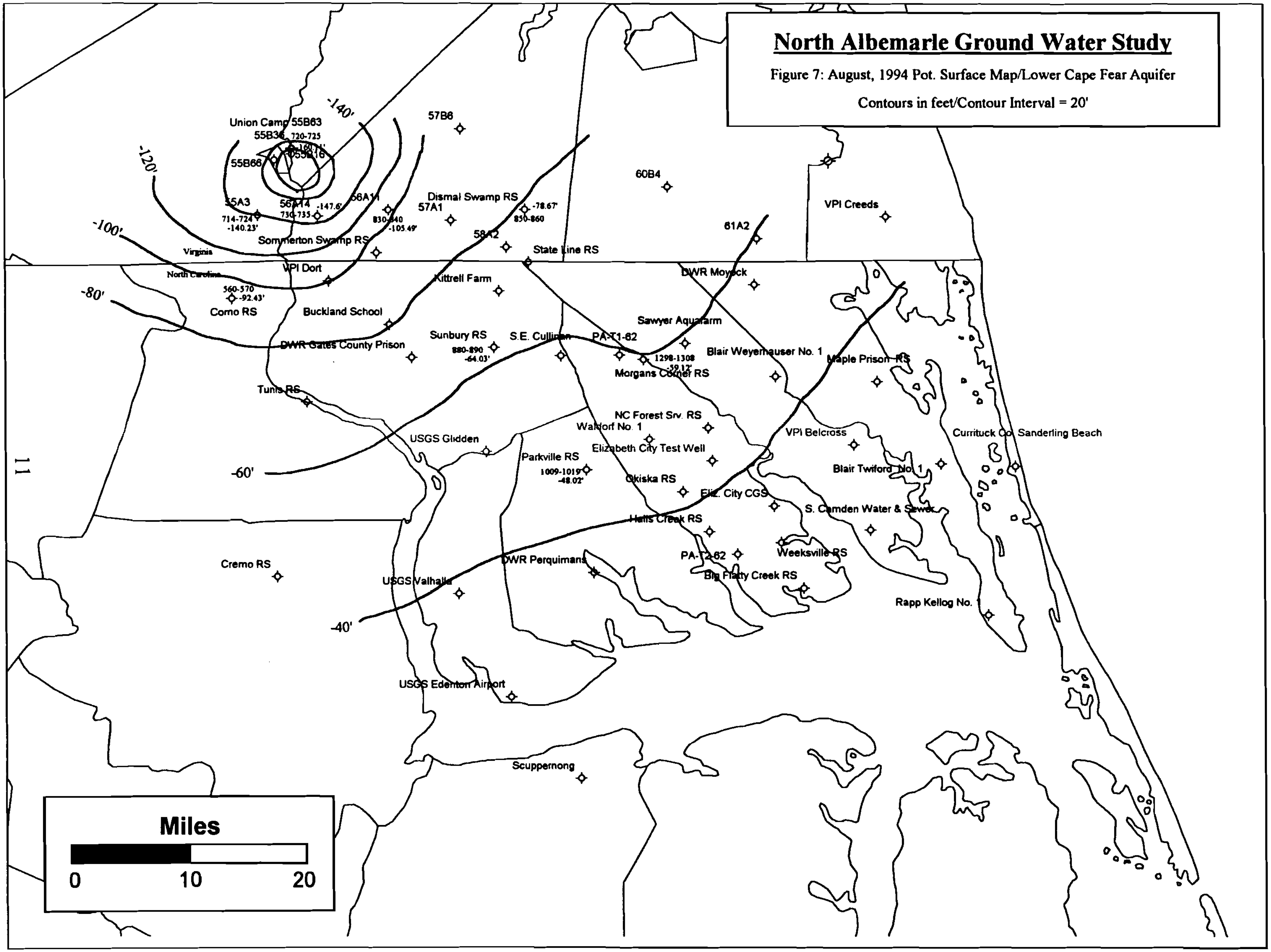


FIGURE 5 Hydrograph of NCDENR Parkville Research Station




North Albemarle Ground Water Study
Figure 6: August, 1994 Pot. Surface/Upper Cape Fear Aquifer
Contour Interval = 10' UL= Updip Limit:Upper Cape Fear Aquifer
-60'
-50'
-40'
-30'
-20'
-10'
0'
+10'
UL
Virginia
North Carolina
Union Camp 55B63
55B36
55B16
55B66
55A3
56A14
56A11
57B6
57A1
Dismal Swamp RS
58A2
60B4
61A2
VPI Creeds
Sommerton Swamp RS
State Line RS
VPI Dort
Kittrell Farm
DWR Moyock
Como RS
Buckland School
Sawyer Aquafarm
DWR Gates County Prison
Sunbury RS
S.E. Cullinan
PA-T1-82
Blair Weyerhauser No. 1
Maple Prison RS
Morgans Corner RS
Tunis RS
NC Forest Srv. RS
Waldorf No. 1
USGS Glidden
Elizabeth City Test Well
VPI Belcross
Currituck Co. Sanderling Beach
Parkville RS
Blair Twiford No. 1
Okiska RS
Eliz. City CGS
S. Camden Water & Sewer
Halls Creek RS
PA-T2-82
Weeksville RS
Cremo RS
DWR Perquimans
Big Flatty Creek RS
USGS Valhalla
Rapp Kellog No. 1
USGS Edenton Airport
Scuppernong
10
Miles
0
10
20



North Albemarle Ground Water Study

Figure 7: August, 1994 Pot. Surface Map/Lower Cape Fear Aquifer

Contours in feet/Contour Interval = 20'

HYDROGEOLOGIC METHODS USED FOR INVESTIGATION OF THE SUBSURFACE

For the purposes of defining the aquifer framework and providing a conceptual model for use in future ground water modeling scenarios, the following interpretive methods and tools were used:

1. Correlation and interpretation of borehole geophysical logs from 41 locations (figure 8), including spontaneous potential (SP), gamma ray, electrical resistivity (16/64'' normal), and single point resistance. In general, these log types were used for identification of aquifers and confining beds, and for their regional correlation across the study area. Gamma ray logs were the most useful for regional correlation by virtue of having produced consistent curve signatures across phosphatic zones. Gamma log measurements are unaffected by borehole and formation fluids, and for this additional reason, were especially reliable for correlation purposes. SP logs were useful for deeper correlations, but sometimes were unusable in the shallow subsurface where salinity contrasts between drilling fluid and formation fluids did not exist. In combination with the SP curve, 16/64'' normal resistivity curves were sometimes useful for correlation of stratigraphic units, and for distinguishing between fresh water and salt water bearing strata. Single point resistance curves generally make their measurement within the flushed zone of the borehole, and thus do not provide measurements of true formation resistivity in permeable beds (Keyes, 1990). Single point resistance logs do however, provide good thin bed definition (Keyes, 1990), and thus were extremely useful for defining vertical lithologic variations.

2. Correlation and interpretation of lithologic logs from core and cuttings samples. Lithologic logs were used in combination with borehole geophysical logs to define vertical and lateral stratigraphic variations in the subsurface. Complex facies changes exist in the sediments of the study area. These variations would have been difficult or impossible to define without the use of core and cuttings data.

3. Observation of significant differences in hydraulic head or chloride concentration across confining units, indicating hydraulic separation between aquifers. In areas that were being influenced heavily by ground water withdrawals, this technique either could not be used, or was used with caution. Employed in combination with borehole geophysical and lithologic log interpretation, this is a reliable technique for differentiating between aquifers and confining units.

4. Observation of regional drawdown effects from high volume ground water withdrawals in the Franklin, Virginia area were used to determine the lateral continuity of the upper and lower Cape Fear aquifers. Observed transmission of drawdown effects from pumping establishes the hydraulic continuity and lateral extent of an aquifer across the region affected. A database of aquifer test information was developed for the study area for the purpose of providing information on various hydraulic properties of the hydrogeologic units (Appendix: table A-1). This included measurements of transmissivity, hydraulic conductivity (including K and some K' values), storativity, and specific capacity. Analytical techniques used to

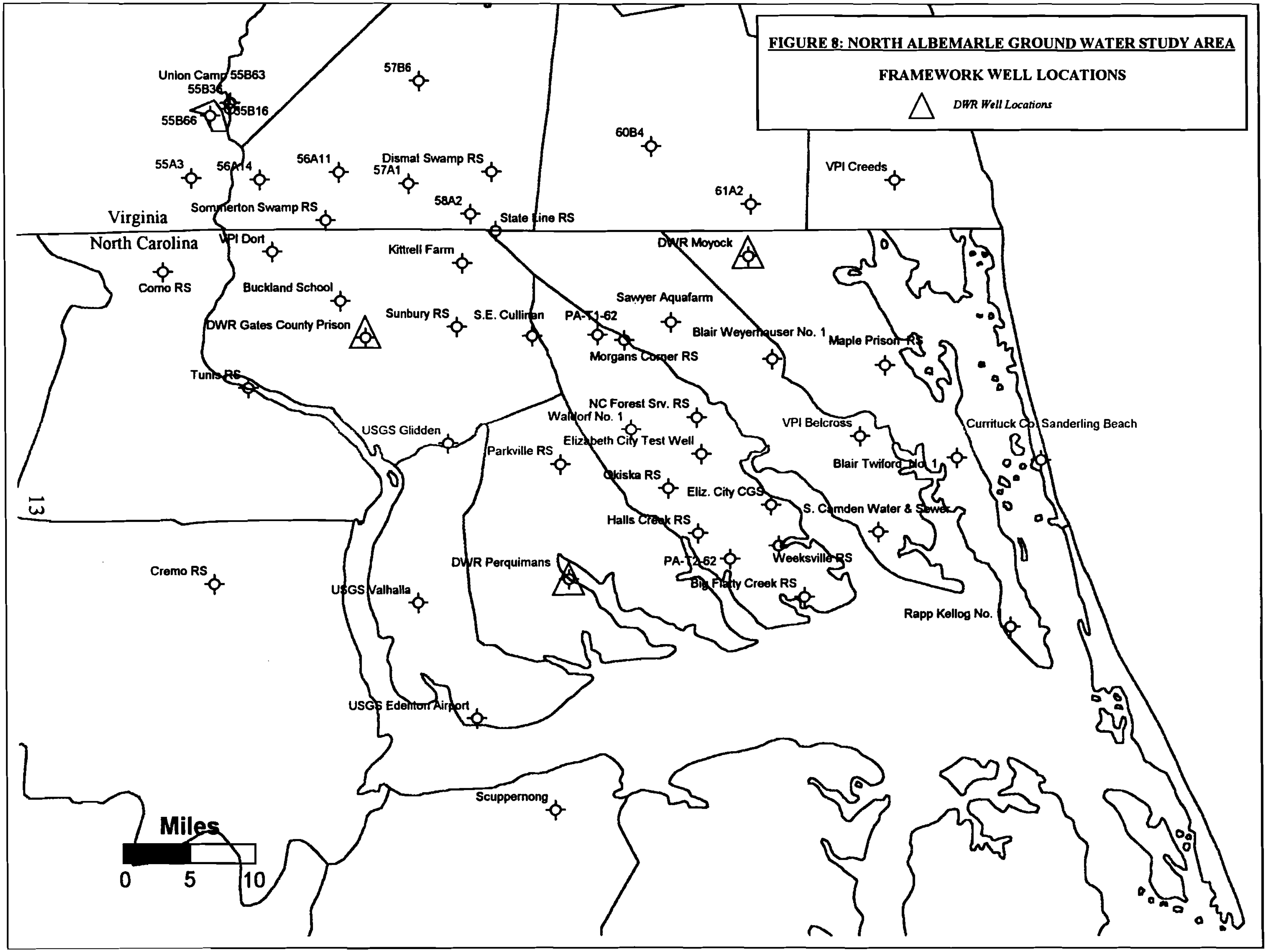


FIGURE 8: NORTH ALBEMARLE GROUND WATER STUDY AREA

FRAMEWORK WELL LOCATIONS

calculate hydraulic parameters included the Jacobs time drawdown and distance drawdown methods, and the Hantush-Jacobs method for aquifers with leaky confining units.

5. Interpretation of apparent resistivity measurements from Time Domain Electromagnetic Soundings (TDEM). This is a surface geophysical technique by which an electromagnetic field is induced at land surface. As soon as the transmitter current is stopped, eddy currents are propagated into the subsurface from a transmitter loop. A secondary magnetic field is generated that changes with time as the eddy currents propagate downward through the subsurface. A central receiver coil measures changes in the magnetic field, which are recorded by the TDEM system over the course of the sounding time. The velocity and decay rate of the eddy currents is directly related to the electrical resistivity of the subsurface, and are converted by TEMIX XL software into apparent resistivity values.
   The resistivity of a geologic formation is affected by the fluid contained within the formation, its effective porosity, and the percentage of clay (Keyes, 1990). Increases in fluid salinity, effective porosity, and clay content all have the effect of causing decreased resistivity values. Decreases in the same produce increased resistivity values. Therefore, it is important to understand how changes in these variables are affecting TDEM response. Employed in conjunction with borehole geophysical logs and chloride sample data, TDEM profiles provided excellent information on chloride distribution patterns and aquifer/confining unit distribution between areas of well control.

6. Construction of a regional cross section network, and preparation of hydrogeologic maps of each of the principal aquifers and confining units. Contour maps were prepared to show the elevation of the top of each regional unit, thickness and areal distribution, percentage of permeable material in each aquifer, aquifer lithofacies distribution, and potentiometric surfaces. Periodic water level and chloride concentration measurements were obtained from a network of ground water monitoring wells that were installed during the 1970 -1990s by the North Carolina Division of Water Quality and Division of Water Resources. Using elevation values calculated from logs, contour maps were prepared of the elevation of the top of each of the major aquifers and confining units recognized. In addition, isopach (thickness) maps were prepared for each aquifer and confining unit. Where a confining unit was inferred to pinch out (due to changes in depositional environment, erosion, or nondeposition) on an isopach map, the isopach map was overlain with an altitude map of the top of the underlying aquifer, and the altitude contours were terminated against the zero thickness line of the confining unit. As a matter of course, if another confining unit exists higher in the stratigraphic section, the top of the mapped aquifer becomes the base of the next higher confining unit. In order to avoid complications that would result from large mapping horizon jumps, altitude lines were left to terminate against zero thickness lines. Moreover, isopach contours of an aquifer were overlain with isopach contours of the overlying confining unit. Aquifer isopach lines were terminated against zero confining unit thickness lines. The aquifer material does not necessarily disappear where its confining unit is absent. It is either unconfined, or confined from another clay or silt unit higher in the section.

In order to gain subsurface information where data gaps existed, three test holes were drilled by the Division of Water Resources during the period of 1994-1995 to depths exceeding 1000 feet below land surface. The three wells were located in Gates (near the Gates Co. Prison), Perquimans (near the town of Hertford), and Currituck (near the town of Moyock) Counties as shown in figure 8. In addition to the running of a suite of borehole geophysical logs, lithostratigraphic logs were constructed by the North Carolina Geological Survey from cutting samples collected at each drill site. Both bio and lithostratigraphic logs were prepared for the Perquimans County test. Pump tests were performed on selected intervals in each borehole, as well as water level measurements, and water quality analyses. A complete presentation of this information is found in the appendix of this report.

HYDROGEOLOGIC FRAMEWORK OF THE STUDY AREA

In as much detail as available data would allow, the Cretaceous through Quaternary sedimentary section across the area of study was defined in terms of its component aquifers and confining units, their thickness, lateral distribution, hydraulic properties, and relationship to stratigraphic units. Aquifers are further described in terms of interrelationships, chloride distribution, and natural or pump induced ground water movement. As mentioned previously, one of the major objectives of this investigation is to delineate in general terms, prospective areas for expansion of ground water supply sources in the eastern counties of the North Albemarle region. Accordingly, areas of exploratory potential in Pasquotank, Perquimans, Camden and Currituck Counties are mentioned in the discussion of each aquifer unit.

Six major aquifers and the confining layers that separate them are described as follows:

SURFICIAL AQUIFER

Over the majority of the study region, the surficial aquifer is primarily composed of Holocene and Pleistocene age sediments that were deposited in a marginal marine environment, and is chiefly made up of shelly, silty sands and thin clay beds. To the northwest, in Gates and eastern Hertford Counties and into the Franklin, Virginia area these units become increasingly nonmarine in character. This is indicated by the occurrence of accessory iron oxide minerals, and by the absence of marine fossils. Where confining beds are absent between the surficial and Yorktown aquifers, the Chowan River and the upper part of the Yorktown Formation are part of the surficial aquifer. The thickness of this aquifer is quite variable over the study region, ranging from as little as 10 feet in the western areas of the region to as much as 100 feet in the outer banks of Currituck County (Appendix: plates A-2 to A-10). In southeastern Virginia it is referred to as the Columbia aquifer (figure 2).

As the uppermost aquifer in the system, the surficial aquifer is the first to receive and store water from recharge and thus serves as a source for water moving both down gradient to deeper aquifers and laterally to discharge areas. Ground water discharge areas comprise a significant geographic area of the study region, including the Dismal Swamp in Pasquotank, Camden and Currituck Counties, other wetland areas, the shorelines of the Albemarle and Currituck Sounds, the Chowan, Perquimans, Little Pasquotank and North Rivers and the smaller rivers, streams and drainage ditches in the area, the shorelines of estuaries, and the shoreline of the Atlantic Ocean. Heath (1994) recognized two types of ground water discharge areas, perennial and intermittent. Perennial discharge areas occur in areas where discharge is continuous, but the discharge rate is not constant. This type of discharge area would include all of the aforementioned rivers and streams, lakes, and shoreline areas. Intermittent discharge occurs in areas where discharge is not continuous, due to the fact that the position of the water table and capillary fringe is sometimes below land surface. Consequently, these areas alternate between periods of recharge and discharge. Higher elevation areas of the Dismal Swamp, and floodplain areas in the study area fit into this category. Heath (1994) also recognized two kinds of recharge areas, perennial and intermittent. Perennial recharge areas constitute regions where the top of the saturated zone is always below land surface or exhibits a downward component of flow, and which are always able to receive additional water when available. On the other hand, intermittent recharge areas correspond to regions where the top of the saturated zone alternates in position between land surface and below land surface. Recharge occurs only when an unsaturated zone develops and allows the aquifer to receive additional water. Perennial recharge areas to the surficial aquifer occur within the non-wetland, inter-stream areas of the study region, whereas intermittent recharge areas occur in higher elevation zones of wetlands, including the Dismal Swamp, and floodplains of the rivers and streams.

Due to variations of soil types and infiltration capacities, vegetation, and slight differences in climate, recharge rates vary considerably within the large area covered in this report. Recharge rates can be estimated using the General Soil Map of North Carolina (Tant and others, 1974). The General Soil Map indicates that the North Albemarle area is made up over about 50 percent of its land area of soils that exhibit good to moderate infiltration capacity. Soils with poor infiltration capacity blanket the remaining 50 percent of the area Over the wide extent of the report region, recharge rates to the surficial aquifer may be predicted to vary within a range of 5 to 20 inches per year.

The presence of salt water in the surficial aquifer is limited to the Tidewater region of the report area, and is found along the shoreline of the Atlantic Ocean, the Albemarle and Currituck Sounds, and along the high tide limit of salt water in the rivers and streams that flow into these sounds.

The surficial aquifer is used chiefly as a domestic water supply source over the study region. However, it is the primary source of municipal, as well as domestic supply on the Outer Banks of Currituck County where it takes the form of lenses resting on denser salt water (Wilson, 1991). It is also used for municipal supply by South Mills in Pasquotank County. Yields from this aquifer are generally too low across the region to provide adequate municipal or large industrial supply unless large numbers of wells are constructed over expansive land areas. Another disadvantage is that the surficial aquifer is unconfined and more susceptible to contamination than deeper confined aquifers.

YORKTOWN CONFINING UNIT

The Yorktown confining unit consists of a series of discontinuous clay and silt beds that vary considerably in stratigraphic position between the Chowan River Formation, and upper part of the Yorktown Formation as illustrated in regional cross sections. It would be more appropriate to refer to the Yorktown aquifer as being confined regionally by a series of confining beds which do not comprise a single unit, since these beds vary significantly in stratigraphic position.

YORKTOWN AQUIFER

The Yorktown aquifer is the uppermost confined aquifer in the report area, and is principally comprised of the Chowan River and Yorktown Formations of Pliocene age (figure 2). It is referred to as the Yorktown-Eastover aquifer in southeastern Virginia. The Yorktown aquifer is separated over regions of varying extent into subaquifers due to its complex, discontinuous nature of deposition (Appendix: plates A-2 to A-10). Lithologically the unit may be described as fine to medium grained shelly, clayey sand, with its topmost and intervening confining layers consisting of gray, glauconitic clay, and shelly, glauconitic silt. Component formations were deposited in a shallow marine shelf setting . The top of the Chowan River Formation is recognized by the North Carolina Geological Survey at the first occurrence of the index fossil *Carolinapecten eboreus bertiensis*.

Recharge to this aquifer is from the overlying surficial aquifer in areas where downward components of flow are present, and occurs at a very slow rate in the eastern North Albemarle counties due to the presence of generally low downward hydraulic gradients. Wilder and others (1978) estimated an average rate of recharge from the surficial to deeper confined aquifers of 1 inch per year based on a generalized water budget model of the coastal plain. In the eastern part of the North Albemarle area, the average rate is probably less than 1 inch per year.

The Yorktown aquifer, including the intervening confining units which hydraulically divide it into subaquifers, is described in terms of lithofacies distribution and percentage of permeable material in the appendix (figures A-12 and A-18). The highest percentage values of permeable material are found in the southwestern portion of the study area (up to 90 percent), while the lowest values (15-35 percent) are found to the northwest in the Franklin, Virginia area and to the east in Currituck and Camden Counties. Since the Yorktown aquifer is principally comprised of sands, shell material, silts and clays, the percentage of sand and shell material calculated in each well is equivalent to the total percentage of permeable material. Percentages were calculated using gamma ray and SP log curves, in conjunction with lithologic logs. The unit exhibits an eastward thickening wedge-shape in west to east cross-sections (Appendix: plates A-5, A-7, A-8, and A-9), achieving a maximum thickness of 690 feet on the Currituck Outer Banks. SP, gamma ray and cuttings logs generally indicate a coarsening upward pattern throughout the area, as shown in regional cross sections. The upper part of the aquifer system is generally sand rich. Individual sand bodies are observed to be laterally discontinuous in the eastern counties as indicated by a lack of consistent correlation on electric and gamma ray logs. Sand bodies are interbedded with thin clay and silt units and are quite often encased in clay or silt such that lateral hydraulic connection is intermittent, and dependent on their lateral continuity.

Regional cross sections indicate positions of 250 and 500 ppm chloride interfaces within the Yorktown aquifer (Appendix: plates A-2 through A-10). The approximate eastward limit of the salt water interface is depicted on figure A-5 where the 250 ppm equal concentration surface intersects the top of the Castle Hayne confining unit (or base of the Yorktown aquifer). The isochlor runs north-south along the Chowan-Perquimans County line, into eastern Gates County, into the northwestern portion of Camden County , and on into Chesapeake City, Virginia. The position of the interface dips steeply westward toward its western limit and then gently eastward where it occurs at shallow depths in parts of Perquimans, Pasquotank, Camden and Currituck Counties (Appendix: plates A-5, A-7, A-8, and A-9). The shallow position of this interface severely limits the thickness of the overlying fresh water system in these counties, thus limiting potable ground water supply. Moreover, salt water encroachment problems have developed in some of the well fields due to over pumping. This has been a particular problem in the Currituck County well field near Maple, which pumps an average of 400,000 gallons of water per day from the Yorktown aquifer. Population growth in recent years has forced the county to pump at maximum capacity. As a consequence, drawdown and salt water intrusion problems have developed in the well field (Floyd, 1996, unpublished consultant report). Reports of salt water intrusion problems have also been noted in the Pasquotank County well system.

The Yorktown aquifer is the primary source of municipal/industrial water supply in Perquimans, Chowan, Pasquotank and Camden Counties, and in mainland Currituck County. With the exception of the Elizabeth City well field, which adequately supplies the city and surrounding areas, water production rates from current well systems in Pasquotank, Currituck, Camden and Perquimans Counties have been low enough to cause concern among local and state officials about population growth rates and future supply problems. Comparisons of transmissivity, hydraulic conductivity, and specific capacity values of various wells screened in the Yorktown aquifer (Appendix: table A-1) indicate a high variability of these parameters, which translates to a wide range of water production capabilities in individual wells or well fields. Ranges of these values are summarized as follows:

Transmissivity:	1.56 to 2352 ft^2/day
Hydraulic Conductivity:	.226 to 98 ft/day
Specific Capacity:	.12 to 36.1 gpm (gallons per minute) /ft

Considering the small geographic area covered by existing well fields (Appendix: figure A-3), the aforementioned counties could find additional potable water supplies by purchasing or using additional land areas, and developing new well fields in the Yorktown aquifer. The key to finding the best locations for new well fields is to find the "sweet spots", or in other words, areas where the aquifer exhibits maximum values of transmissivity, hydraulic conductivity and specific capacity. Another important factor is to find areas of maximum depth to the 250 ppm chloride interface, to minimize the possibility of salt water upconing. Using data compiled in table A-1 (appendix), future drilling programs should be focused on areas where aquifer quality is known to be high. These areas are listed as follows:

1. The vicinity of the Elizabeth City well field in Pasquotank County.
2. The vicinity of ENR Big Flatty Creek Research Station in southern Pasquotank County.
3. The vicinity of ENR Halls Creek Research Station in southern Pasquotank County.
4. The vicinity of the ENR Moyock test well in northern Currituck County.

In order to assist the counties in their efforts to locate additional water supplies in the Yorktown aquifer, a series of Time Domain Electromagnetic Soundings were taken over much of the North Albemarle region. As discussed previously, TDEM soundings are used to create resistivity versus depth profiles of the earth's subsurface. A series of TDEM transects (figures 10 through 13) were constructed across the study area by creating contour maps of xyz data exported from the TEMIXXL program. Z data values denote electrical resistivity in ohm-meters. Borehole geophysical logs and chloride levels from wells drilled along the transect lines were superimposed on the transects for lithologic and chloride concentration control. In order to determine the relationship between chloride concentration and TDEM resistivity in the Yorktown aquifer, soundings were made at several research stations where recent chloride samples could be obtained from the Yorktown aquifer. Subsequently, a log plot was constructed of TDEM resistivity values vs. chloride concentration (Appendix: figure A-1). A close fit to a straight line is apparent within the 10 to 100 ppm chloride concentration range. Much higher resistivity variations are observed in the 100 to 2000 ppm chloride range. Deviations from the straight line are due to variations in effective porosity and clay percentage. The chart indicates that the resistivity range of fresh water bearing sand in the Yorktown aquifer is 22 to 102 ohm-meters. This resistivity relationship is apparent in TDEM transects a-a',b-b',c-c' and d-d' (figures 10 through 13) and is displayed where the grayish red to black colored zone occurs near the top of each transect. This color range corresponds to a resistivity value range of 22 to 102 ohm-meters. The base of the grayish red to black colored area roughly corresponds to the 250 ppm chloride transition zone, although the resistivity along this transition zone also decreases in some areas due to an increase in clay content in the Yorktown Formation with depth.

In order to display the lateral distribution and thickness of fresh water zone in the surficial and Yorktown aquifers combined, an isopach map (Appendix: figure A-4) was constructed by calculating the thickness of the >22 ohm-meter zone at each sounding location. The map indicates a range in thickness of the fresh water zone of 59 to 306 feet. Areas of maximum thickness are found in the vicinity of the Halls Creek research station in south central Pasquotank County, and in a linear northwest-southeast trending pattern in northern Pasquotank, central Camden, and northern and central Currituck Counties. Thicker zones do not necessarily correspond to areas of greater yield, as indicated by the isopach thin (55 to 86 feet) in the vicinity of the Elizabeth City well field, which produces the best yields from the Yorktown in the study region. Resistivity magnitude is not always a good predictor of aquifer quality in the Yorktown, due to its interbedded

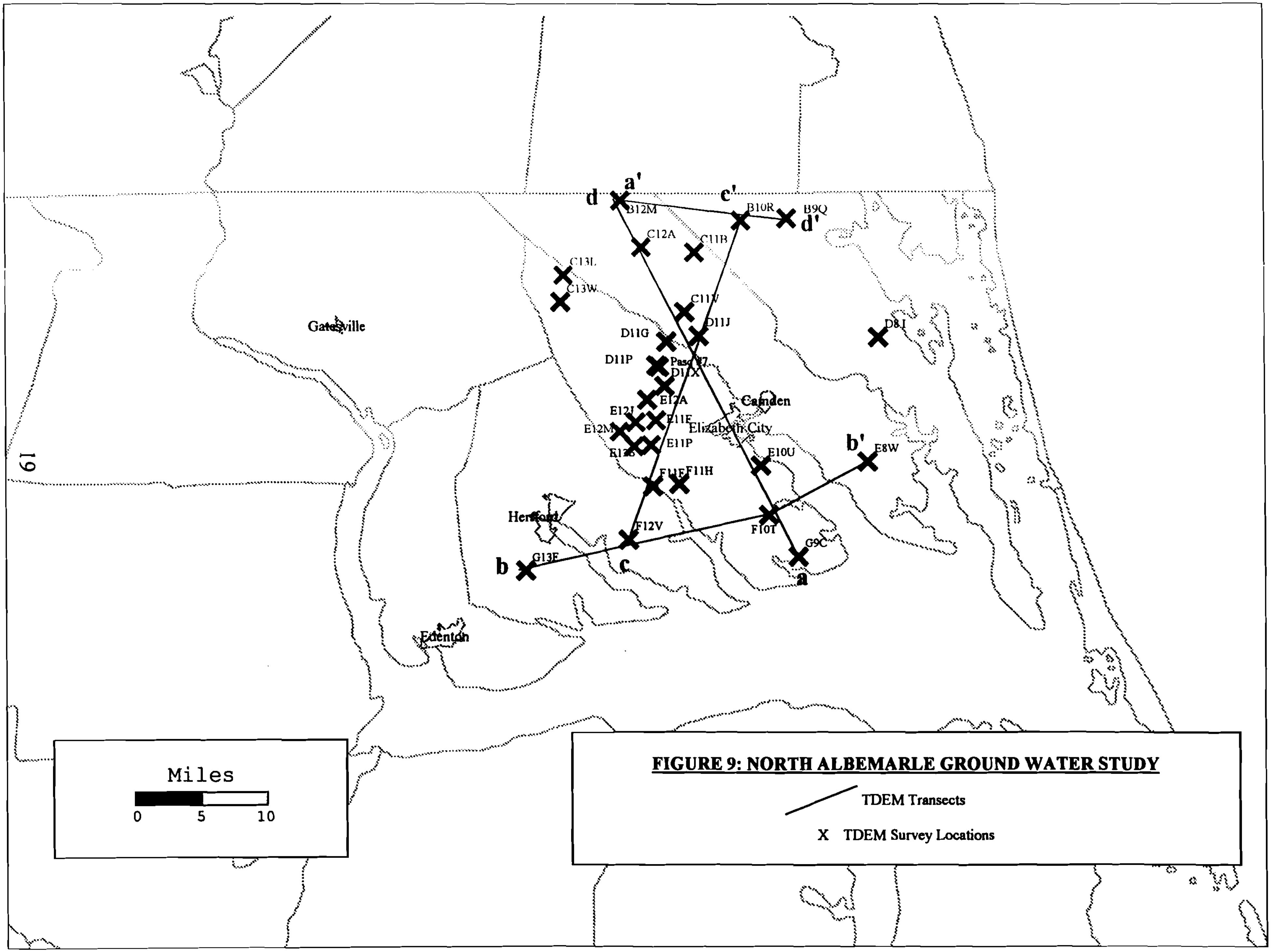


FIGURE 9: NORTH ALBEMARLE GROUND WATER STUDY

Figure 10: TDEM Cross Section a-a' (south to north) through Pasquotank and Camden Counties

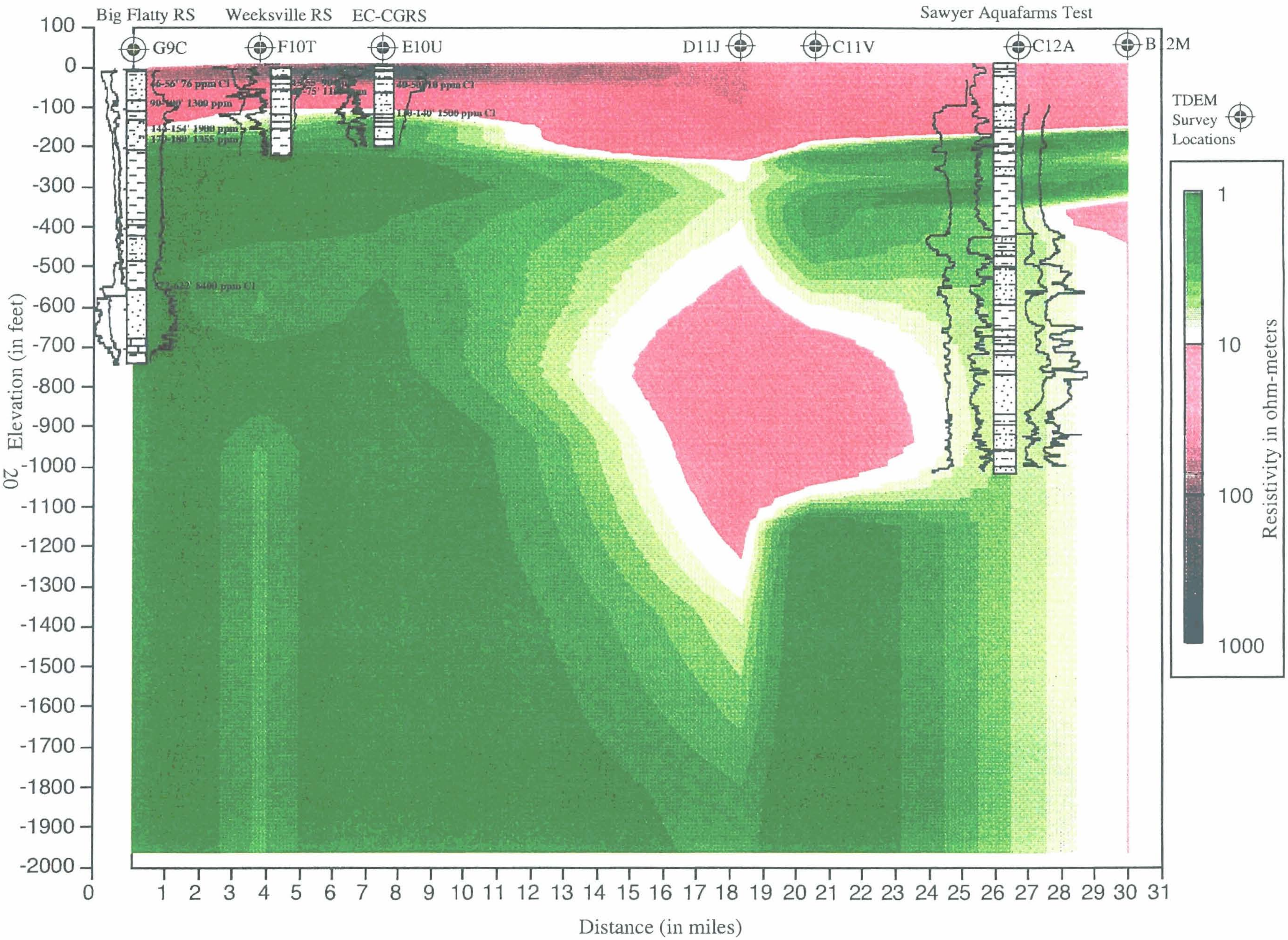


Figure 11: TDEM Cross Section b-b' (west to east) through Perquimons, Pasquotank, and Camden Counties

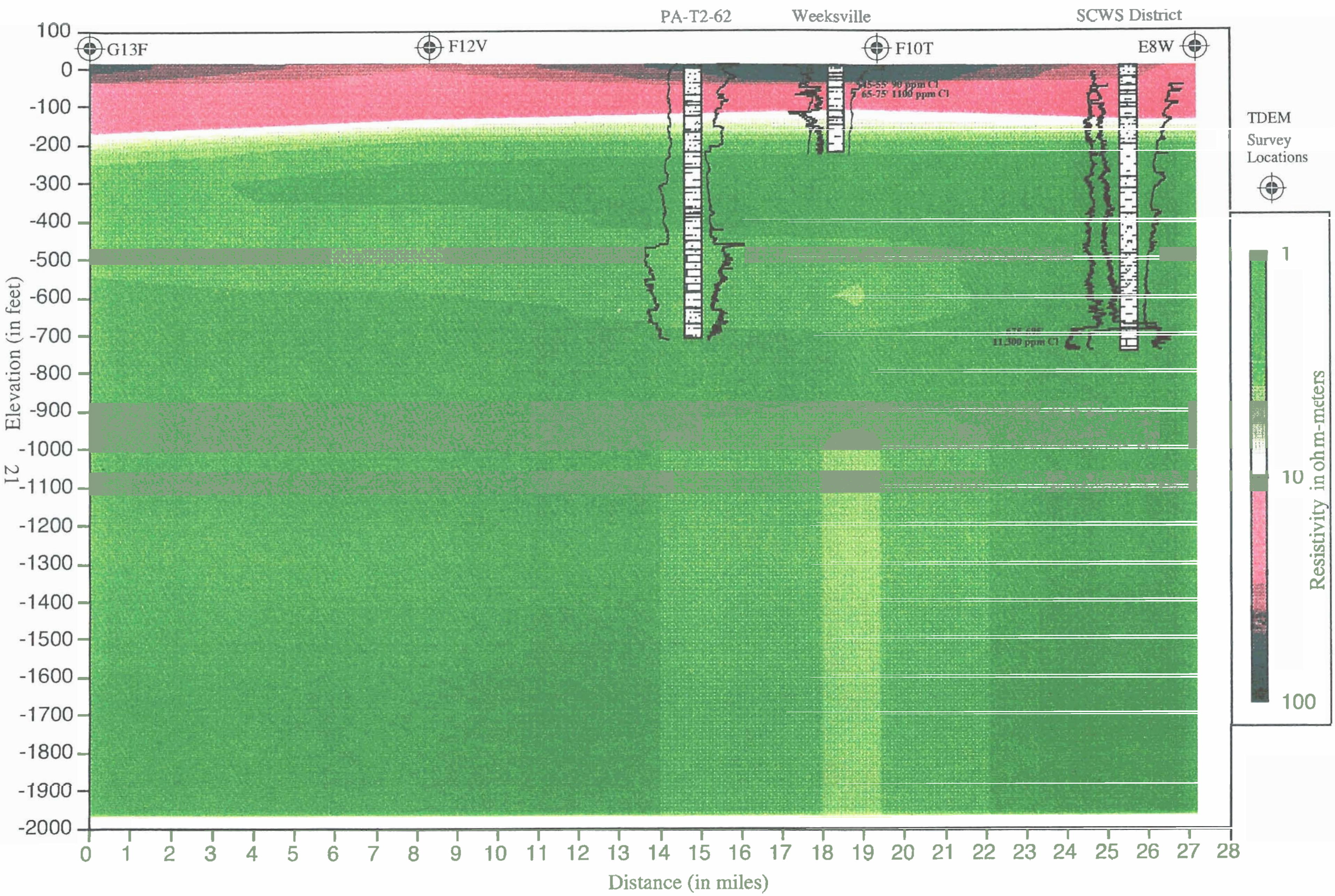


Figure 12: TDEM Cross Section c-c' (south to north) through Perquimons, Pasquotank, Camden, and Currituck Counties

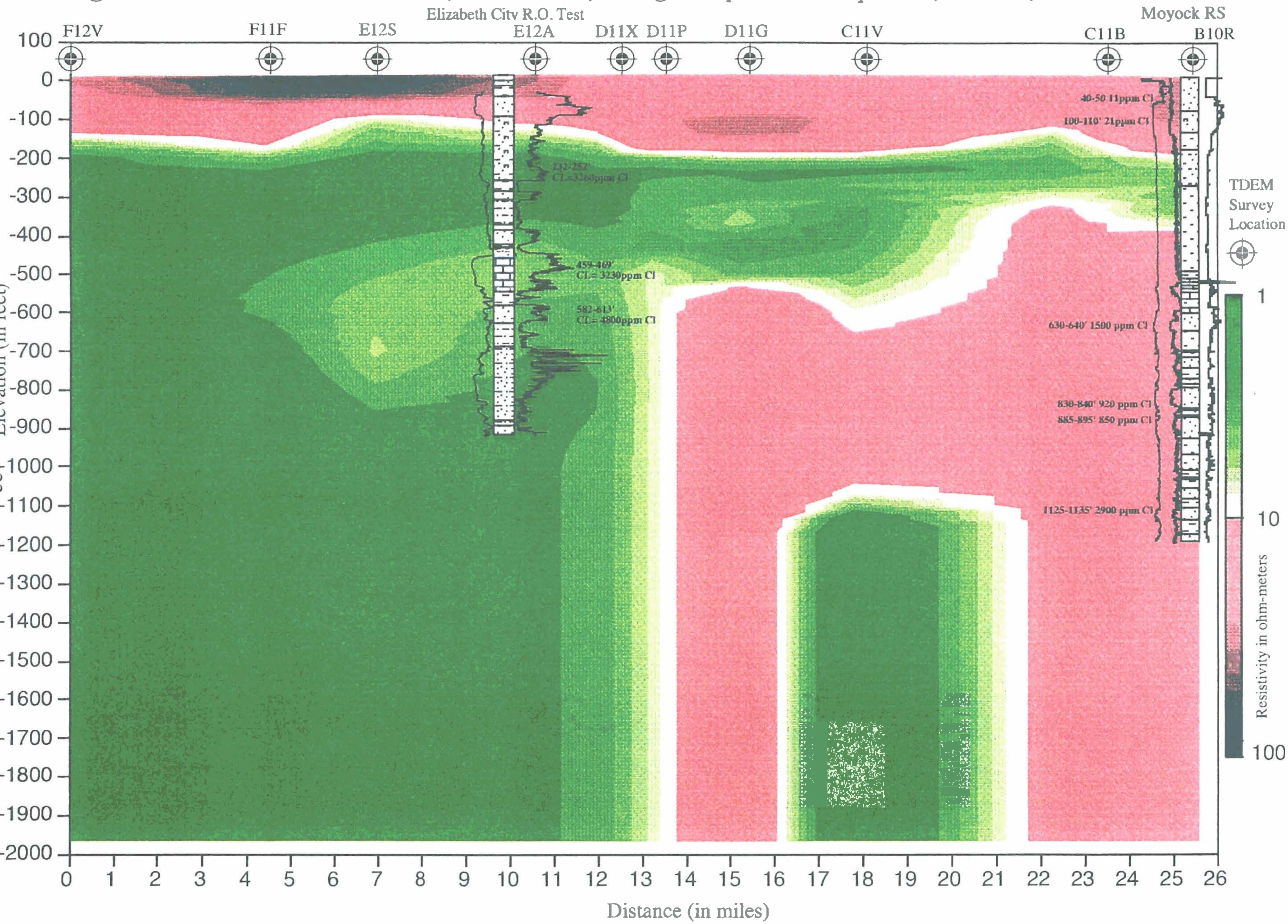
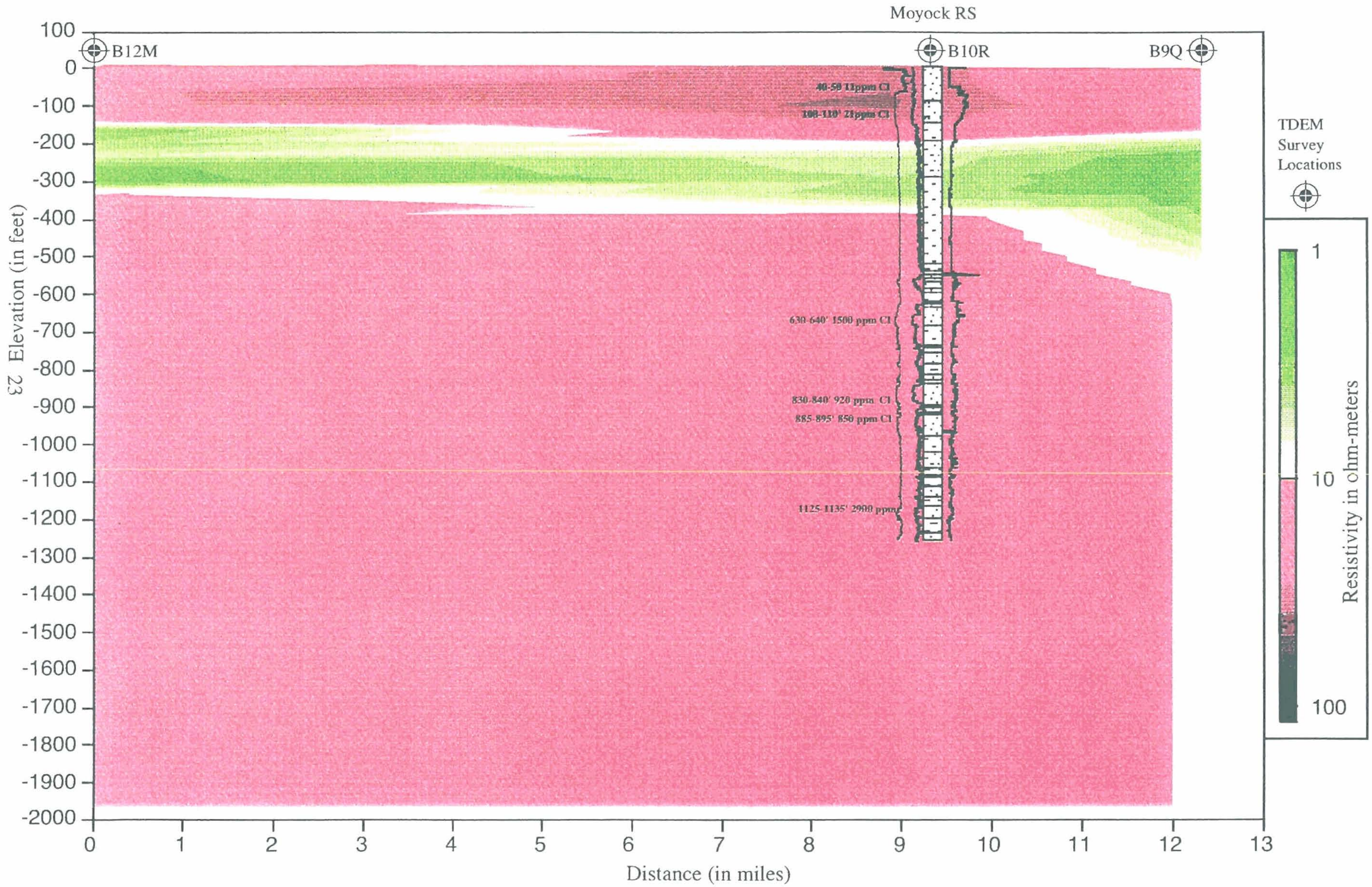


Figure 13: TDEM Cross Section d-d' (west to east) through Camden and Currituck Counties



nature. The presence of thin clay layers between thin, high permeability layers of sand and shell material will produce suppressed resistivity values on electric logs. This characteristic is observed on logs in the Elizabeth City well field. Nevertheless, zones of higher resistivity generally indicate a minimum amount of intersticial or interbedded clays in the fresh water zone, and are good indicators of aquifer quality. This characteristic is observed in particular at the Halls Creek Research Station site in south central Pasquotank County.

The value of TDEM as a reconnaissance tool for locating fresh water bearing Yorktown aquifer sand is amply demonstrated by the findings of this study. The transects indicate the approximate depth to the 250 ppm interface, the presence or absence of fresh water bearing sands, and their approximate thickness. Selection of future drilling locations for water supply wells can be guided by these data interpretations.

CASTLE HAYNE CONFINING UNIT

The Castle Hayne confining unit consists of clay and silt beds present in the Miocene Pungo River Formation (figure 2). The top and base of this confining unit correspond respectively to the base of the Yorktown aquifer, and the top of the Castle Hayne aquifer. The top of the Castle Hayne confining unit slopes toward the east at an average rate of 13 feet per mile in the western part of the study area, increasing to 19.5 feet per mile to the east in Currituck County (Appendix: figure A-5). The thickness of the unit is shown by an isopach map (Appendix: figure A-13) to vary between 0 feet where it pinches out to the west, to 203 feet, as measured in a well on the Currituck County Outer Banks. Clay and silt beds present in this unit are sometimes incised by sand filled channels as seen in cross sections E-E, and F-F' (Appendix: plates A-7 and A-8). In these areas, the thickness of this confining unit is minimal.

CASTLE HAYNE AQUIFER

The Castle Hayne aquifer is comprised over regions of variable extent, of permeable sediments in the lower part of the Pungo River Formation (middle Miocene), the middle Eocene Castle Hayne Formation, and the upper part of the Beaufort Formation of Paleocene age. The Castle Hayne Formation pinches out along a line extending north-south through Chowan and Gates Counties (Appendix: plates A-5, A-7, A-8, and A-9). To the west of this pinchout, as shown on regional cross sections, the Castle Hayne aquifer is made up of permeable beds in the lower part of the Pungo River and upper part of the Beaufort Formations. In Virginia, this unit is referred to as the Chickahominy-Piney Point aquifer.

Regionally, the top of this aquifer is picked at the top of a high positive gamma ray log deflection that corresponds to a zone of phosphatic sand in the lower part of the Pungo River Formation. The positive gamma ray response generally continues into an upper phosphatic section of the Castle Hayne Limestone. The upper part of the Castle Hayne Formation is generally phosphatic due to downward leaching of phosphorus laden solution into the Castle Hayne Formation from Pungo River age sediments. In areas where clay is in contact with the upper part of the Castle Hayne Formation, phosphate leaching did not occur. Below the phosphatic zone, the Castle Hayne Formation displays a characteristic, regionally correlative negative gamma ray response, as is apparent in regional cross sections. The base of the aquifer occurs at the top of the Beaufort confining unit which is made up of clay and silt beds that vary in stratigraphic position between the upper and middle part of the Beaufort Formation.

The lithology of the Castle Hayne aquifer varies considerably across the area due to facies changes in the formations it contains. East of the updip limit of the Castle Hayne Formation, the aquifer contains from top to bottom, a lower phosphatic sand zone of the Pungo River Formation; the shelly, sandy limestones (biosparite) of the Castle Hayne, which grade down dip in the easternmost counties into sandy, glauconitic biomicrite, interbedded with pale green dolomite; and the glauconitic upper sand and limestone beds of the Beaufort Formation. West of the updip limit of the Castle Hayne Formation, the lithologies of the lower section of the Pungo River and upper section of the Beaufort Formations are predominant.

A contour map of the elevation of the top of the Castle Hayne aquifer (Appendix: figure A-6) indicates that it slopes toward the east at the same rate as the top of the Castle Hayne confining unit. The thickness of the aquifer, as shown by an isopach map (Appendix: figure A-13), varies between 0 feet where it dies out to the west in Bertie, Hertford, and western Gates Counties, and 230 feet, as measured in the Currituck County Sanderling Beach well.

Very little useable pump test data from this aquifer was available in the study area for calculation of hydraulic parameters. Data from a 1968 study of Chowan County (Lloyd) indicated an average transmissivity value of 4,010 ft^2/day, average hydraulic conductivity value of 100 ft/day, and average storativity of .0001, based on analysis of 22 pump tests (Appendix: table A-1). An isopercentage map of permeable material within the aquifer was prepared using gamma ray, SP, and lithologic logs. The map indicates a range of 40 to 100% permeable material, with areas of lowest percentage found in eastern Currituck County, and the highest in the southern parts of Chowan, Perquimans, Pasquotank, and Camden Counties.

Isochlors representing a chloride concentration of 250, 500 and 10,000 ppm are plotted in approximation to where they intersect the top and base of the aquifer in figures A-6 and A-7 (Appendix). The narrow distance between isochlor positions at the top and base is attributable to the low thickness, and to the sluggish circulation of ground water through the aquifer. As discussed previously, the presence of higher salt water head values at depth over much of the area, prevents the downward movement of fresh water through the system, and maintains the shallow presence of salt water.

East of the 250 ppm chloride interface, chloride concentrations in this aquifer are too high for potable water supply, and generally increase eastward to a maximum known value of 11,600 ppm, as measured at in a well drilled by the South Camden Water and Sewer District in southern Camden County. A plot of TDEM derived resistivity in ohm-meters vs. measured chloride concentrations at four research station sites in the eastern North Albemarle region indicate a near straight line logarithmic relationship (Appendix: figure A-2). This is apparently due to the very high range of chloride concentration values (1,820 to 11,300 ppm). High chloride concentrations tend to dominate over other variables that affect the resistivity measurement. TDEM transects prepared over the eastern North Albemarle Counties indicate a resistivity range of 1.7 to 20 ohm-meters in the Castle Hayne aquifer, which corresponds roughly to a chloride concentration range of 11,600 to 700 ppm according to the log plot. The lowest apparent concentrations are observed in northern Camden and Currituck Counties.

In the North Albemarle region, potable ground water in the Castle Hayne aquifer can be found to the west of the 250 ppm chloride interface in southeastern Hertford, eastern Bertie, western Gates and central Chowan Counties, and possibly in the northwestern tip of Camden County.

The Castle Hayne aquifer is used for water supply in the Chowan County municipal well field, where it is screened in conjunction with the lower part of the Yorktown aquifer in certain wells. It is used exclusively in the City of Edenton well field where maximum safe yields are reported in the local water supply plan to average .72 million gallons per day per well (10 inch diameter). Lloyd (1968) reported yields in the range of 10 to 25 gpm in domestic wells of 1.25 to 4 inch diameter, and calculated specific capacities of 10 gpm/ft and 13 gpm/ft for 2 and 36 inch wells respectively in southern Chowan County. In other locations within the study area specific capacity values were calculated, and found to range between 1.96 and 3.92 gpd/ft for 2 to 6 inch wells (Appendix: table A-1).

BEAUFORT CONFINING UNIT

The Beaufort confining unit is comprised of clay and silt beds that vary in stratigraphic position between the upper and middle parts of the Beaufort Formation (figure 2). The top of this unit corresponds to the base of the Castle Hayne aquifer, and the base of the unit to the top of the Beaufort aquifer. The top of the Beaufort confining unit slopes toward the east at an average rate of 13 feet per mile in the western part of the study area, increasing to 26 feet per mile to the east in Currituck County (Appendix: figure A-7). Its thickness, as displayed by an isopach map (Appendix: figure A-15), varies between a minimum of 10 feet in the western limit of the report area and a maximum of 200 feet on the Currituck County Outer Banks.

BEAUFORT AQUIFER

The Beaufort aquifer is present throughout the area of study, and is principally comprised of highly glauconitic sand and sandy limestone beds present within the middle and lower part of the Beaufort Formation of Paleocene age. It is recognized by correlatable, negative gamma ray and positive SP curve responses that occur between the Beaufort and upper Cape Fear confining units, and by its typically high glauconite content in cuttings descriptions. Its southeastern Virginia equivalent is referred to as the Aquia aquifer

The top of the aquifer, as displayed by a contour map of its elevation, slopes gently toward the east at a rate of 13 feet per mile in the western part of the study area, increasing to 32.5 feet per mile down slope in Currituck County (Appendix: figure A-8). The thickness of the unit ranges between 29 feet at the western fringe of the report area to 151 feet at the ENR Maple Prison Research Station in Currituck County.

Analysis of available pump test data indicates a transmissivity range of 11 to 1,604 ft^2/day, and a hydraulic conductivity range of .09 to 29 ft^2/day (Appendix: table A-1). Values of specific capacity were calculated at the DWR Moyock and Gates County Prison test well sites, and were found to be very low (.3 to 2.25 gpm/ft.) An isopercentage map of permeable material within the aquifer was prepared for this study. The map indicates that the highest percentages (up to 90%) of permeable material are found in southern Chowan and Pasquotank, southern Currituck, western Gates, and northern Hertford Counties, and in the Franklin, Virginia area.

A plot of the approximate intersection of 250 ppm and 500 ppm chloride isochlors with the top and base of the Beaufort aquifer indicates a similarity of characteristics with the Castle Hayne aquifer in that a narrow separation exists between intersections at the top and base of the aquifer. Again, this is a result of low aquifer thickness, a very slow rate of ground water movement through the aquifer, and maintenance of salt water at shallow levels in the aquifer system due to the presence of higher salt water heads at depth and generally lower fresh water heads. East of the 250 ppm chloride interface within the Beaufort aquifer, ground water in this aquifer is too salty to be used for drinking purposes unless treated by reverse osmosis. Chloride concentrations in the aquifer increase eastward to a maximum of 12,000 ppm as measured at the ENR Maple Prison Research Station in Currituck County. The approximate position of 10,000 ppm isochlors are plotted on elevation maps of the top and base of the aquifer using the only point of control at the Maple Prison Research Station. Concentrations in excess of 12,000 ppm are probably found to the east of the Maple Prison site, toward the Atlantic Coastline. Potable ground water can be found in this aquifer to the west of the position of the 250 ppm chloride interface in Bertie, Hertford, western Gates, and west central Chowan Counties.

The Beaufort aquifer is used for water supply in Hertford and Bertie Counties, as well as western Chowan and Gates Counties. Lloyd (1968) reported a yield range of 3 to 25 gpm in 2 and 4 inch diameter wells, and an average calculated specific capacity of 4.6 gpm/ft for 2 inch wells and 5.2 gpm/ft for 36 inch wells in Chowan County. The Gates County well field pumps water from one 12 inch well screened in the Beaufort and upper Cape Fear aquifers combined, with a reported maximum safe yield of .65 mgd.

UPPER AND LOWER CAPE FEAR CONFINING UNITS

The upper Cape Fear confining unit is comprised of clay and silt beds present within the upper Cretaceous Peedee and Black Creek Formations. The Peedee Formation pinches out in southern Chowan, Perquimans, Pasquotank, and Currituck Counties as indicated on cross sections A-A' and B-B' (Appendix: plates A-2 and A-3). Thus, the Black Creek Formation is the principal component of the upper Cape Fear confining unit across the study area. A regional elevation map of the unit indicates that it slopes eastward at a rate of approximately 13 feet per mile in the western portion of the study region, increasing to 52 feet per mile near the Atlantic Coast. The thickness varies between 0 feet where the unit pinches out in the Franklin, Virginia area, and in the vicinity of the ENR Maple Prison well, and a maximum of 164 feet in Currituck County.

The lower Cape Fear confining unit is made up of groups of laterally discontinuous clay and silt beds that vary in stratigraphic position regionally within the Cape Fear Formation. The thickness and aerial distribution of this unit is displayed in regional cross sections (Appendix: plates A-2 to A-10). Evidence of the regional presence of this unit is exhibited by wide elevation differences that occur over a large area between the potentiometric surfaces of the upper and lower Cape Fear aquifers (figures 6 and 7).

UPPER AND LOWER CAPE FEAR AQUIFERS

The upper Cape Fear aquifer is made up of the upper Cretaceous Cape Fear Formation. The lower Cape Fear aquifer includes the Cape Fear Formation and deeper, lower Cretaceous sediments. Both aquifers are comprised of permeable beds of sand with numerous silt and clay interbeds that were deposited in alternating marine to nonmarine environments of deposition. Where nonmarine in origin, sands commonly are interbedded with layers of gravel, and are reddish to tan colored from the presence of iron oxides. Where the unit is marine in origin, sands alternate with beds of shell limestone and dolomite. Individual beds are laterally discontinuous, as indicated by a lack of consistent well to well correlation with borehole geophysical logs, even over short distances. Nevertheless, permeable sediments are in good hydraulic communication as evidenced by widespread lateral transmission of drawdown effects due to pumping. The upper and lower Cape Fear aquifers are referred to as the upper, middle and lower Potomac aquifers in southeastern Virginia, and are the source aquifers for heavy industrial and municipal pumping in the Franklin, and Suffolk City, Virginia area. Heavy withdrawals have occurred since the early 1940s, exceeding 40 million gallons per day for the past two decades.

The top of the upper Cape Fear aquifer ranges in elevation between -85 and -1,500 feet below sea level in the report area, and slopes to the east-southeast at an average rate of 13 feet per mile in the western part of the study area (Appendix: figure A-10). Near the Atlantic Coast the top of the aquifer increases in rate of slope to an average of 39 feet per mile. The base of the aquifer is defined as the top of the lower Cape Fear confining unit. The top of the lower Cape Fear aquifer ranges in elevation between -240 and -2,325 feet below sea level in the study region, as displayed by regional cross sections (Appendix: plates A-2 to A-10). The base of the aquifer is defined as the top of basement.

The upper Cape Fear aquifer pinches out between upper and lower Cape Fear confining units in southeastern Virginia as indicated on cross section D-D' (Appendix: plate A-5). The limit of the upper Cape Fear aquifer is recognized by the updip disappearance of beds of which it is comprised, and by the fact that head differences in the Cape Fear system are no longer apparent to the north of where the pinchout occurs in southeastern Virginia. This is apparent by observation of potentiometric surface maps of upper and lower Cape Fear aquifer (figures 6 and 7). Potentiometric surfaces are shown along a modified version of cross section D-D' (Appendix: plate A-6) in order to illustrate this relationship. Recent water level data from wells to the north in the Franklin, Virginia area indicate only slight differences in elevation values within the Cape Fear system, and that the system behaves as a single aquifer. Prepumping potentiometric surface maps in the southeastern Virginia area from Hamilton and Larsen (1987) indicate only small differences in water levels in the Franklin, Virginia area between upper, middle and lower screened zones within the Cape Fear aquifer. Current similarities in water levels after nearly 5 decades of pumping are therefore not a result of equalization of heads due to pumping, but are evidence that northwest of the pinchout of the upper Cape Fear aquifer, the system behaves as one aquifer in the Franklin area.

Ground water withdrawal data was collected for the purpose of this study for the years 1980, 1982, and 1992 from the major pumping centers in the Cape Fear system, which are located in Suffolk City, Virginia and at the Union Camp Corporation in Franklin, Virginia. Combined totals are shown in million gallons per day as follows:

	Combined	Union Camp	Suffolk City
1980	46.912	39.915	6.997
1982	43.502	39.453	4.049
1992	43.226	38.644	4.582

As indicated by potentiometric surface maps prepared for this report (figures 6 and 7), heavy ground water withdrawals have produced a widespread cone of depression that extends into a significant portion of northeastern North Carolina. Hydrographs were prepared for key observation wells in the North Albemarle region, including the EHNR Parkville and Sunbury research stations in Perquimans and Gates Counties (figures 4 and 5). Water level declines, as shown by hydrographs in both research stations, have occurred at a rate of approximately 2 feet per year in the lower Cape Fear aquifer since measurements began. Measurements taken at the Sunbury Research Station from January, 1967 to January, 1996 indicate a total drawdown of 55 feet in the lower Cape Fear aquifer. Water levels are being affected in shallower aquifers, but have declined at much slower rates as indicated by the hydrographs. The potentiometric surface at the center of the cone of depression at Union Camp is presently located below the top of the lower Cape Fear aquifer, indicating that aquifer dewatering is occurring (Appendix: plate A-6).

Using the Jacobs distance drawdown technique, May, 1985 water levels from wells screened in the lower Cape Fear aquifer were plotted for the Como, Sunbury, and Parkville Research stations against distances to the center of pumping in Franklin, Virginia (Appendix: figure A-21). The data points plotted along a straight line on a semi-log graph, indicating that the method was valid. Using a total pumping rate of 43 million gallons per day (converted to cubic feet per/day) a transmissivity value of 22,388 ft^2 per day, hydraulic conductivity of 56 feet per day (based on 400 feet of aquifer thickness), and storativity of .00319 was calculated for the lower Cape Fear aquifer. A Hantush Jacobs pump test analysis of the lower Cape Fear aquifer at the Sunbury Research Station, using the pumping center from Virginia, indicated a transmissivity of 19,130 ft^2 per day, hydraulic conductivity of 48 feet per day, and storativity of .0025.

The approximate position of the 250 ppm chloride interface was plotted where it intersects the top of the upper Cape Fear aquifer in figure A-10 (Appendix), indicating that the isochlor trends northeast-southwest through northern Camden, northern Pasquotank, southern Gates, and along the western border of Chowan County. Southeast of the 250 isochlor, as plotted in figure A-10, chloride concentrations in ground water in the upper Cape Fear aquifer are above the 250 ppm drinking water standard. The 500 ppm isochlor parallels the 250, and maintains a position about 5 miles to the southeast on average. The position of the 10,000 ppm isochlor is loosely approximated based on a 13,000 ppm chloride concentration level measured at ENR, Maple Prison. Lower Cape Fear aquifer isochlors are indicated in regional cross sections (Appendix: plates A-2 to A-10). The maximum known chloride concentration value measured in the lower Cape Fear aquifer was 8,400 ppm at the Morgans Corner Research Station in northern Pasquotank County.

Potable water supplies in the upper and lower Cape Fear aquifers are limited to the area west of their 250 ppm chloride interfaces in Gates, Hertford, and Bertie Counties, and possibly in the northwestern tips of Pasquotank and Camden Counties. Present ground water usage in the upper Cape Fear aquifer within the study area is limited to Gates County. The Gates County water system pulls approximately 623,000 gallons per day from the Beaufort aquifer and the upper Cape Fear aquifer

CONCLUSIONS

The North Albemarle Ground Water Study has been carried out in order to develop an up-to-date hydrogeologic framework analysis of the region. A major objective of the study has been to evaluate the ground water resources of the area in terms of supply and availability. This was carried out with particular attention to the easternmost counties, including Currituck, Camden, Pasquotank, and Perquimans, where existing municipal well fields are considered inadequate to provide for future population growth. Another objective of the study was to provide a conceptual model extending into southeastern Virginia pumping centers for future ground water modeling simulations, if needed. This study will serve as a guide to those conducting more detailed ground water resource investigations in the North Albemarle counties.

Six major regional aquifers were identified in the study, as well as the intervening confining layers that separate them. They include the surficial, Yorktown, Castle Hayne, Beaufort, upper and lower Cape Fear aquifers. Each aquifer unit was mapped and described in as much detail as available data would allow in order to define them in terms of regional elevation, thickness and lateral distribution, hydraulic properties, relationship to stratigraphic units, ground water flow, and chloride distribution. The approximate positions of 250, 500, and 10,000 parts per million chloride interfaces were plotted for each aquifer in order to identify where potable water supplies may be found, and where reverse osmosis treatment would be necessary in order to produce potable water.

Potable ground water supplies can be found over the entire region in the surficial and Yorktown aquifers, with the exception of the Outer Banks of Currituck County, where fresh water has not been identified to date in the Yorktown aquifer. Due to the shallow position (39 to 180 feet below land surface) of the 250 ppm chloride interface in the Yorktown aquifer in mainland Currituck, Camden, Pasquotank, and eastern Perquimans Counties, the thickness of the fresh water zone is very limited in some areas (Appendix: plates A-2 through A-10).

In the North Albemarle region, potable ground water in the Castle Hayne aquifer can be found to the west of the 250 ppm chloride interface (Appendix: figures A-6 and A-7) in southeastern Hertford, eastern Bertie, western Gates, and central Chowan Counties, and possibly in the northwestern tip of Camden County. West of the position of the 250 ppm interface, reverse osmosis treatment would be necessary in order to produce potable water from this aquifer. Water supply wells positioned between the 250 and 500 ppm chloride interfaces as delineated in this study, would provide the most economically treatable concentrations. Very little pump test data is available in the eastern North Albemarle counties to delineate areas where the productive ability of the Castle Hayne aquifer is suitable for municipal supply.

The Beaufort aquifer contains potable ground water to the west of the position of the 250 ppm chloride interface (Appendix: figure A-8 and A-9) in Bertie, Hertford, western Gates and west central Chowan Counties. East of the position of this interface, reverse osmosis treatment would be required. Specific capacity data from a few tests (Appendix: table A-1) in the eastern North Albemarle Counties indicate that the productive ability of this aquifer is generally poor.

Potable water supplies in the upper Cape Fear aquifer are found to the west of the 250 ppm chloride interface (Appendix: figure A-10) in Hertford, Bertie, and Gates Counties and may possibly be found in the northwestern tips of Pasquotank and Camden Counties. Development of the aquifer in northwestern Pasquotank and Camden Counties would, however, be inhibited by the presence of the Dismal Swamp. Economically treatable supplies of lower chloride range salt water (250-1000 ppm) may be found in Chowan, northern Perquimans, northwestern Pasquotank, northwestern Camden, and northwestern Currituck Counties in the upper Cape Fear aquifer. A

Jacobs Distance drawdown test performed on the upper and lower Cape Fear aquifers (Appendix: figure A-21) indicates that the transmissivity and hydraulic conductivity of this aquifer is very high in the area covered by the Como, Sunbury, and Parkville research stations. It is possible that highly transmissive zones are present further to the east in the counties where ground water supply is a concern.

The lower Cape Fear aquifer contains fresh water in Gates, Hertford, Bertie and possibly the northwestern tip of Pasquotank County as indicated by the 250 ppm chloride interface plotted on regional cross-sections (Appendix: plates A-2 through A-10). East of this interface, lower chloride range salt water may be found in northwestern Camden, northwestern Pasquotank, and possibly in Chowan County.

The best option for the water concerned counties in the eastern North Albemarle region for expansion of existing municipal water supplies is to further develop the potable water supply in the Yorktown aquifer. This could be prudently accomplished by locating new well fields where transmissivity and hydraulic conductivity values are highest, in conjunction with areas of maximum depth to the fresh water-salt water interface. Proper well field design is also an important consideration, in order to maximize aquifer productivity, and minimize the possibility of salt water upconing. Findings in the main body of the report will provide guidance with regard to identifying optimal target areas for well field placement in the Yorktown aquifer.

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APPENDIX

FIGURE A-1

PLOT OF RESEARCH STATION CHLORIDE CONCENTRATIONS VS. TDEM DERIVED RESISTIVITY IN THE YORKTOWN AQUIFER

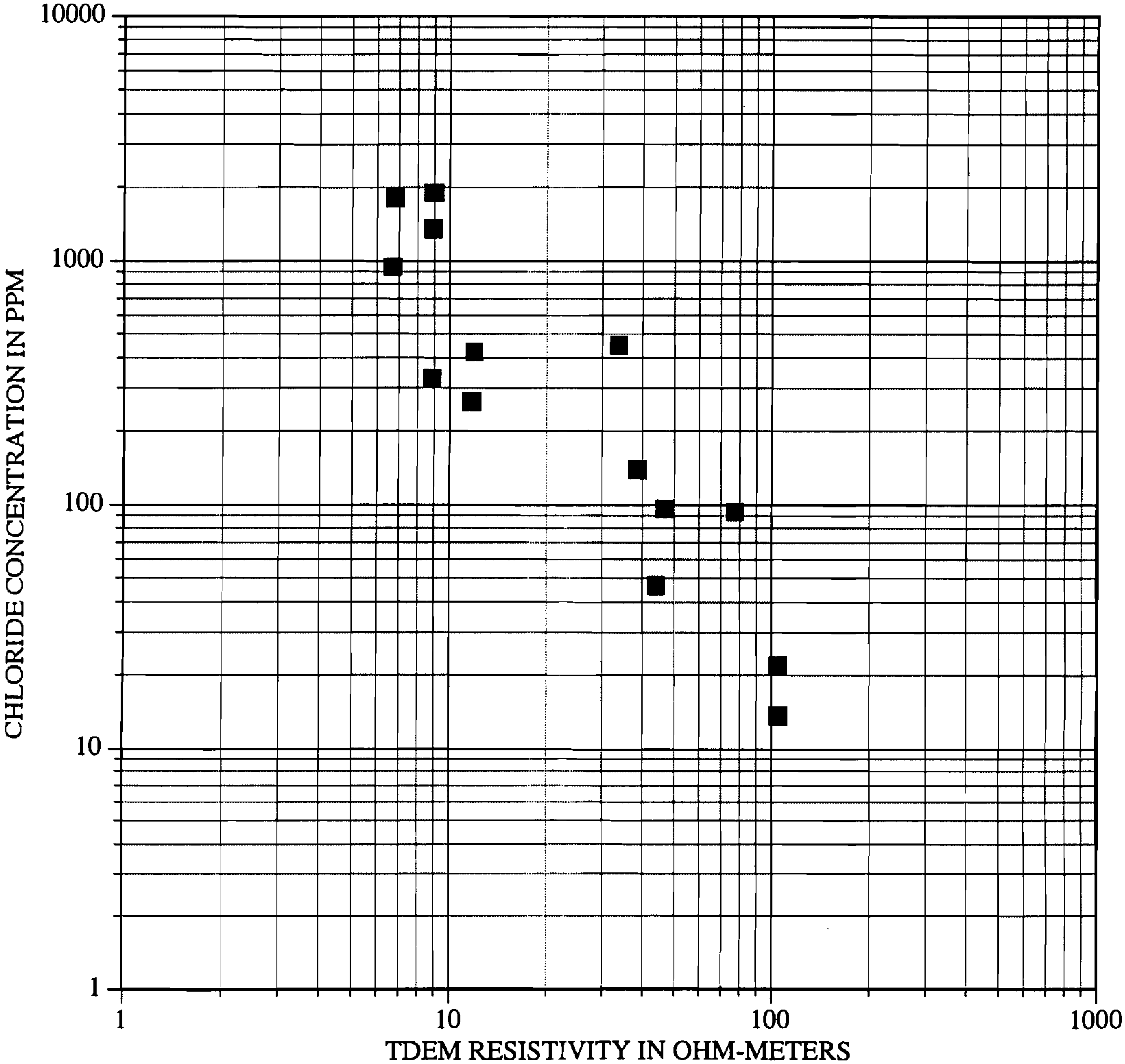
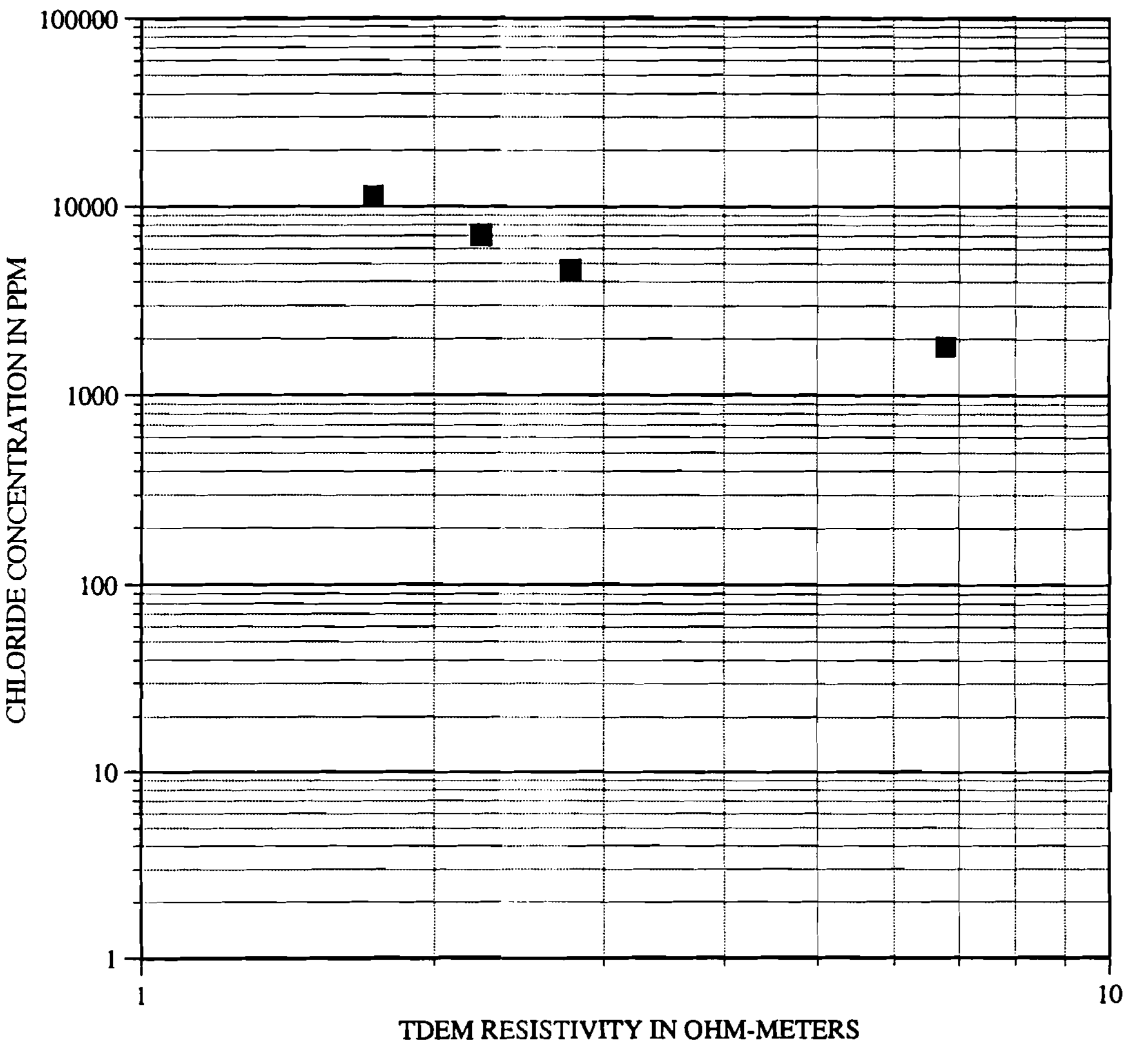


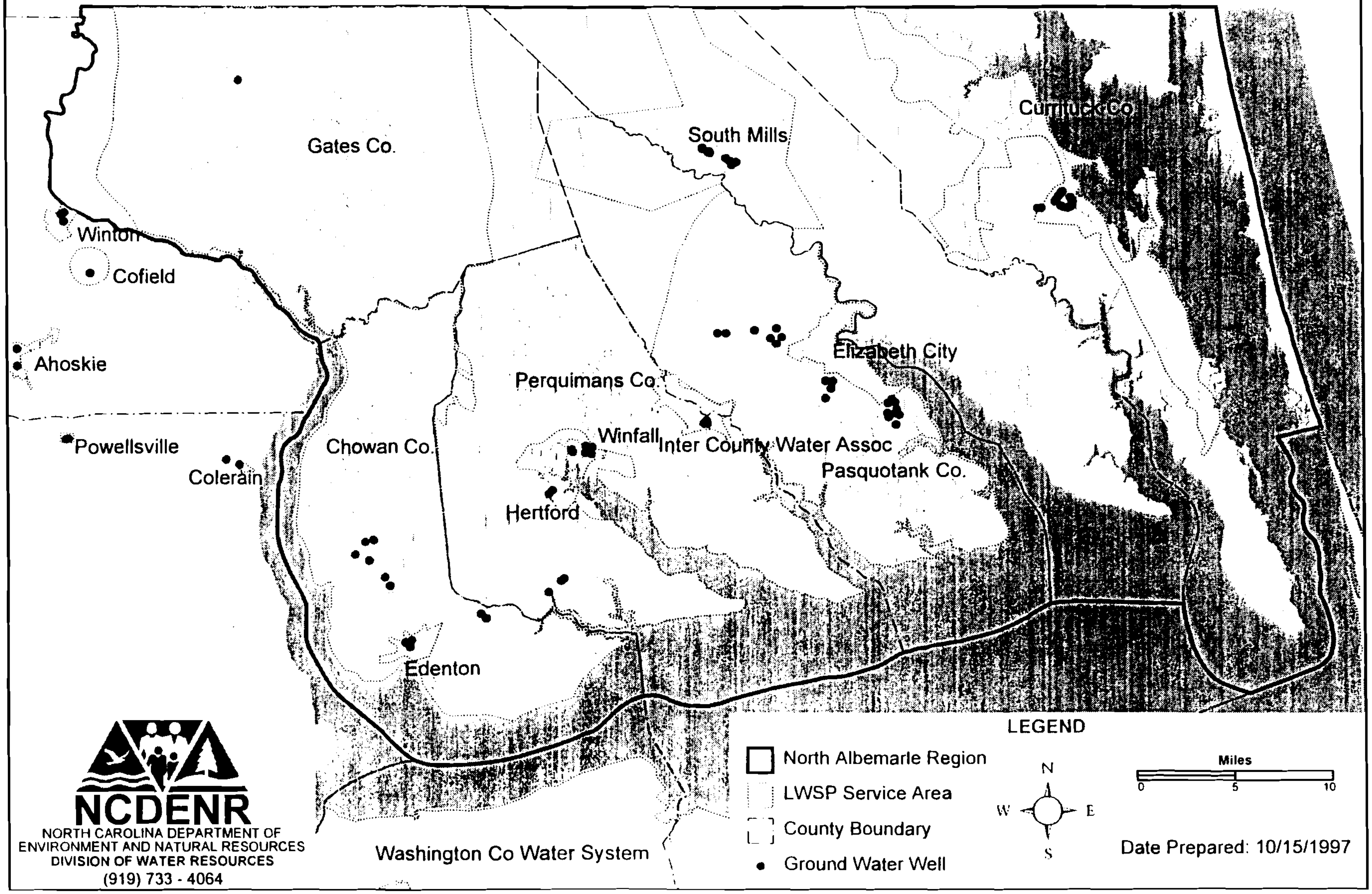
FIGURE A-2

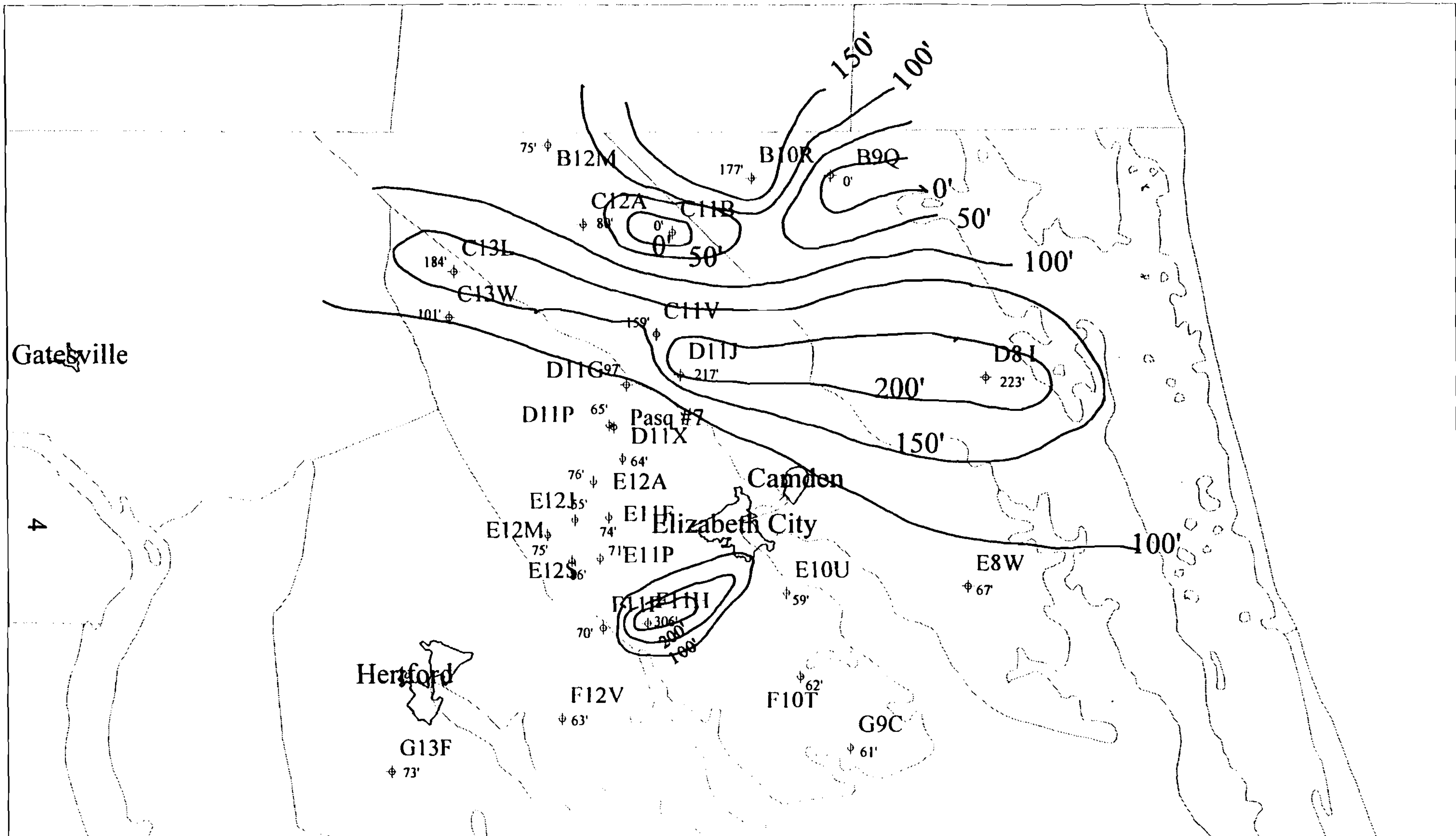
PLOT OF RESEARCH STATION CHLORIDE CONCENTRATIONS VS. TDEM DERIVED RESISTIVITY IN THE CASTLE HAYNE AQUIFER



North Albemarle Ground Water Study

Well Field Locations as Indicated by 1992 Local Water Supply Plans

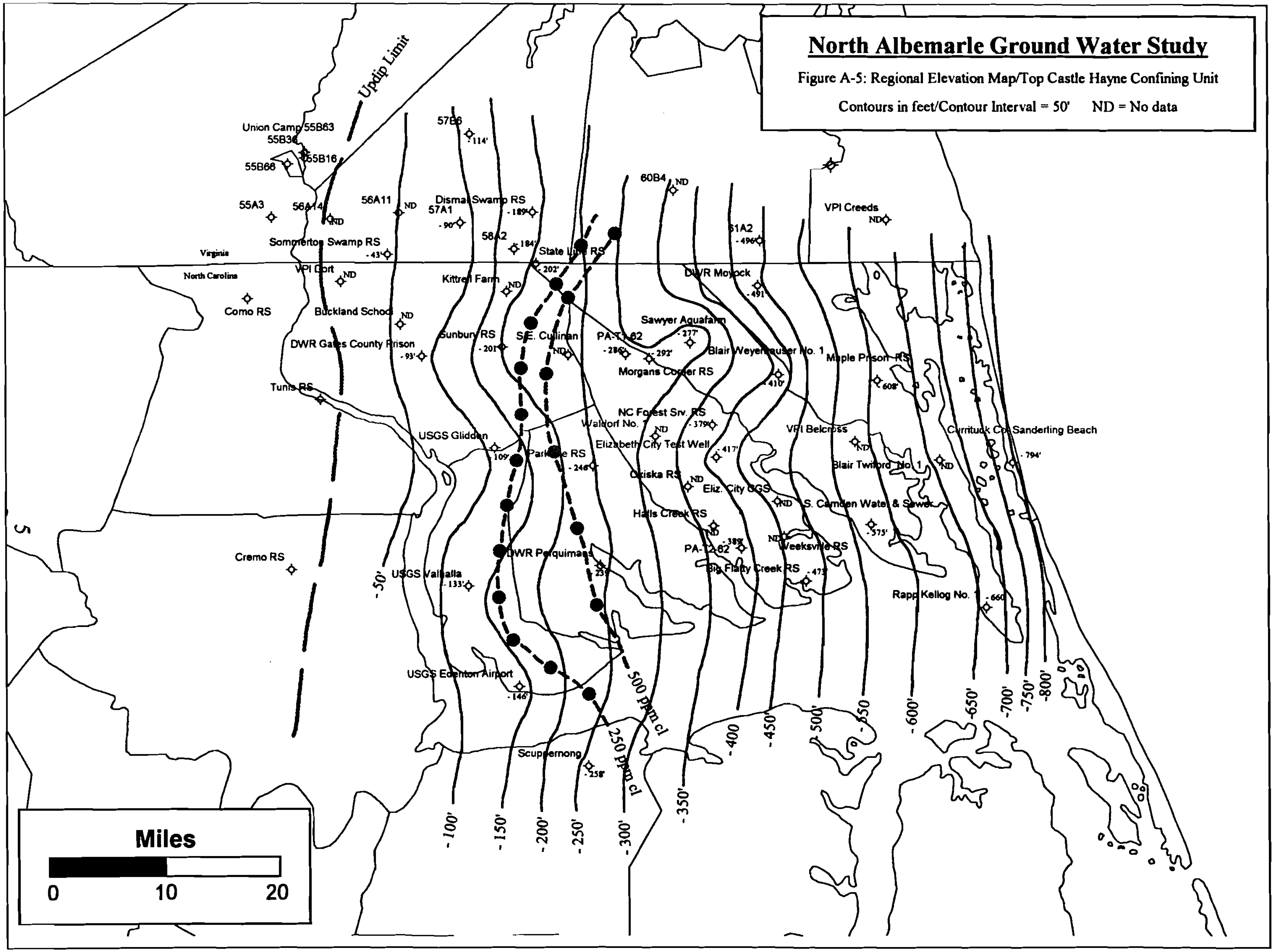




NORTH ALBEMARLE GROUND WATER STUDY

Figure A-4: Isopach Map: Fresh Water Zone in Yorktown Aquifer

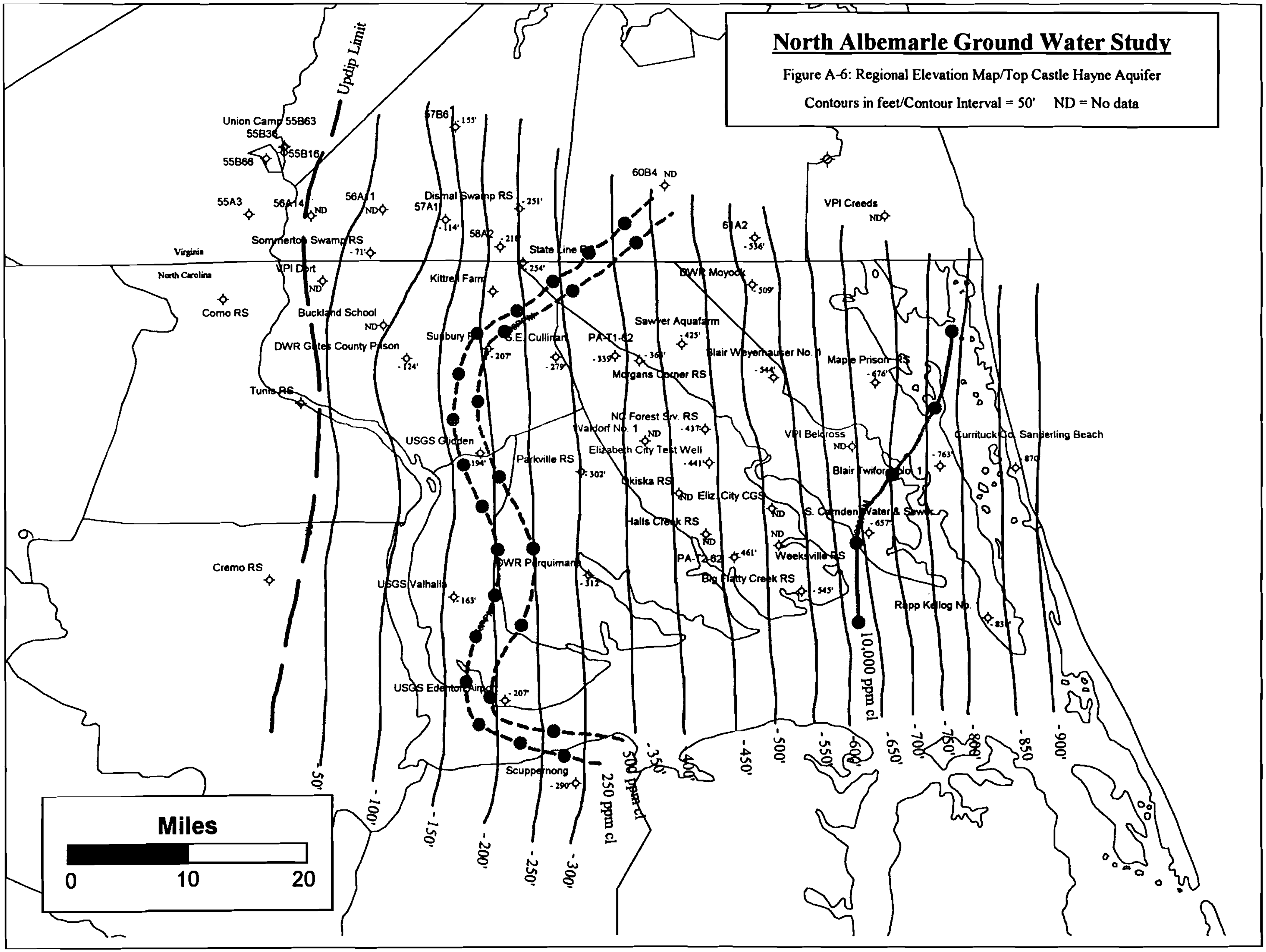
Based on 22 ohm-meter TDEM Resistivity Cutoff

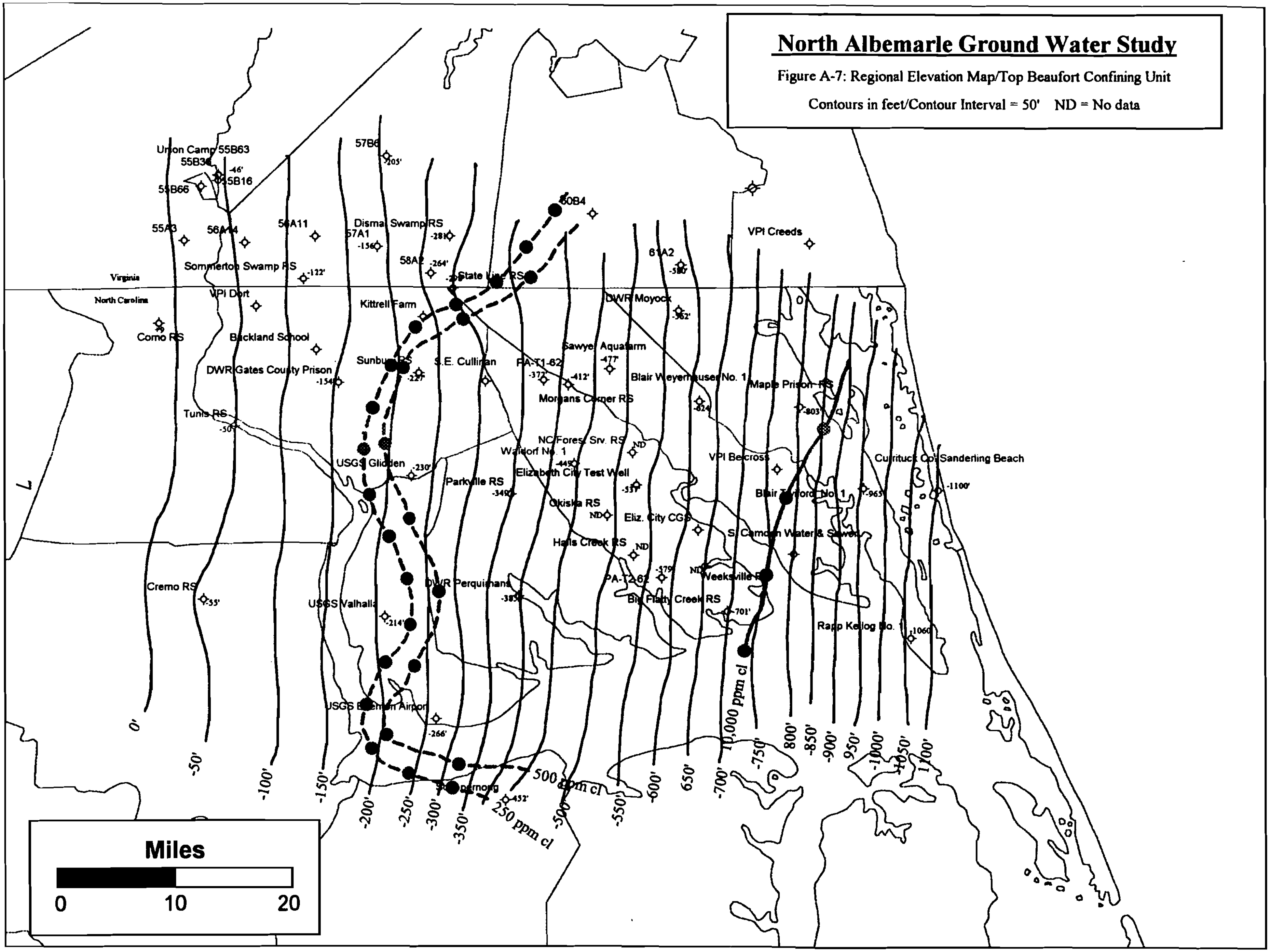


North Albemarle Ground Water Study

Figure A-5: Regional Elevation Map/Top Castle Hayne Confining Unit

Contours in feet/Contour Interval = 50' ND = No data

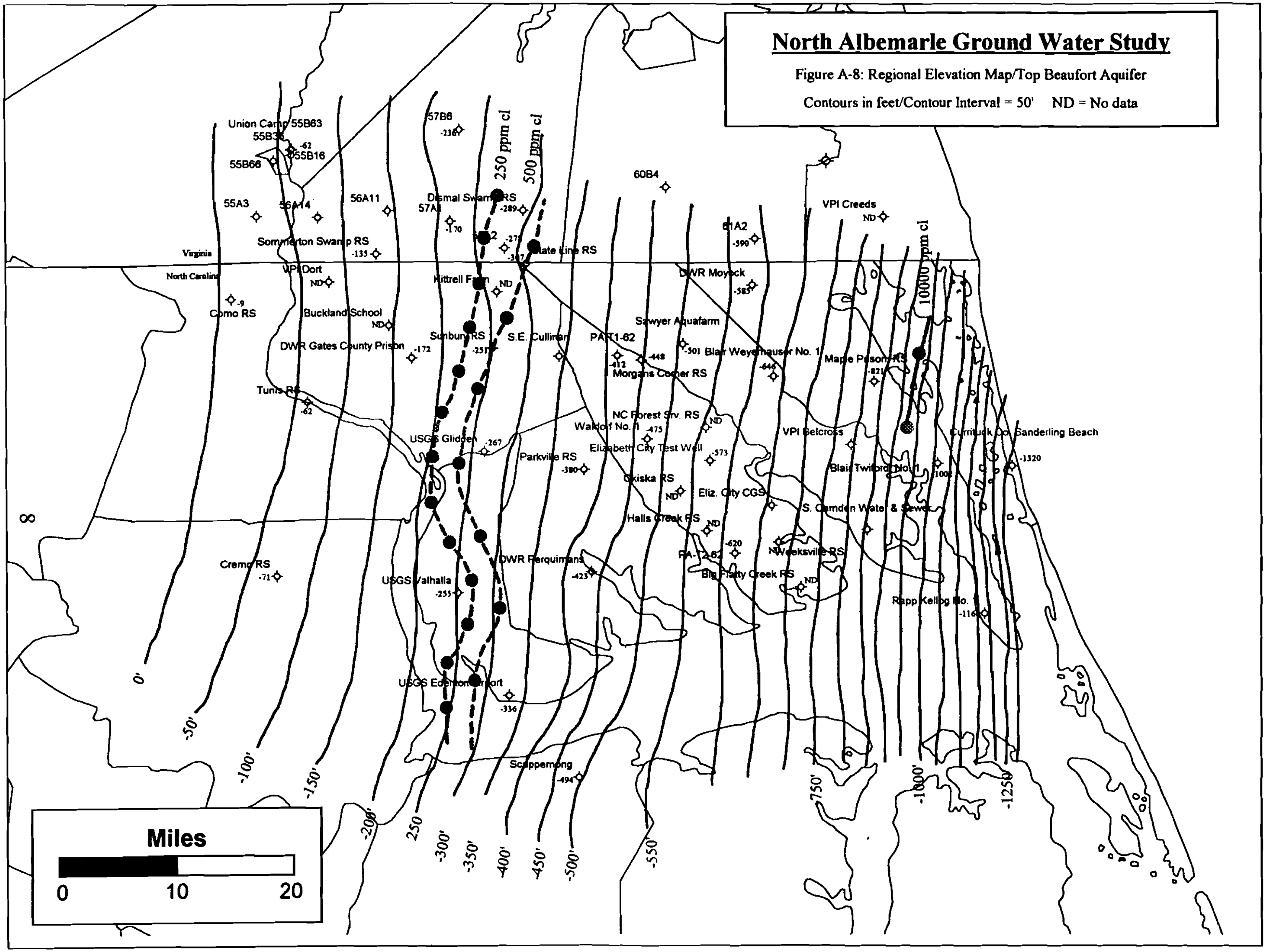

North Albemarle Ground Water Study
Figure A-6: Regional Elevation Map/Top Castle Hayne Aquifer
Contours in feet/Contour Interval = 50' ND = No data
Updip Limit
Virginia
North Carolina
Union Camp 55B63
55B36
55B16
55B66
55A3
56A14
56A11
57B6
57A1
Dismal Swamp RS
58A2
60B4
61A2
VPI Creeds
Sommerton Swamp RS
VPI Dort
State Line RS
Kittrell Farm
DWR Moyock
Como RS
Buckland School
Sawyer Aquafarm
Sunbury RS
S.E. Cullinan
PA-T1-62
Blair Weyerhauser No. 1
DWR Gates County Prison
Morgans Corner RS
Maple Prison RS
Tunis RS
NC Forest Srv. RS
Waldorf No. 1
VPI Belcross
Currituck Co. Sanderling Beach
USGS Gidden
Elizabeth City Test Well
Parkville RS
Blair Twiford No. 1
Okiska RS
Eliz. City CGS
S. Camden Water & Sewer
Halls Creek RS
Weeksville RS
Cremo RS
DWR Perquimans
PA-T2-62
Big Flatty Creek RS
USGS Valhalla
Rapp Kellog No. 1
USGS Edenton Airport
Scuppernong
10,000 ppm cl
500 ppm cl
250 ppm cl
- 50'
- 100'
- 150'
- 200'
- 250'
- 300'
- 350'
- 400'
- 450'
- 500'
- 550'
- 600'
- 650'
- 700'
- 750'
- 800'
- 850'
- 900'
Miles
0
10
20



North Albemarle Ground Water Study

Figure A-7: Regional Elevation Map/Top Beaufort Confining Unit

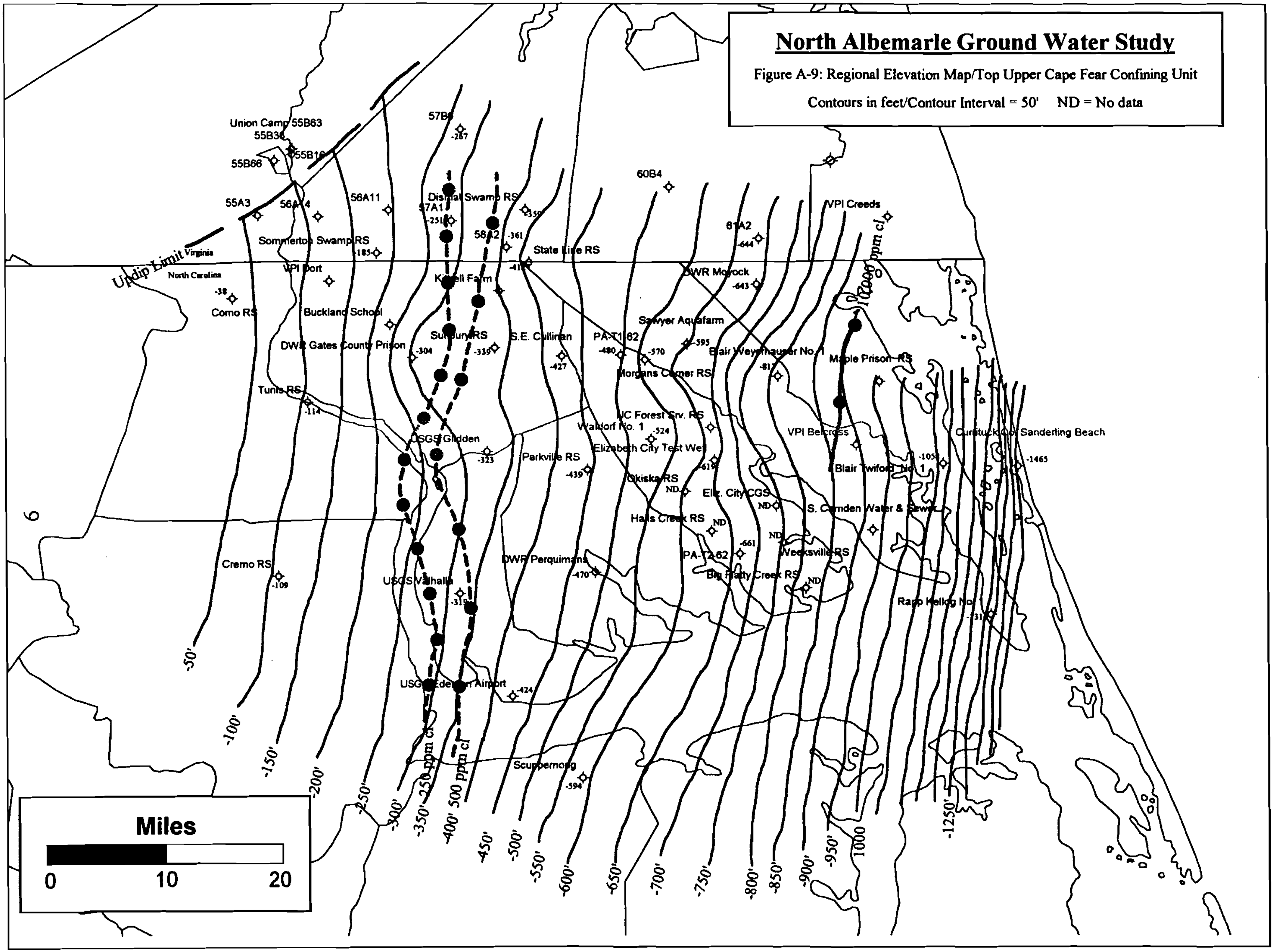
Contours in feet/Contour Interval = 50' ND = No data

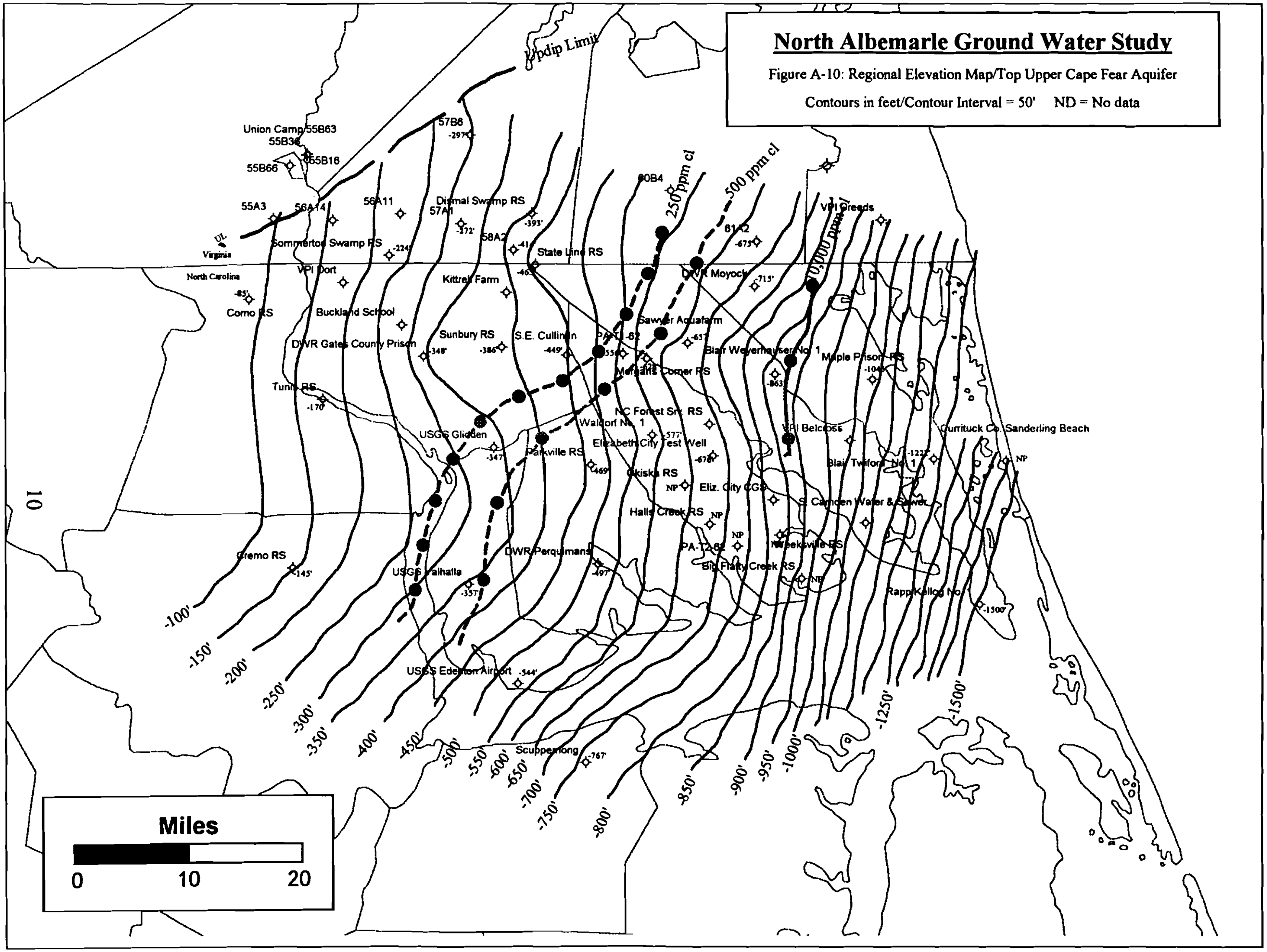


North Albemarle Ground Water Study

Figure A-8: Regional Elevation Map/Top Beaufort Aquifer

Contours in feet/Contour Interval = 50'   ND = No data

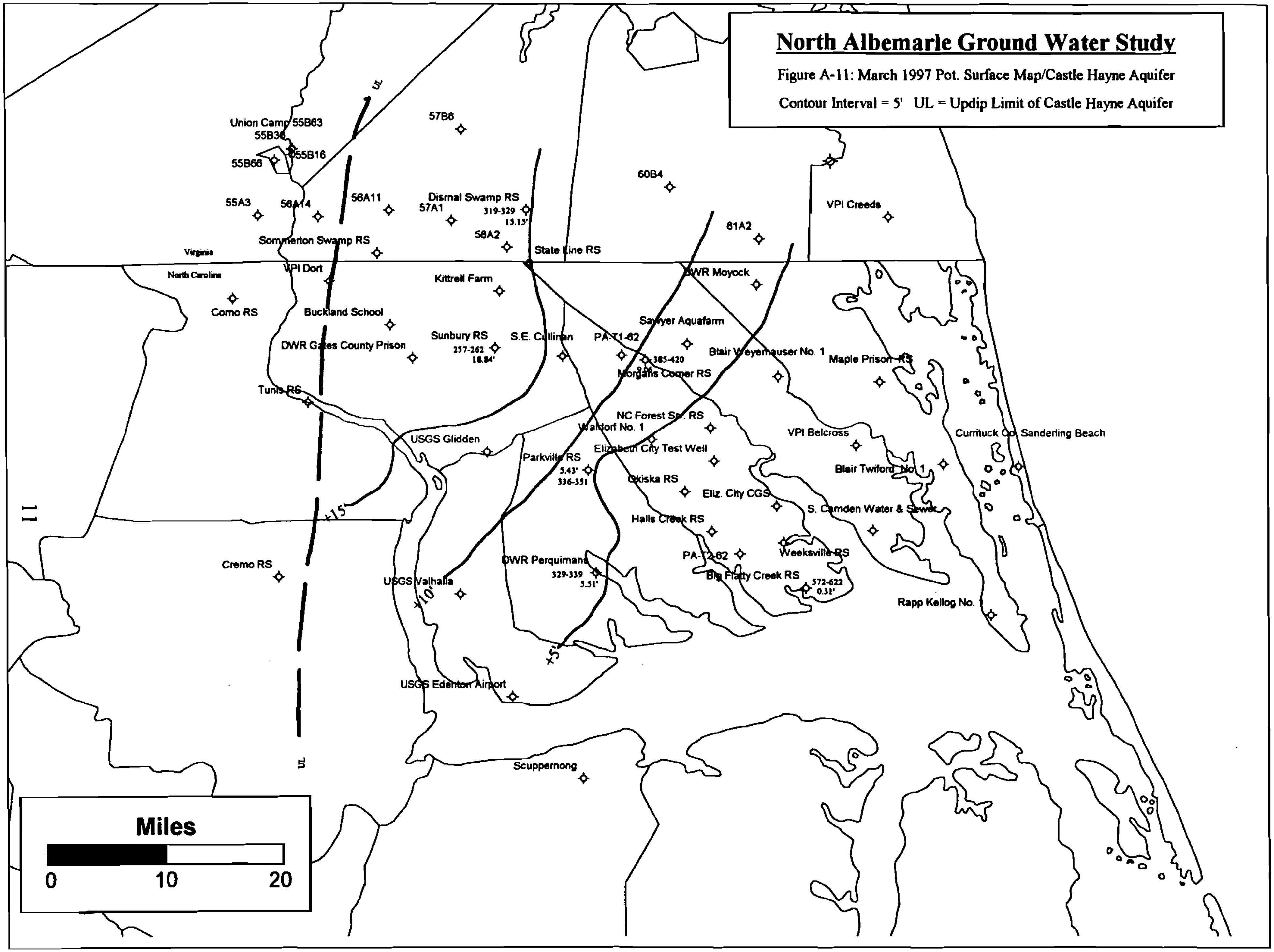

North Albemarle Ground Water Study
Figure A-9: Regional Elevation Map/Top Upper Cape Fear Confining Unit
Contours in feet/Contour Interval = 50'   ND = No data
Miles
0
10
20
Updip Limit
Virginia
North Carolina
Union Camp 55B63
55B36
55B16
55B66
55A3
56A11
57B6
-267
Dismal Swamp RS
57A1
-251
58A2
-361
-359
60B4
VPI Creeds
61A2
-644
Sommerton Swamp RS
-185
State Line RS
-41
VPI Dort
DWR Moyock
-643
-38
Como RS
Buckland School
Kittrell Farm
Sawyer Aquafarm
-595
DWR Gates County Prison
-304
Sunbury RS
-339
S.E. Cullinan
-427
PA-T1-62
-480
-570
Blair Weyerhauser No. 1
-817
Maple Prison RS
Morgans Corner RS
Tunis RS
-114
NC Forest Srv. RS
Walford No. 1
-524
USGS Glidden
-323
Parkville RS
-439
Elizabeth City Test Well
-619
VPI Belcross
Currituck Co. Sanderling Beach
-1465
-1058
Blair Twiford No. 1
Okiska RS
ND
Eliz. City CGS
ND
S. Camden Water & Sewer
Halls Creek RS
ND
-661
PA-T2-62
ND
Weeksville RS
Cremo RS
-109
DWR Perquimans
-470
Big Flatty Creek RS
ND
USGS Valhalla
-319
Rapp Kellog No.
USGS Edenton Airport
-424
Scuppernong
-594
-50'
-100'
-150'
-200'
-250'
-300'
-350'
-400'
-450'
-500'
-550'
-600'
-650'
-700'
-750'
-800'
-850'
-900'
-950'
1000
-1250'
250 ppm cl
500 ppm cl
10000 ppm cl



North Albemarle Ground Water Study

Figure A-10: Regional Elevation Map/Top Upper Cape Fear Aquifer

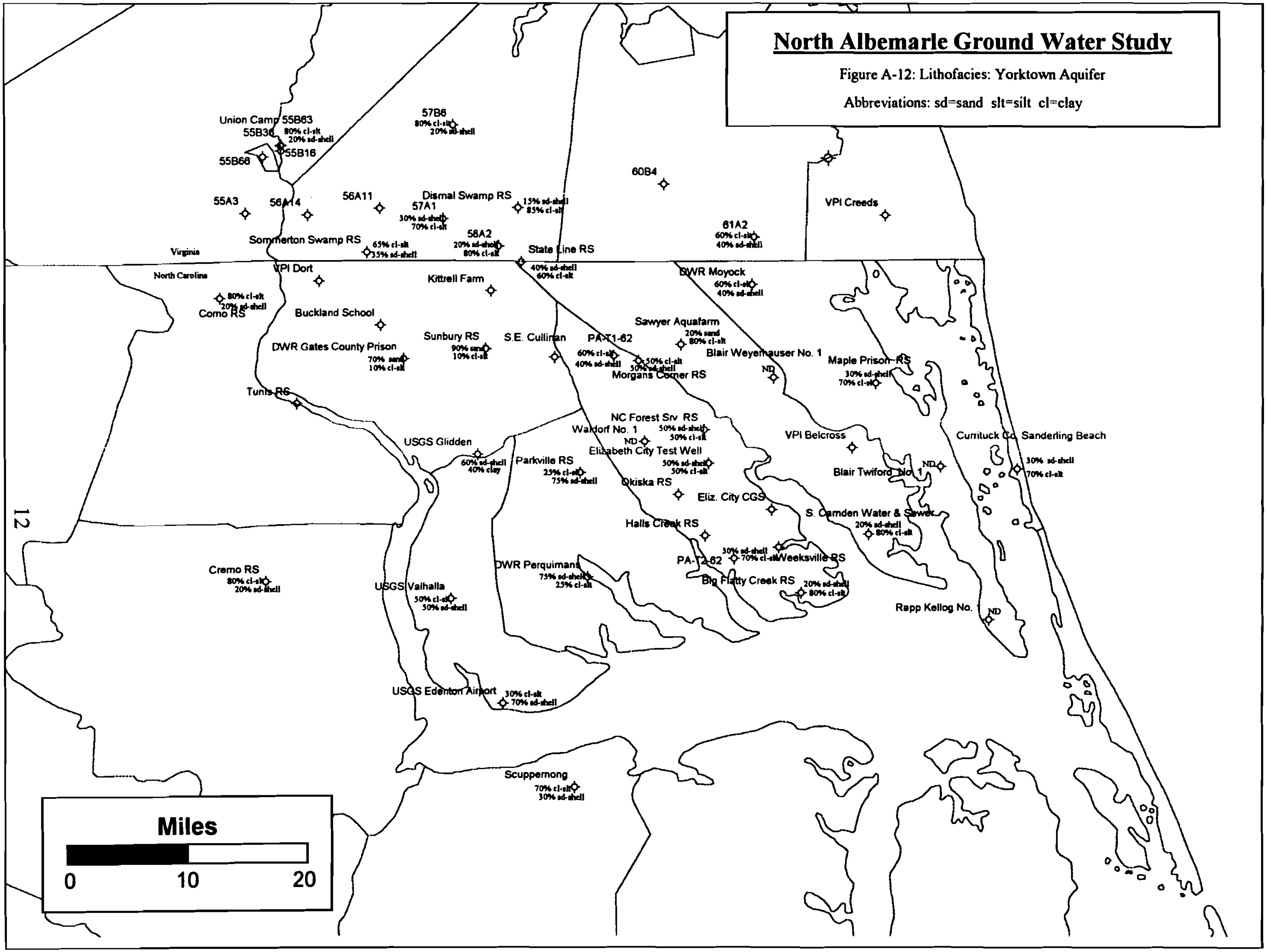
Contours in feet/Contour Interval = 50' ND = No data



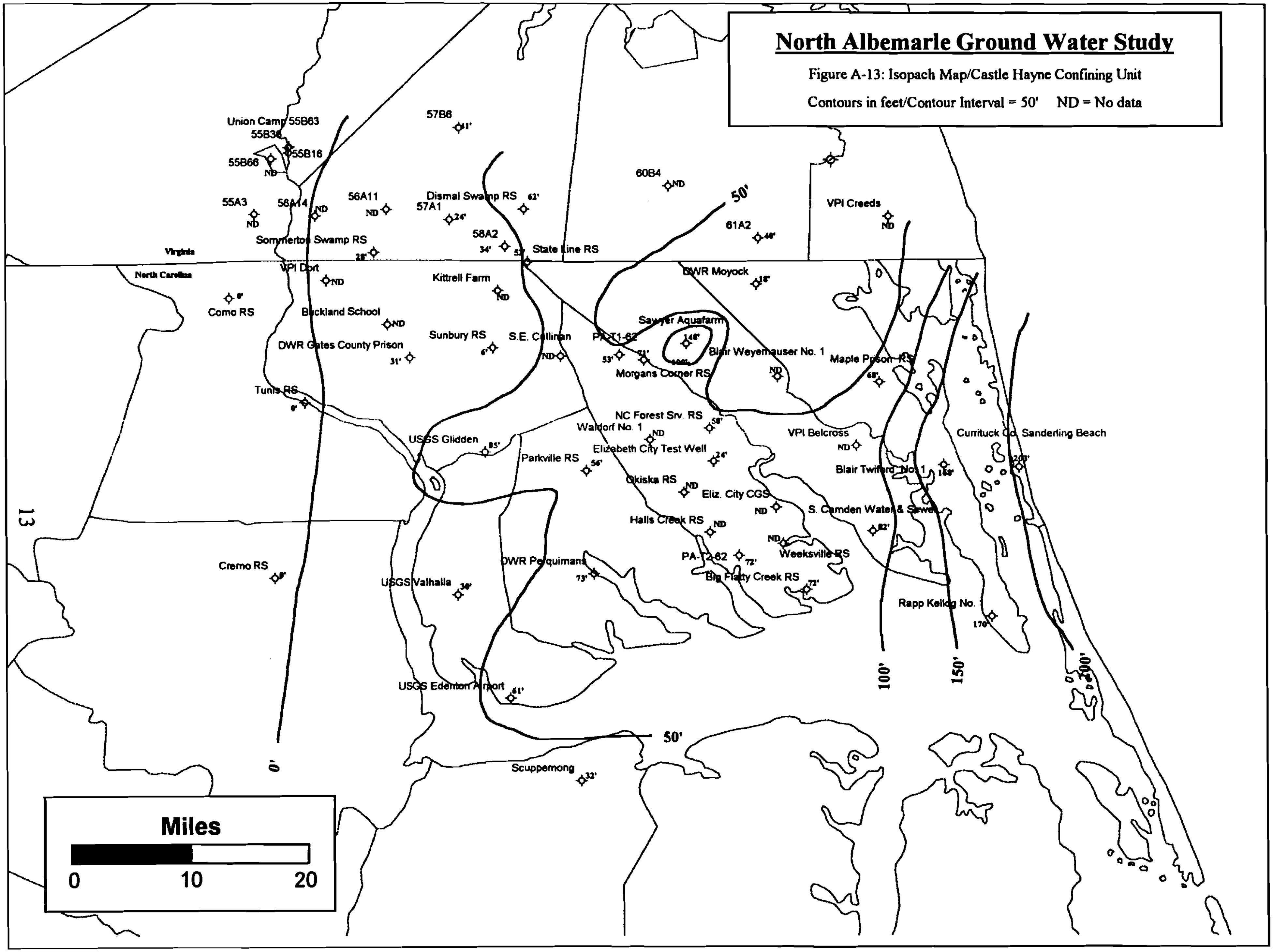
North Albemarle Ground Water Study

Figure A-11: March 1997 Pot. Surface Map/Castle Hayne Aquifer

Contour Interval = 5' UL = Updip Limit of Castle Hayne Aquifer



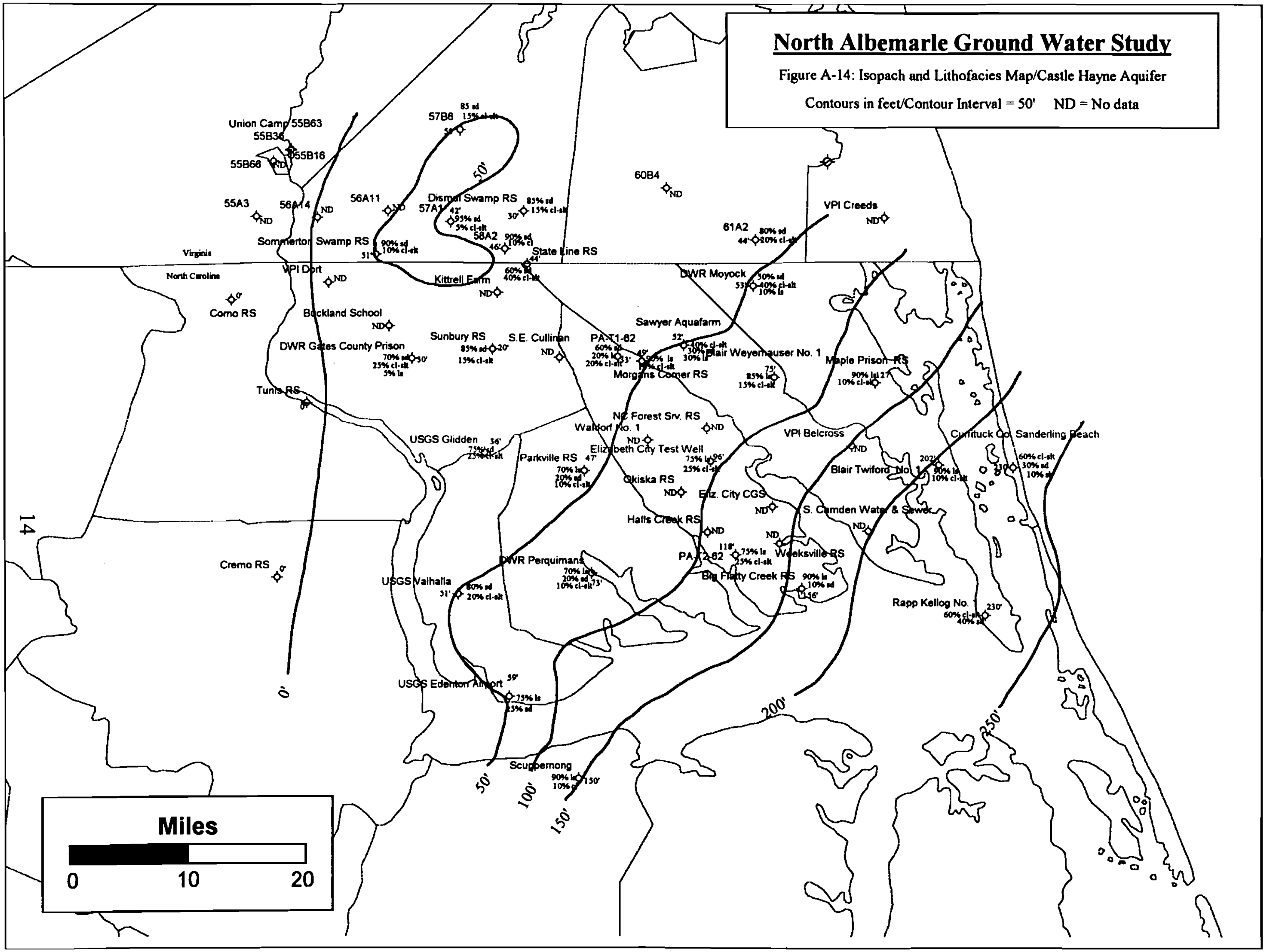
North Albemarle Ground Water Study
Figure A-12: Lithofacies: Yorktown Aquifer
Abbreviations: sd=sand slt=silt cl=clay
Union Camp 55B63
55B36
80% cl-slt
20% sd-shell
55B16
55B66
57B6
80% cl-slt
20% sd-shell
60B4
VPI Creeds
55A3
56A14
56A11
Dismal Swamp RS
15% sd-shell
85% cl-slt
57A1
30% sd-shell
70% cl-slt
58A2
20% sd-shell
80% cl-slt
61A2
60% cl-slt
40% sd-shell
Sommerton Swamp RS
65% cl-slt
35% sd-shell
State Line RS
40% sd-shell
60% cl-slt
Virginia
North Carolina
VPI Dort
Kittrell Farm
DWR Moyock
60% cl-slt
40% sd-shell
80% cl-slt
20% sd-shell
Como RS
Buckland School
Sawyer Aquafarm
20% sand
80% cl-slt
Sunbury RS
90% sand
10% cl-slt
S.E. Cullinan
PA-T1-62
60% cl-slt
40% sd-shell
50% cl-slt
50% sd-shell
Blair Weyerhauser No. 1
ND
DWR Gates County Prison
70% sand
10% cl-slt
Morgans Corner RS
Maple Prison RS
30% sd-shell
70% cl-slt
Tunis RS
NC Forest Srv RS
50% sd-shell
50% cl-slt
Waldorf No. 1
ND
USGS Glidden
60% sd-shell
40% clay
VPI Belcross
Currituck Co. Sanderling Beach
30% sd-shell
70% cl-slt
Elizabeth City Test Well
50% sd-shell
50% cl-slt
Parkville RS
25% cl-slt
75% sd-shell
Blair Twiford No. 1
ND
Okiska RS
Eliz. City CGS
S. Camden Water & Sewer
20% sd-shell
80% cl-slt
Halls Creek RS
30% sd-shell
70% cl-slt
Weeksville RS
PA-T2-62
Cremo RS
80% cl-slt
20% sd-shell
DWR Perquimans
75% sd-shell
25% cl-slt
Big Flatty Creek RS
20% sd-shell
80% cl-slt
USGS Valhalla
50% cl-slt
50% sd-shell
Rapp Kellog No.
ND
USGS Edenton Airport
30% cl-slt
70% sd-shell
Scuppernong
70% cl-slt
30% sd-shell
Miles
0
10
20



North Albemarle Ground Water Study

Figure A-13: Isopach Map/Castle Hayne Confining Unit

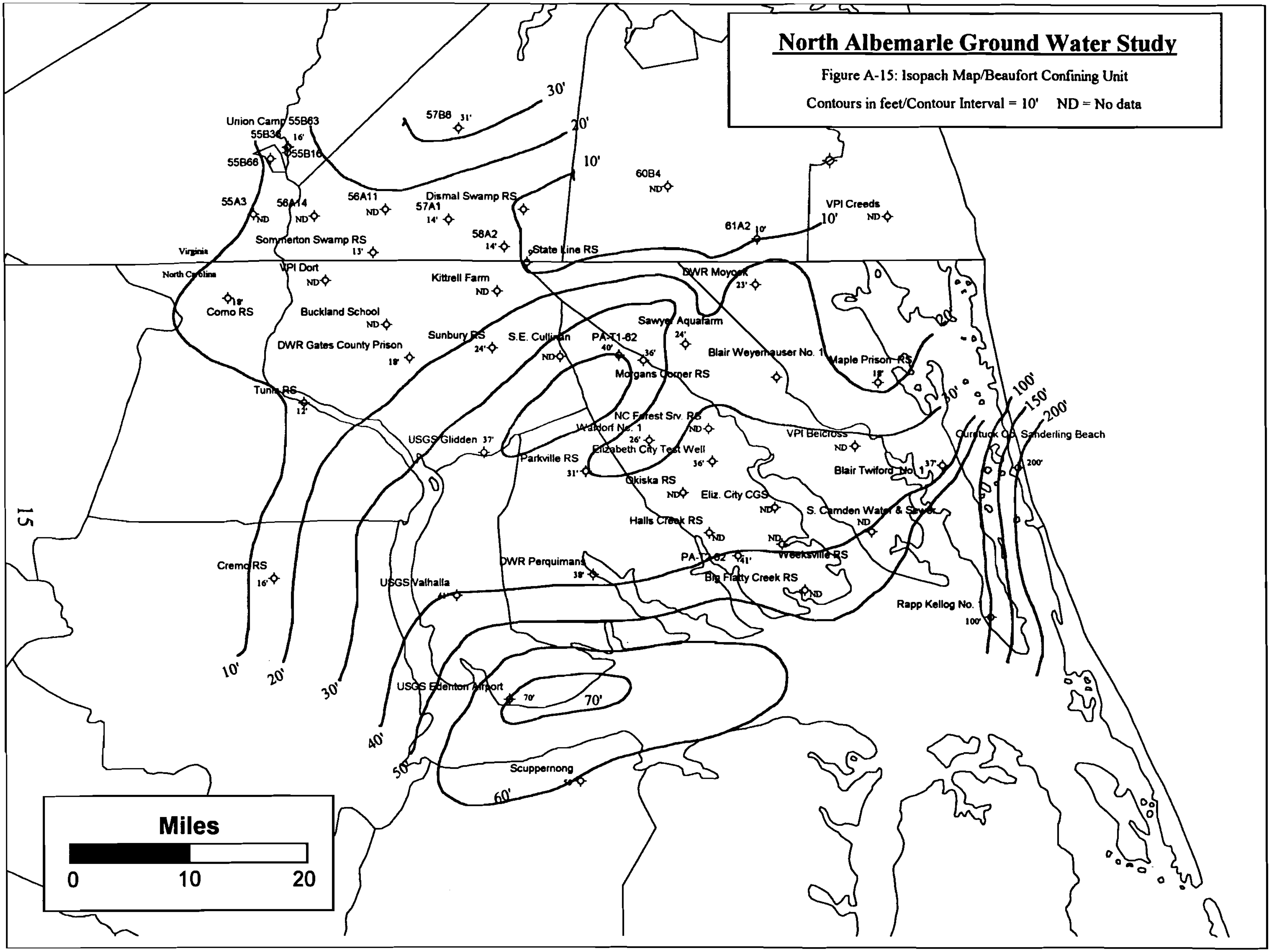
Contours in feet/Contour Interval = 50' ND = No data

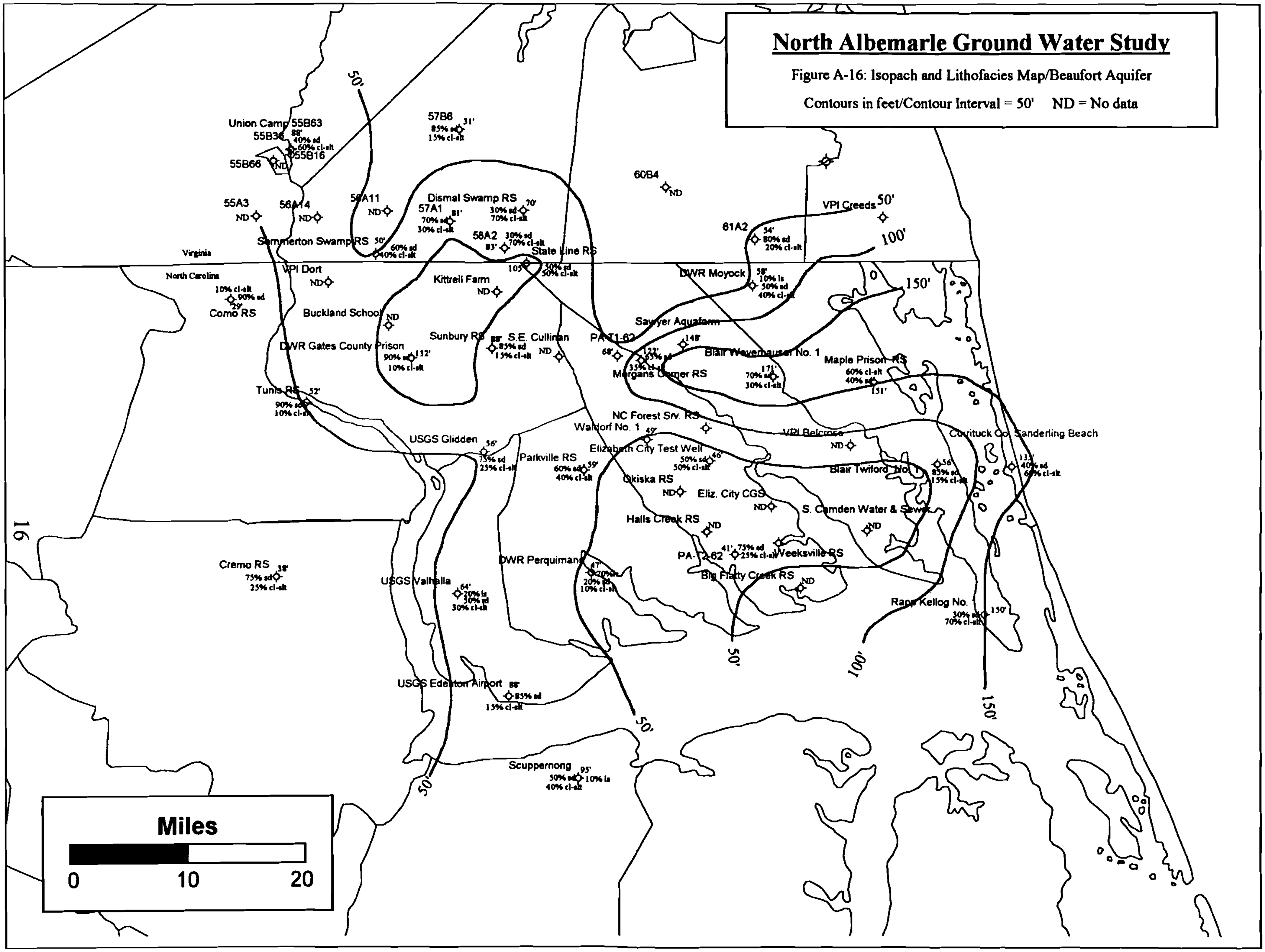


North Albemarle Ground Water Study

Figure A-14: Isopach and Lithofacies Map/Castle Hayne Aquifer

Contours in feet/Contour Interval = 50' ND = No data

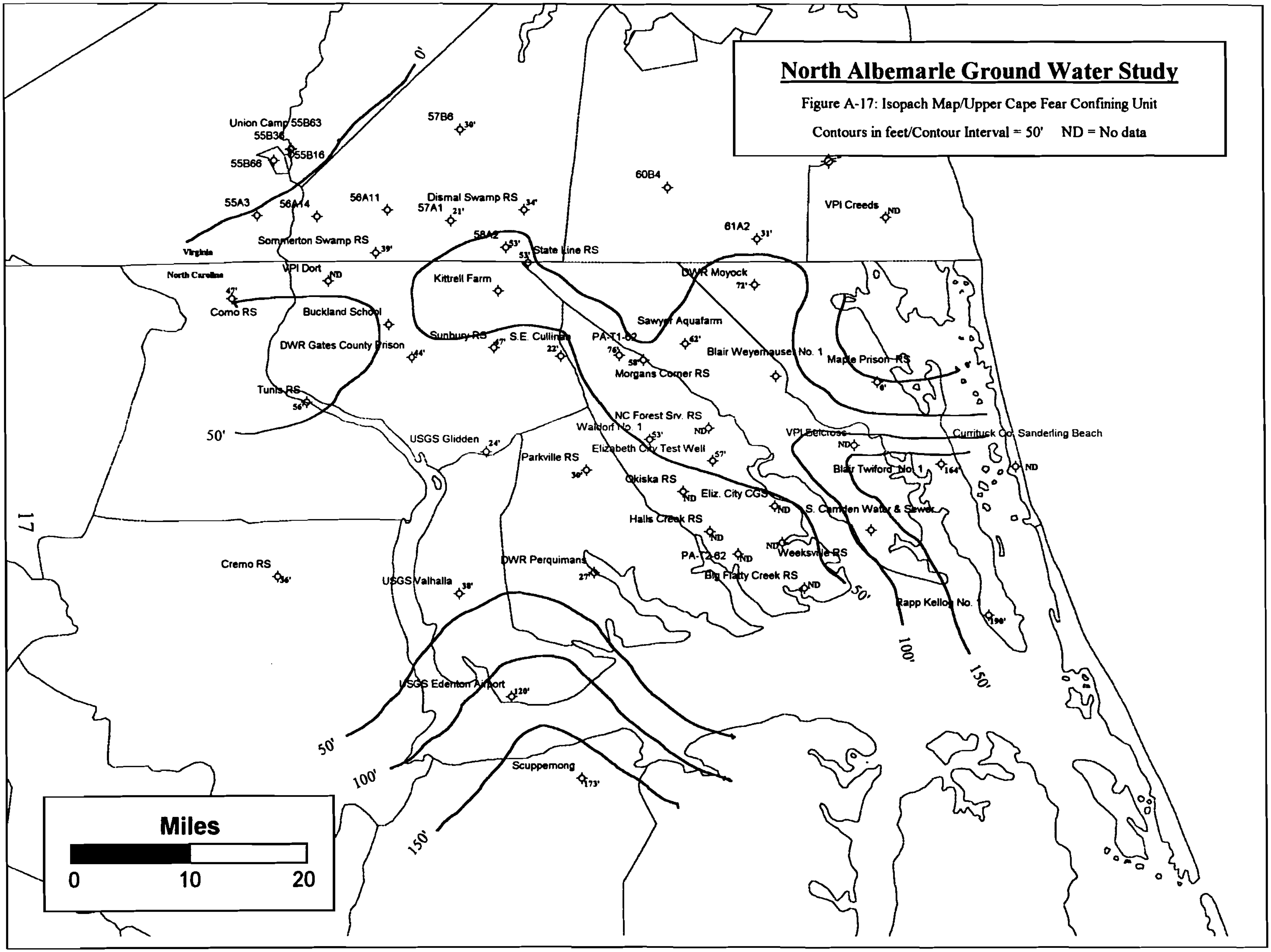

North Albemarle Ground Water Study
Figure A-15: Isopach Map/Beaufort Confining Unit
Contours in feet/Contour Interval = 10'
ND = No data
Miles
0
10
20
Virginia
North Carolina
Union Camp 55B63
55B36
55B16
55B66
55A3
56A14
56A11
57B8
57A1
Dismal Swamp RS
58A2
Sommerton Swamp RS
State Line RS
60B4
61A2
VPI Creeds
VPI Dort
Kittrell Farm
Como RS
Buckland School
DWR Gates County Prison
Sunbury RS
S.E. Cullipan
PA-T1-62
DWR Moyock
Sawyer Aquafarm
Blair Weyerhauser No. 1
Maple Prison RS
Morgans Corner RS
Tunis RS
NC Forest Srv. RS
Waldorf No. 1
USGS Glidden
Parkville RS
Elizabeth City Test Well
VPI Belcross
Currituck Co. Sanderling Beach
Blair Twiford No. 1
Okiska RS
Eliz. City CGS
S. Camden Water & Sewer
Halls Creek RS
Cremo RS
DWR Perquimans
PA-T1-62
Weeksville RS
Big Flatty Creek RS
USGS Valhalla
Rapp Kellog No.
USGS Edenton Airport
Scuppernong
10'
20'
30'
40'
50'
60'
70'
100'
150'
200'



North Albemarle Ground Water Study

Figure A-16: Isopach and Lithofacies Map/Beaufort Aquifer

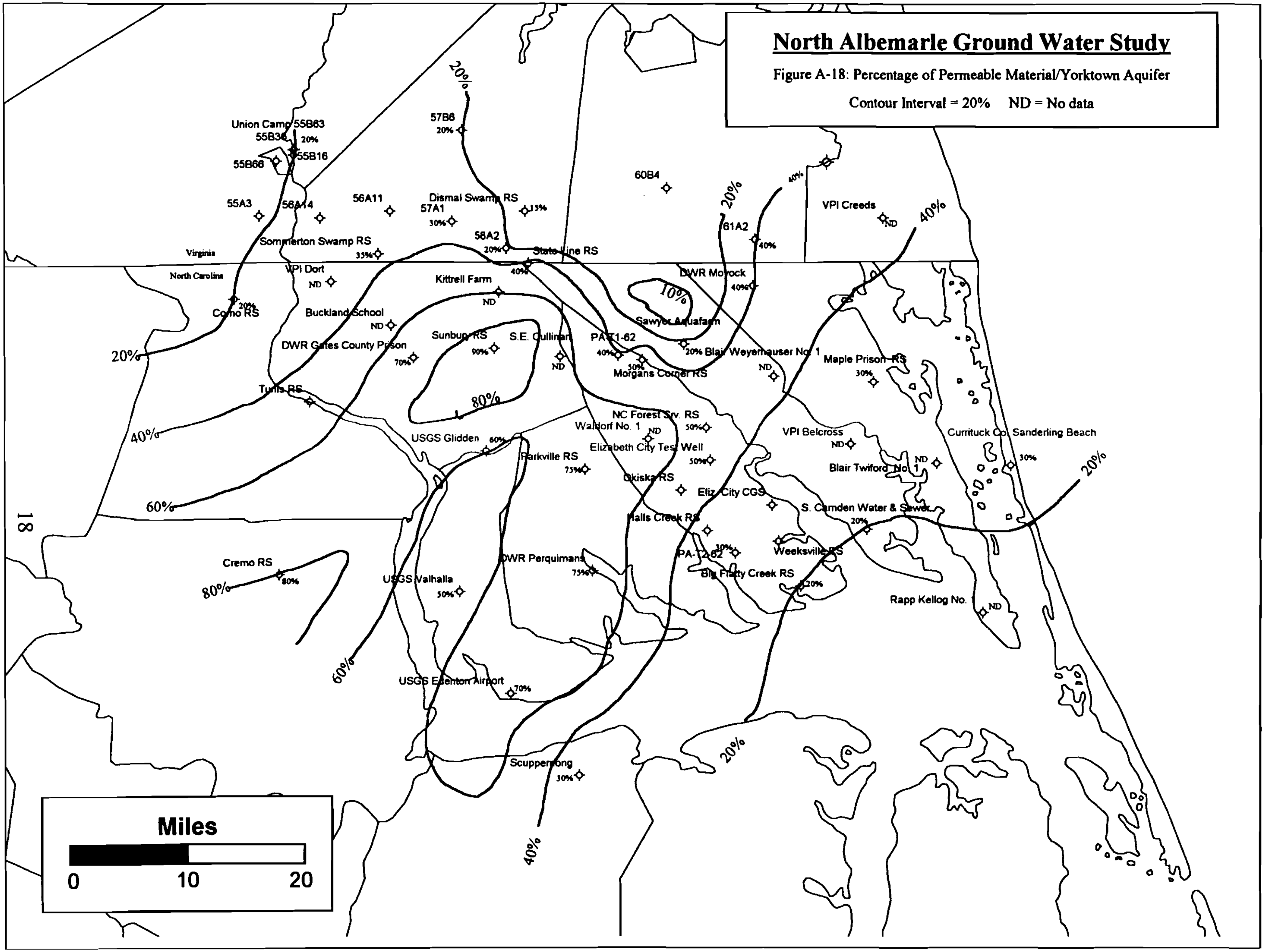
Contours in feet/Contour Interval = 50' ND = No data

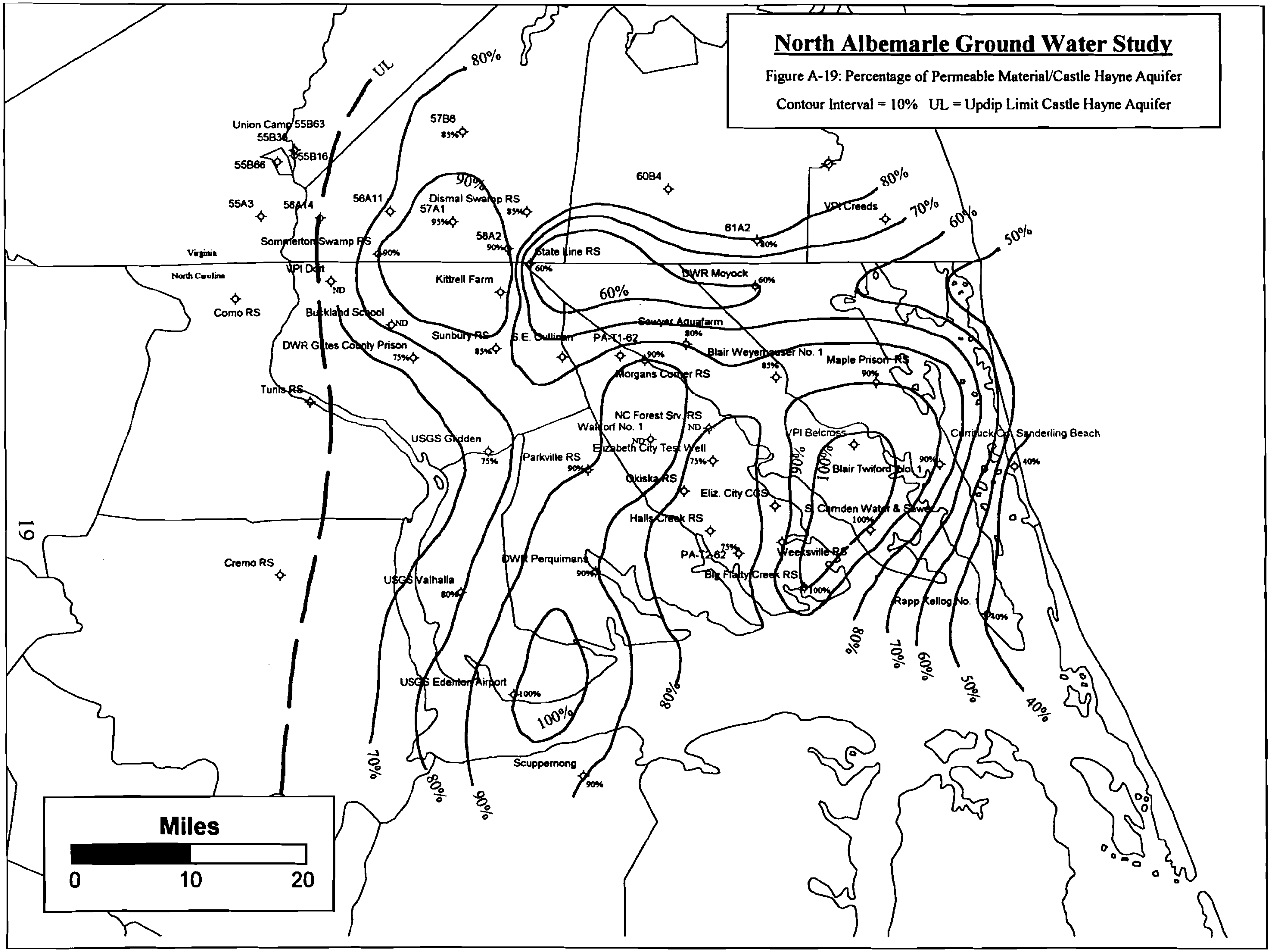


North Albemarle Ground Water Study

Figure A-17: Isopach Map/Upper Cape Fear Confining Unit

Contours in feet/Contour Interval = 50' ND = No data

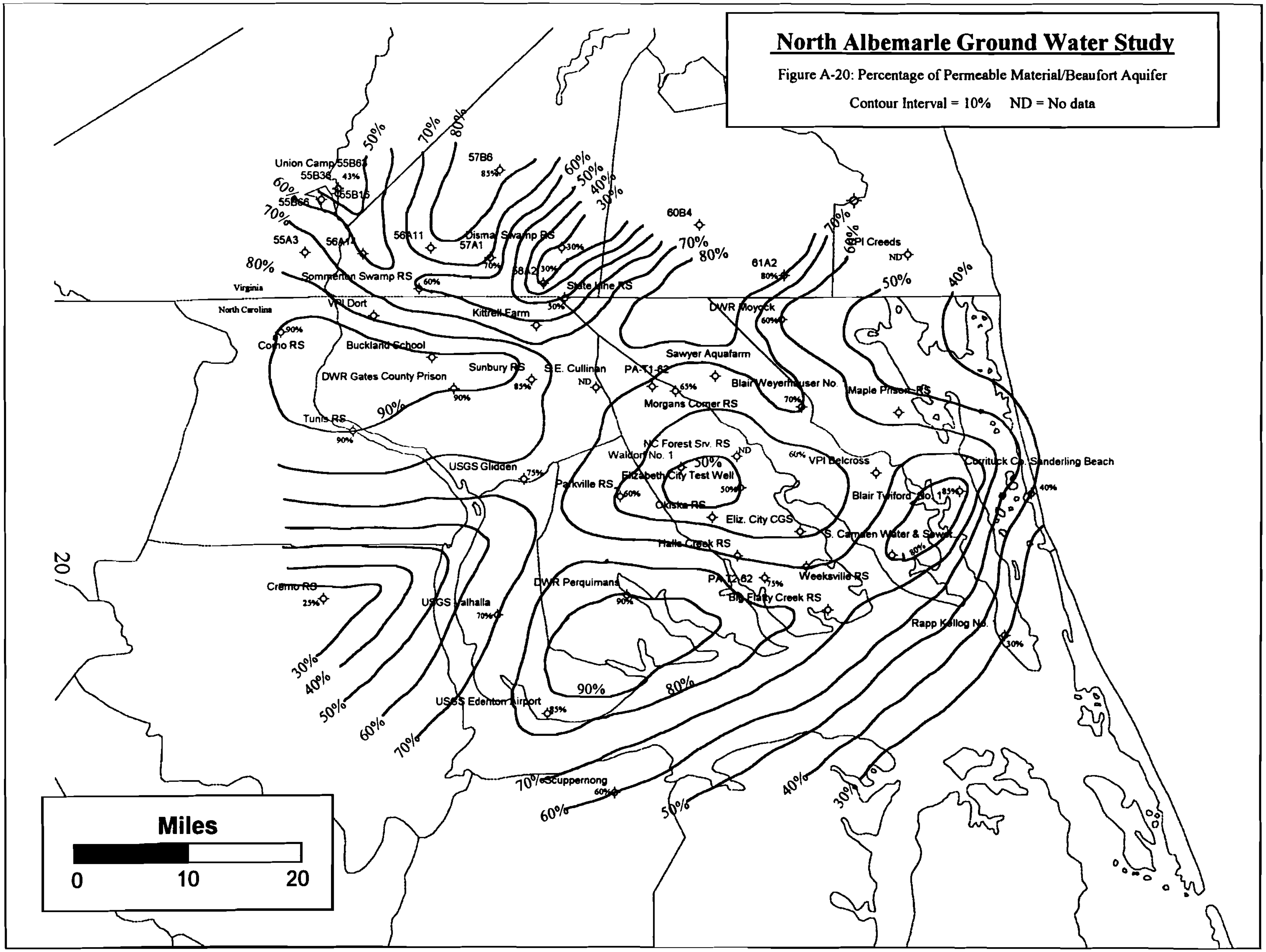

North Albemarle Ground Water Study
Figure A-18: Percentage of Permeable Material/Yorktown Aquifer
Contour Interval = 20%   ND = No data
Union Camp 55B63
55B36
20%
55B16
55B66
55A3
56A14
56A11
57B8
20%
Dismal Swamp RS
15%
57A1
30%
60B4
VPI Creeds
ND
61A2
40%
Sommerton Swamp RS
35%
58A2
20%
State Line RS
40%
Virginia
North Carolina
VPI Dort
ND
Kittrell Farm
ND
DWR Moyock
40%
10%
Como RS
20%
Buckland School
ND
Sawyer Aquafarm
Sunbury RS
90%
S.E. Cullinan
ND
PA-T1-62
40%
20% Blair Weyerhauser No. 1
ND
DWR Gates County Prison
70%
50%
Morgans Corner RS
Maple Prison RS
30%
Tunis RS
80%
NC Forest Srv. RS
50%
Waldorf No. 1
ND
VPI Belcross
ND
Currituck Co. Sanderling Beach
30%
USGS Glidden
60%
Elizabeth City Test Well
50%
Parkville RS
75%
Blair Twiford No. 1
ND
Okiska RS
Eliz. City CGS
S. Camden Water & Sewer
20%
Halls Creek RS
Cremo RS
80%
DWR Perquimans
75%
PA-T2-62
30%
Weeksville RS
Big Flatty Creek RS
20%
USGS Valhalla
50%
Rapp Kellog No.
ND
USGS Edenton Airport
70%
Scuppernong
30%
20%
40%
60%
80%
18
Miles
0
10
20



North Albemarle Ground Water Study

Figure A-19: Percentage of Permeable Material/Castle Hayne Aquifer

Contour Interval = 10%   UL = Updip Limit Castle Hayne Aquifer



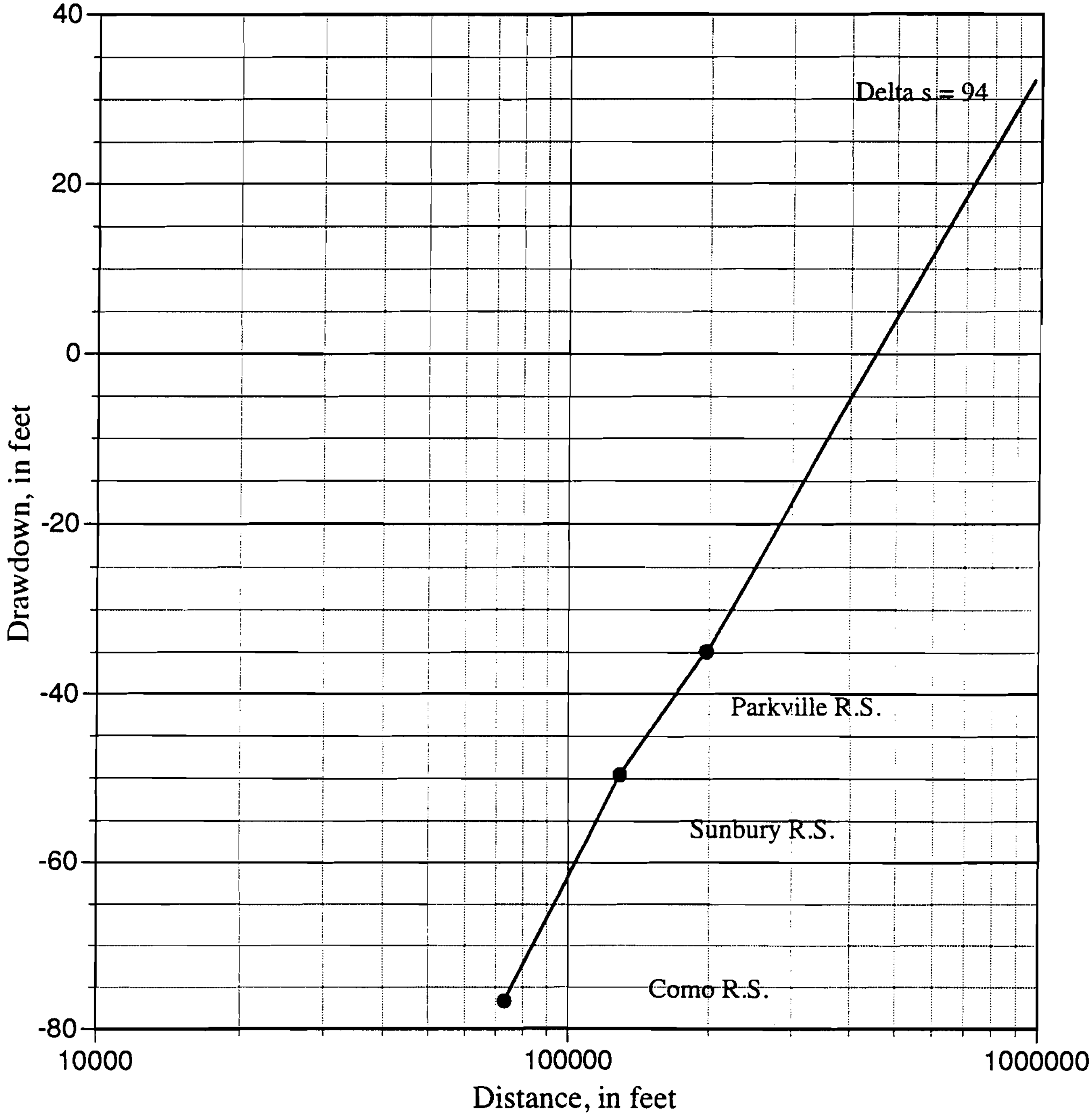
North Albemarle Ground Water Study

Figure A-20: Percentage of Permeable Material/Beaufort Aquifer

Contour Interval = 10% ND = No data

FIGURE A-21

Jacob Distance Drawdown Method Applied to
NCDENR-Sunbury, Parkville, and Como
Research Stations



$$T = \frac{(2.3)(5{,}749{,}100 \text{ ft3/d})}{(6.2831853)\ (94 \text{ ft})}$$

<u>Lower Cape Fear Aquifer</u>

T= 22,388 ft2/day   S=.00319

K=56 ft/day

Figure A-22: Division of Water Resources, Gates County Prison Test

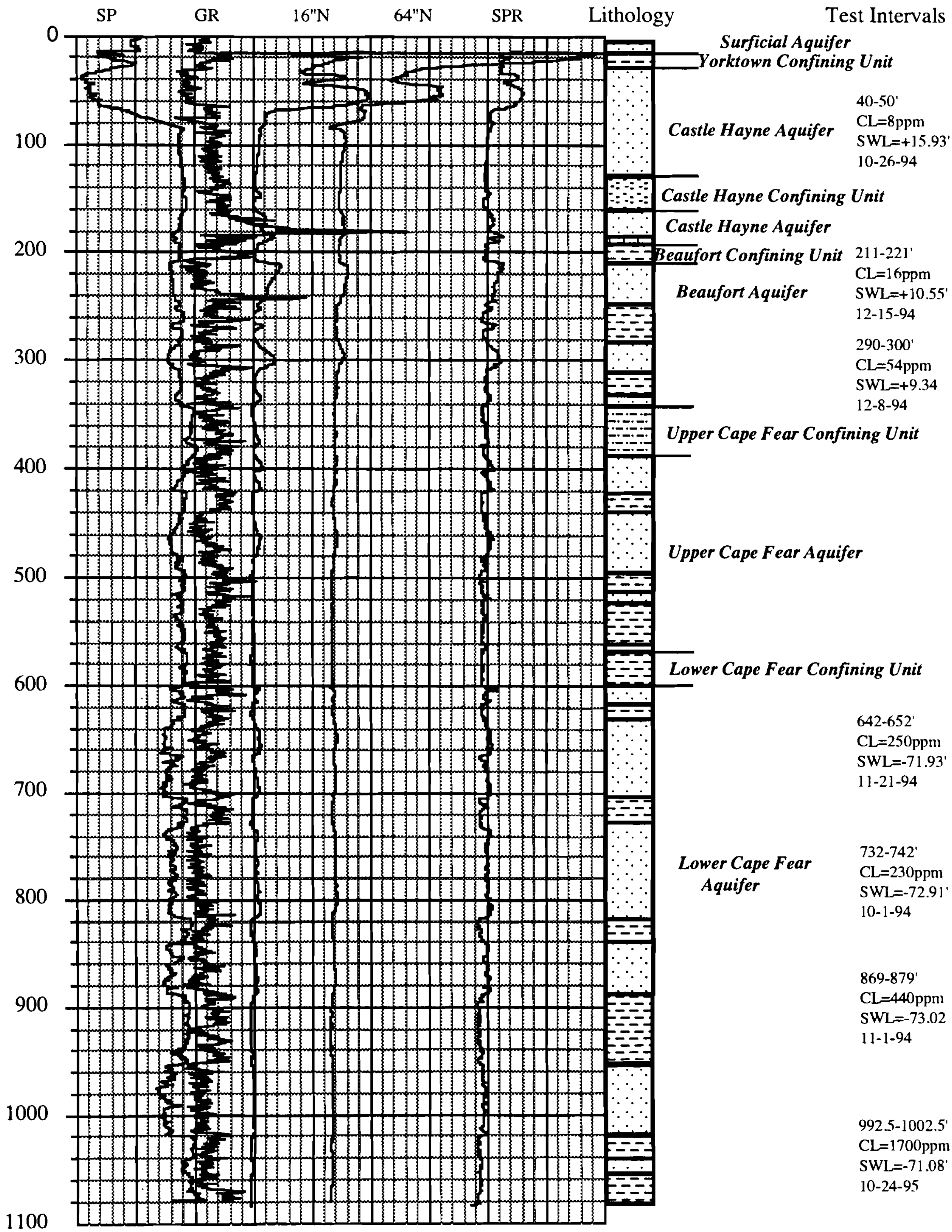


Figure A-23: Division of Water Resources, Perquimans Test

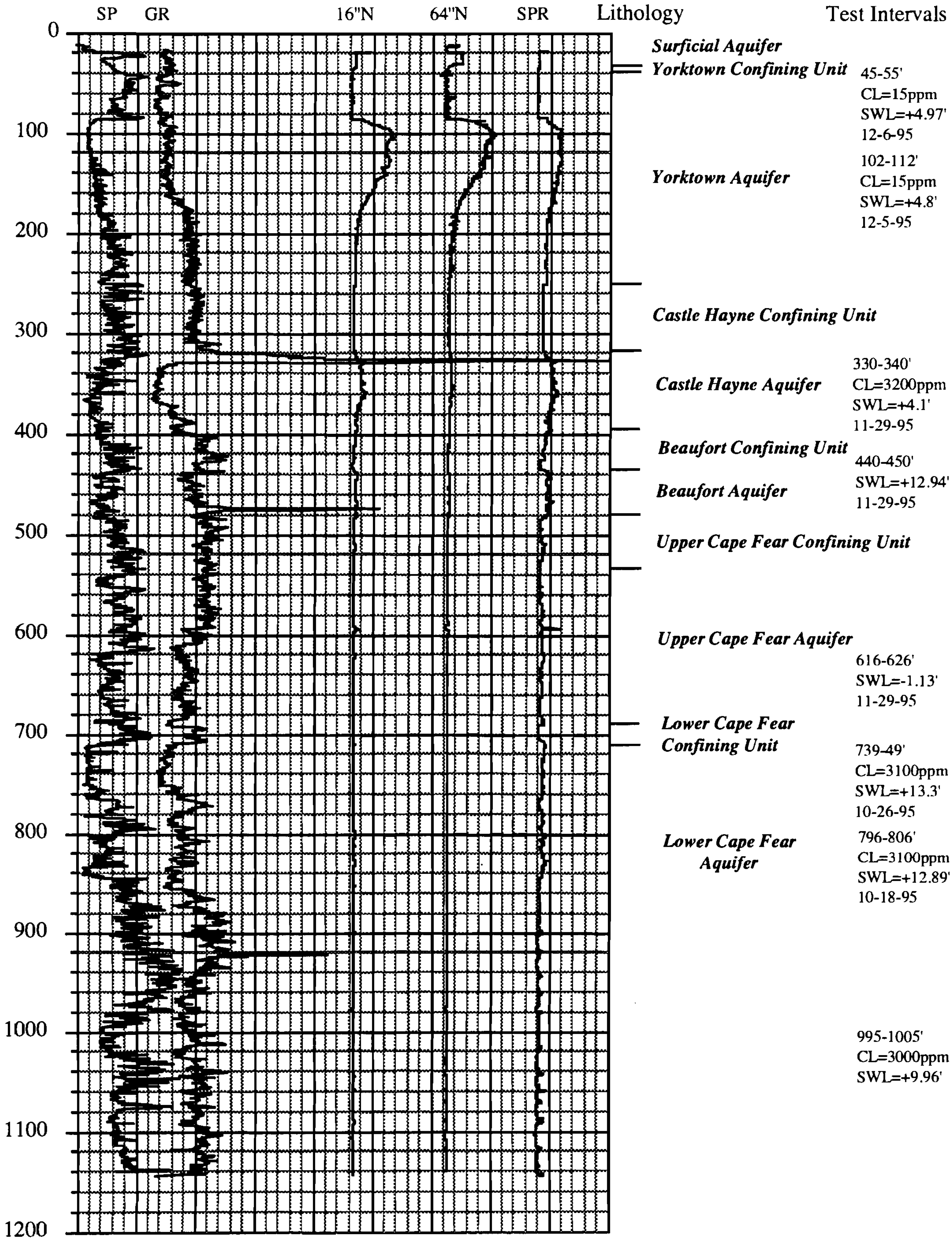
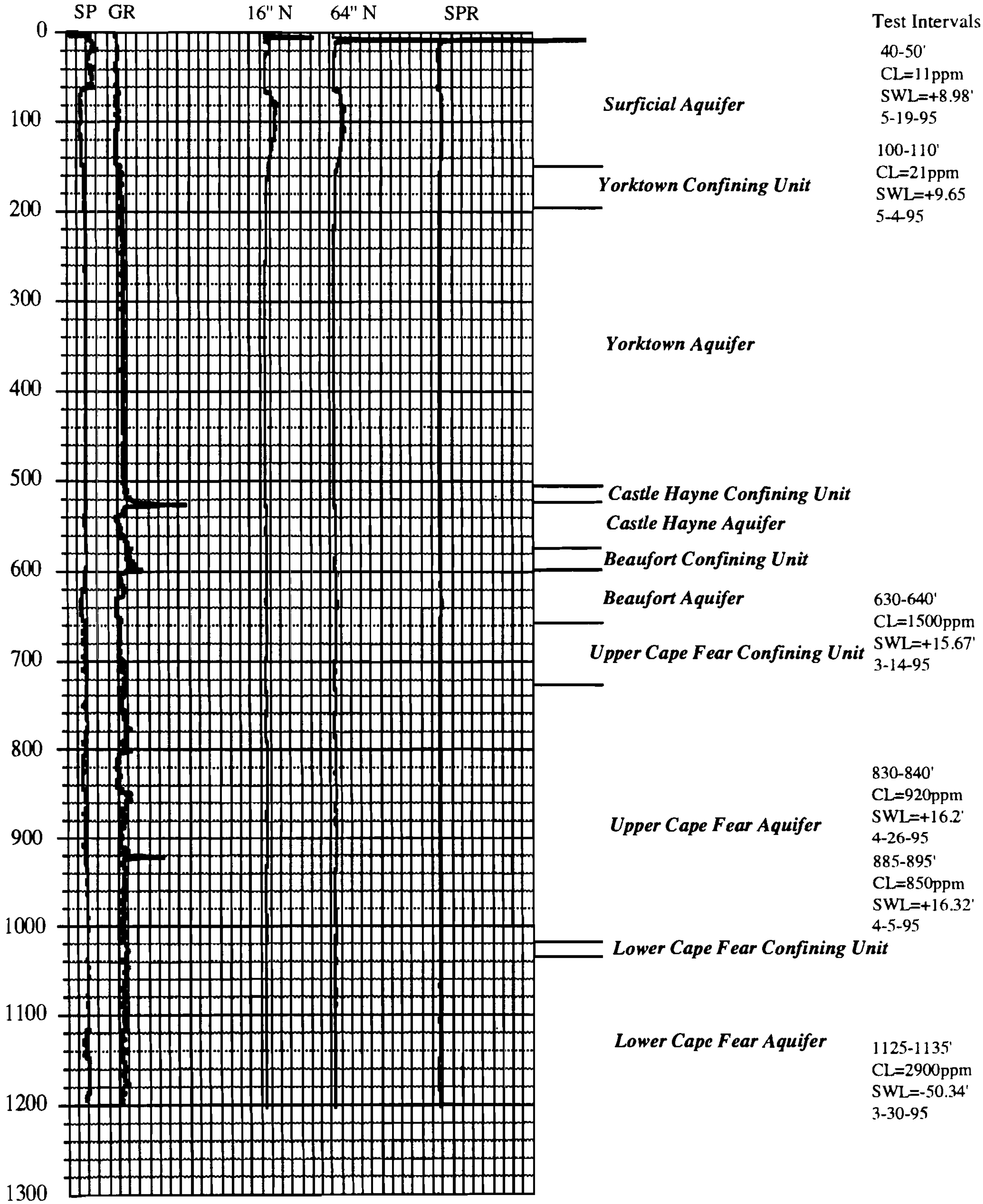


Figure A-24: Division of Water Resources, Moyock Test



Report A-1: Gates County Prison Test-Stratigraphic Log

(by John Nickerson-North Carolina Geologic Survey)

Discussion

Regional Setting

This well is located in Gates County, North Carolina, northeast of Gatesville, approximately 1500 feet east of junction of US 158 and 158A, latitude: 36° 26' 14", and longitude: 76° 43' 26", elevation of ground level is 36 feet (11 m). The hole is on the property of the Gates County Prison, it was drilled and logged by the State Groundwater Section for the N.C. Division of Water Resources. Cuttings from the well delivered to the N.C. Geological Survey's Coastal Plain Office were very complete (0/84'; 90/1080'). This hole has been incorporated into the NCGS Repository, and has been assigned the well code GA-T-1-94.

Sample Examination

Samples from the well were washed over a 200 mesh screen (3.75Ø) to remove drilling mud, and then dried. They were examined under a stereo-binocular microscope at low-power magnifications (typically 6x to 12x). Dominant components, sediment color, sediment texture (grain size, grain shape and sorting), and accessories were noted. No biostratigraphic information is presented; formational correlation is strictly lithologic. The sample data and geophysical logs were both used to develop the lithologic log.

Sample contamination

Because of severe sample contamination in most samples, it was difficult to consistently determine in situ material in most samples. This became more of a problem with increasing depth. Above 250 feet, there is generally good agreement between the samples and the log responses; below this depth, quartz sand (virtually all size classes) and glauconite are ubiquitous as contamination. Also below 250 feet, formational clays and clay-rich material indicated on the geophysical logs are not typically present in the samples. Some of the clays might have been broken up and incorporated into the drilling fluid. Because of this poor clay recovery, I inferred that most of the finer-grained material in this hole is clayey sand, with perhaps some siltstone. No "true" clay was observed in the sample examination process.

Five (5) stratigraphic packages were determined from the above process. Tentative formational calls are listed below. It is essential to explain and qualify the stratigraphy here. The units used in this report are those that are generally recognized by the NCGS and numerous other workers on a regional (Northeastern N.C.) basis. Various workers have defined or recognized other units locally throughout this region and in southeastern Virginia. Examples include the upper Pliocene to early Pleistocene Chowan River, Bacons Castle, and James City formations, the upper Miocene Eastover and St. Marys Formations, other Paleocene units, and various upper Cretaceous units. The problem is that these units are either: 1) not correlated between the outcrop and subsurface sections or visa versa, 2) not recognizable or distinguishable in well cuttings, or 3) a matter of conflict between different studies and not resolvable without considerable additional work. Several of these other units very likely occur within this borehole and it may be that subsequent data and correlations will permit us to revise this preliminary stratigraphy toward a higher resolution.
From the surface, the five stratigraphic packages are:

- an unnamed (Pleistocene or upper Pliocene ?) sand unit - fine-grained to pebbly sands; top = +36 feet MSL; 65 feet thick.
- Yorktown Formation (lower to upper Pliocene) - shelly sands and silty sands; top = -29 feet MSL; 103 feet thick.
- Pungo River Formation (early to middle Miocene) - phosphatic quartz sands; top = -132 feet MSL; 16 feet thick.
- Beaufort Formation (upper Paleocene) - glauconitic shelly sands and sandy biomicrite; top = -148 feet MSL; 61 feet thick.
- Cape Fear Formation equivalent (Upper Cretaceous) - medium-grained to pebbly sands and clayey sands; top = -209 feet MSL; 835 feet thick.

A graphic lithologic log, at a scale of 1" = 10', was prepared for the hole. A listing of lithologic symbols is attached for reference. Lithologies below 250 feet depicted on the graphic log are chiefly based on log signatures, because of the contamination problem stated above.

Correlations

Two additional wells drilled on the prison grounds provide good correlation. The first, GA-T-3 (supplemental sheet listing in USGS Professional Paper 796, photocopy attached) was drilled approximately 4,000 feet due south of GA-T-1-94, at an elevation of 30 feet. This hole was drilled to a depth of 615 feet and encountered a similar section as GA-T-1-94.

The second well, #108 of Gates County Prison, was drilled on the prison property in 1947, presumably close to US Highway 158 - exact location unknown. A detailed log (photocopy attached) of this well was published in NCGS Bulletin 72, Well Logs from the Coastal Plain of North Carolina, by Philip M. Brown.

Attached is a compilation of formational tops and thicknesses from these wells (Correlation Data). I have also included a photocopy of a portion of the Merchants Millpond USGS 7.5' quadrangle with these wells spotted on it.

Lithologic Description

Total sample depth = 1080 feet; Elevation = 11m (36 feet).

Unnamed Surficial deposits (holocene ?) 0/65' (65' thick) ; Top = +36' MSL

0/8 — Sand; quartz; very-fine to fine-grained; subangular to angular; very well sorted; light-tan in color; trace of ilmenite; trace to minor amount of muscovite; trace to rare clayey aggregates; trace to minor white feldspar.

8/32 — Sand; quartz; fine- to very coarse-grained; very poorly sorted; light-grey in color; trace limonite-colored clayey aggregates correlated to Gamma-ray kick at 18' - 26'; trace to minor slightly weathered white and grey feldspar grains; trace to minor muscovite; trace organics; trace to rare amethyst.

32/51 — Sand; quartz; fine-grained to granule-sized; very poorly sorted; subangular; correlated to SP and Gamma-ray lows and SPR high from.

51/65 — Sand; quartz; medium- to coarse-grained; moderately well to well sorted; angular to subrounded; trace to minor anethyst; trace rose quartz; trace pyroboles, tourmaline, rutile, garnet, kyanite, and ilmenite. Gamma-ray and SPR log curves generally agree on sandy section here. Lower contact (65') is picked based upon increase in Gamma-ray and SP curve deflection and coincident decrease in SPR deflection at this depth. Contact is also marked by a quartz pebble conglomeratic zone based on appearance of pebbles recovered in 70/80' sample; these pebbles are subrounded quartz and very uniform in size- 4-6mm.

Yorktown Formation (lower Pliocene) 65/168' (103' thick) ; Top = -29' MSL

65/128 Silty quartz sand; fine- to medium-grained; angular to subangular; very well sorted. Trace to minor amounts of tan to white (weathered) molluscan shell fragments; trace of echinoid spines; trace of light-grey silty aggregates - which probably account for the Gamma-ray sensitivity increase at 65'. Trace of garnet, epidote, ilmenite, tourmaline, and amethyst. Sharp increase in amount of tan to white molluscan shell fragments toward base. Also sharp increase in silty aggregates - (Gamma-ray, SP, and SPR log curves are basically tracking straight lines between 84' and 140').

128/134 Sand; quartz; fine- to medium-grained; angular to subangular; moderately well sorted; common to abundant dark-green and pale-green glauconite; minor to common amount of shell fragments as above; (Gamma-ray log does not show an appreciable positive deflection to account for the sharp increase in glauconite).

134/139 Siltstone; light-grey; common to abundant glauconite; minor amount of tan, relatively unweathered molluscan shell fragments; all log curves show subtle deflection (135'-138') toward shale base-line.

139/147 Sand; quartz; medium- to granule-sized; well-sorted; logs show sandy (coarse?) section at ~144'-147'. Rare pebbles of quartz (up to 12mm), from the 150/160' sample are correlated to the ~144'-147' section noted here.

147/168 Siltstone; as in 134/139' sample, but contains abundant dark-green and pale-green glauconite (~ 40%). Trace of phosphate.Geologist on-site noted that an increase in glauconite occurred from 148'-150', this fits the Gamma-ray and SPR log response at this depth.

Pungo River Formation (early to middle Miocene) 168/184' (16' thick) Top = -132' MSL
(tentative call based upon occurrence of water polished quartz grains, and brown phosphate)

168/184 Sand; quartz; medium- to coarse-grained; mostly subrounded; moderately well sorted; common glauconite; minor brown phosphate, trace black phosphate; many quartz grains show evidence of polishing. Phosphate content increases (+/- 5-7% maximum) with depth, and is a common constituent in 170/180' sample. This increase in phosphate is calibrated to a strong positive Gamma-ray deflection (highest Gamma-ray deflection for the entire hole) at 181'-184'.

Beaufort Formation (upper Paleocene) 184/245' (61' thick) Top = -148' MSL

184/207 Sand, quartz, angular to subangular; moderately well sorted; abundant dark-green and pale-green glauconite (~40%) with notable cracks and subsequent infilling with chalcedony (?) and/or pyrite; area around fractures on darker pieces are noticeably lighter in color (alteration); trace brown and black phosphate - (from above ?).

207/211 Limestone; glauconitic, sandy biomicrite; slightly phosphatic; mollusc shell impressions common; abundant loose, pale-green glauconite. Biomicrite occurs coincident with a Gamma-ray low and a SPR high (207').

211/235 Sand, quartz, coarse- to very coarse-grained; subangular to subrounded; moderately well sorted; common to abundant tan-colored shell fragments (probable Oleneothyris harlani) correlated to 226'-231' zone, which is characterized by a Gamma-ray increase and SPR decrease, which could represent an interval of finer-grained material.

235/245 Sand, quartz, medium- to coarse-grained; angular to subangular; sorting is better with depth; abundant tan-colored shell fragments (probable Oleneothyris harlani); abundant dark-green botryoidal glauconite (+/- 25%); trace coarse-grained phosphate; Gamma-ray high 243'-245' which probably represents increase in amount of phosphate, and coincident with SPR high is recognized as base of unit.

Cape Fear Formation ? (Upper Cretaceous) 245/1080' (835' thick) Top = -209' MSL (provisional call based upon first occurence of siderite and unweathered grey feldspar in 250/260' sample). Severe contamination throughout this section: sandy biomicrite, glauconite, shell fragments, and quartz grains.

245/280 Sand, and clayey sand, fine-to coarse-grained, angular to subangular, trace of coarse-grained grey unweathered feldspar, trace of pyritized lignite, trace of siderite, rare limonite-colored clayey sand aggregates.

280/307 Sand, coarse to very coarse grained, gravelly at base, common grey unweathered feldspar, oxidized staining is also common on quartz grains, quartz grains are angular to subangular, trace rose quartz, grain size increases with depth.

307/331 Clayey sand, hematitic and limonitic, minor amount of siderite, good positive Gamma-ray deflection coincident with SPR high at 306.5' marks the top of this bed.

331/420 Sand, medium- to very coarse-grained, three distinct fining-upward sequences noted: 420'-400'; 400'-375.5'; 375.5'-331', trace of hematitic clayey sand aggregates, very coarse sand present in the samples is interpreted to be from the basal portions of these sequences.

420/439 Clayey sand, inferred from log response, sand is medium- to coarse-grained, subangular to angular, slightly micaceous, no clay present in samples, common grey and white unweathered feldspar.

439/478 Sand, coarse to very coarse grained, angular to subangular, moderately well sorted, common grey and white feldspar.

478/512 Clayey sand, first occurrence of hematitic mottled clayey sand, red, rose, and yellow in color, note: water pump on drill rig was replaced during this interval.

512/629 Sands, and clayey sands, interbedded, medium to very coarse grained quartz sand, tan, light green, and grey micaceous sandy clay, probable coarse zones at 512'-518'; 598'-604' and 611'-615', common white feldspar.

629/703 Sand, medium to very coarse grained, some gravel present, two fining-upward sequences noted (703'-667'; 663'-629'), separated by a 4' clay-rich bed (663'-667').

703/731 Clayey sand, inferred from log responses, no appreciable fine-grained material in samples, sand is medium- to coarse grained, moderately well sorted, trace of pyrite.

731/815 Sand, coarse-grained to pebbly, subangular to subrounded, common white feldspar, coarsens towards top.

815/839 Clayey sand, hematitic, medium- to coarse-grained quartz sand, angular to subangular.

839/886 Sands, and clayey sands,, inferred interbedded sands and clayey sands based upon log responses, sands are mostly coarse to very coarse grained and subangular to subrounded, common white and grey unweathered feldspar.

886/950 Clayey sand, hematitic and limonitic, coarse- to very coarse grained sand present at 936'-946', drilling rate slowed considerably during this interval — up to 83 minutes to cut a 10 foot section (900'-910') was noted by geologist-on-site.

950/1018 Sand, coarse to very coarse grained, feldspathic subangular to subrounded, thin hematitic clayey interbeds present (970'-972'; 988'-990').

1018/1080 Clayey sand, hematitic, light tan and light grey sandy clay also, sand is predominantly medium- to coarse-grained, and has common oxidized (yellow) staining. Bit sample contained clayey sand aggregates, with fine to granule-sized sand mixed in.

Report A-2: DWR Perquimans Test-Lithostratigraphic/Biostratigraphic Log

(by Kenny Gay-North Carolina Geologic Survey)

Discussion

General

This well is located in Perquimans County, North Carolina, about 1.5 miles southeast of Hertford, along SR 1336, latitude: 36° 10' 09", and longitude: 76° 27' 06", elevation of ground level is about 13.0 feet. The hole was drilled and logged by the Groundwater Section of EHNR-DEM for the N.C. Division of Water Resources (DWR). Cuttings from the well delivered to the N.C. Geological Survey's Coastal Plain Office were complete (0 feet/1140 feet). This hole has been incorporated into the NCGS Repository, and has been assigned the well code PQ-T-1-95; NCDWR code is PER-T1-95.

The well is located on the northern fringe of the Albemarle embayment. This portion of the embayment has received sediments from Late Cretaceous to recent (the past 100 million years or so).

Sample Examination

Samples from the well were washed over a 200 mesh screen (3.75 phi; 0.074 mm) to remove drilling mud, and then dried. They were examined under a stereo-binocular microscope at low-power magnifications (typically 6x to 12x). Dominant lithologies, sediment color, sediment texture (grain size, grain shape and sorting), and accessories were noted. Formational correlation is mainly lithologic, however, some biostratigraphic information was utilized. The sample data and geophysical logs were both used to develop the lithologic log.

Sample contamination

Efforts by the drill crew and the personnel of the DWR to reduce the amount of sample contamination in this well were, for the most part, successful. Considerable contamination was detected from 940 feet to the bottom of the hole. Contamination usually consisted of glauconite, shell fragments, limestone fragments, and quartz sand. The Tertiary fossils seen from 940 to 1140 feet consists of whole fragile shells, this suggests that these fossils were being "sucked" out of the formation and were being gently lifted up in the drilling mud after a collapse of the mud cake. The fossils that were recovered when the Tertiary section was drilled were broken and fragmental.

Stratigraphy

Nine (9) stratigraphic packages were determined from the above procedure. Tentative formational calls are listed below. The units used in this report are those that are generally recognized by the NCGS and numerous other workers on a regional (Northeastern N.C.) basis. Various workers have defined or recognized other units locally throughout this region and in southeastern Virginia. Examples of these other units include the upper Pliocene to early Pleistocene Bacons Castle and James City formations, the upper Miocene Eastover and St. Marys Formations, other Paleocene units, and various upper Cretaceous units. The problem is that these units are either: 1) not correlated between the outcrop and subsurface sections or visa versa, 2) not recognizable or distinguishable in well cuttings, or 3) a matter of conflict exists between different studies and are not resolvable without considerable additional work. Some of these other units very likely occur within this borehole and it may be that subsequent data and correlations will permit us to revise this preliminary stratigraphy toward a higher level of resolution.

From the surface, the nine stratigraphic packages are:

- an unnamed (Holocene or Pleistocene ?) sand and clay unit - fine-grained to pebbly, slightly silty and shelly sands; top = +13 feet (MSL); 72 feet thick.

- Chowan River Formation (upper Pliocene) - shelly silty sands; top -59 feet (MSL); 99 feet thick.

- Yorktown Formation (lower to upper Pliocene) - shelly, glauconitic, calcareous, silty sands; top = -158 feet (MSL); 81 feet thick.

- Pungo River Formation (early to middle Miocene) - slightly phosphatic quartz sands; top = -239 feet (MSL); 76 feet thick.

- Castle Hayne Formation (middle Eocene) - glauconitic sandy biosparite; top = -315 feet (MSL); 50 feet thick.

- Beaufort Formation (upper Paleocene) - highly glauconitic calcareous silty sands and sandy biomicrite; top = -365 feet (MSL); 105 feet thick.

- Peedee Formation (?) (Upper Cretaceous) - glauconitic silty medium-grained sands; top = -470 feet (MSL) 117 feet thick

- Black Creek Formation (?) (Upper Cretaceous) - fine- to coarse-grained, micaceous and pyritic silty sands; top = -587 feet (MSL); 166 feet thick.

- Cape Fear Formation equivalent (?) (Upper Cretaceous) - interbedded clayey sands, ferrugenous silt stones and claystones, and dense dolostones; top = -753 (MSL); at least 374 feet thick.

A graphic lithologic log, at a scale of 1 inch equals 10 feet, was prepared for the hole. A listing of lithologic symbols is attached for reference.

Correlations

The nearest interpreted wells are CO-T-2-62 (USMC Air Base, USGS Test, TD=857) and CM-OT-1-65 (Blair #1, TD=3750 feet). Correlations are summarized below.

	Unit	C0-T-2-62	PO-T-1-95		CM-OT-1-65	
	Top	*Thickness*	*Top*	*Thickness*	*Top*	*Thickness*
Holocene/Pleistocene undivided	+15	48	+13	72	+8	100
Pliocene Chowan River Fm.	NR	NR	-59	99	NR	NR
Pliocene Yorktown Fm.	-33	168	-158	81	-92	268
middle Miocene Pungo River Fm.	-201	12	-239	76	-360	165
middle Eocene Castle Hayne Fm.	-213	52	-315	50	-525	74
lower Eocene unnamed unit	-265	22	NR	NR	-599	25
Paleocene Beaufort Fm.	-287	134	-365	105	-624	55
Upper Cretaceous Peedee Fm	-421	58	-470	117	NP	NP
Upper Cretaceous Black Creek Fm	-479	91	-587	166	-679	205

Upper Cretaceous Cape Fear equiv.	-570	>272	-753	>374	-884	268

Tops are in feet, reference mean sea-level; thicknesses are in feet.
NR = not recognized.
NP = not present.
Lithologic Description

Total sample depth = 1140 feet; Elevation = about 13 feet.
Base of casing 83 feet

Log Depths Sample Description

Unnamed surficial deposits (Holocene/ Upper Pleistocene ?) 0/72 feet thick ; Top = +13 feet MSL (Depths listed in descriptions refer to log depths.)

0/32 Sand; quartz; fine-grained; silty in upper 10 feet, clay content increases downward; subangular to subrounded; moderate to very well sorted; tan to light gray in color; trace of heavy minerals; minor gray feldspar from 10/20 feet; minor reworked white chalky shells in upper 10 feet; section from 20/30 feet contains diverse marine fauna including: bivalves *Mulinia, Ensis, Divaricellia, Lucina, arcacea*, gastropod *Marginella*, and echinoderm fragments; quickly grades to below.

32/39 Clay; slightly sandy; gray; sand is quartz, very fine to fine-grained; angular to subangular; well sorted; common diatoms; trace muscovite; common gypsum.

39/72 Sand; quartz; light gray; coarse-grained, gravelly and slightly silty; subrounded to rounded; moderately sorted; no fossils; trace heavy minerals; minor to trace gray and white feldspar; trace amethyst; rare chert and rose quartz.

Chowan River Formation (upper Pliocene) 72/171 feet (99 feet thick), Top = -59 feet MSL; (call based upon the occurrence of the index fossil *Carolinapecten eboreus bertiensis* (Mansfield) and other faunal elements)

72/106 Sand; quartz; silty, clayey 72/80 feet; gray to blue-gray in color; fine to medium-grained; subrounded; moderately sorted; trace rounded black phosphate, rare to trace fine-grained glauconite, trace amethyst; abundant fresh, very diverse fauna as white to light gray fossils: barnacles, echinoderm spines, corals, bivalves including *Carolinapecten eboreus bertiensis, Costaglycymeris, Astarte, Nuculana, Corbula,, Pandora, Glans, Mulinia, Modiolus, Lucinia*, gastropods including *Turritella, Polynices, scaphopod Dentalium.* forams and ostracods

106/171 Sand; quartz; silty, silt fraction increases down section; gray; medium-grained; subrounded; moderately sorted; trace heavy minerals; trace rounded black and brown phosphate, trace glauconite,rare muscovite; rare amethyst; abundant fresh white to dark gray fossils: barnacles, bivalves including *Carolinapecten eboreus bertiensis, Modiolus, Mulinia, Lucinia, Venericardia, Corbula*, gastropod *Turritella*, forams and echinoderm spines; faunal diversity and density decreased from above.

Yorktown Formation (lower Pliocene) 171/252 feet (81 feet thick); Top = -158 feet MSL (call based upon the absence of *Carolinapecten eboreus bertiensis* (Mansfield), decrease in resistivity on log, the presence of calcareous pellet-shaped lithic clasts, and a decrease in grain size.)

171/252 Sand; quartz; silty; gray (dry), blue-gray (wet); fine-grained; subangular to subrounded; moderately well sorted; trace heavy minerals; trace rounded black and brown phosphate, trace glauconite; common pellet-shaped indurated, micaceous very silty fine sand to fine sandy silt, cement is calcareous; fauna less diverse than above, fewer identifiable forms, more worn and bored shell, fauna includes: barnacles, common to 220 feet then become rare and worn, forams and echinoderm spines, the bivalve Yoldia becomes abundant at 210 feet, pectinids common to 210 feet then rare.

Pungo River Formation (early to middle Miocene) 252/328 feet (76 feet thick) Top = -239 feet MSL; (tentative call based upon occurrence of water polished quartz grains, trace amounts of brown phosphate, high Gamma kick at 324-329 feet, and decrease in faunal diversity).

252/328 Sand; quartz; very silty; fine-grained, grain size increases downward; subangular to subrounded; moderately well sorted; trace to minor rounded black and brown phosphate; trace to minor glauconite trace heavy minerals; trace muscovite; fauna includes: common *Yoldia*, rare *Modiolus*, gastropod *Ecphora* at 270/280 feet, common to abundant forams, diatoms and echinoderm spines. High gamma ray peak at 322/328 feet is a phosphate rich hardground.

Castle Hayne Formation (middle Eocene) 328/378 feet (50 feet thick) Top = -365 feet MSL; (tentative call based upon occurrence of glauconitic sandy limestone) Good log response - Gamma and SP decrease with coincident SPR increase over this interval. Geologist-on-site noted considerable chatter during this interval; note resistive streaks on SPR between 335 and 364 feet.

328/378 Limestone; sandy biosparite; light gray; abundant biomolds; quartz sand is fine to medium-grained; subrounded; moderately sorted; minor glauconite and phosphate, fauna includes calcitic oysters and pectinids and echinoderms, also phosphatic bone fragments and teeth.

Beaufort Formation (upper Paleocene) 378/483 feet (105 feet thick) Top = -365 feet MSL; (based upon first occurrence of abundant dark green glauconite)

378/420 Sand; quartz,very silty; calcareous; gray; fine-grained; subangular to subrounded; moderately to very well sorted; common medium to coarse-grained dark-green glauconite; trace black phosphate; common tan-colored shell fragments.

420/438 Sand; quartz; very silty; calcareous; gray; medium-grained; subangular to subrounded; poorly sorted; common tan-colored shell fragments probable *Olenothyris* (?); minor amount of oxidized (yellow, red, and green) quartz sand; common medium-grained glauconite; minor brown medium-grained phosphate.

438/483 Limestone; glauconitic sandy biomicrite; light tan to white; abundant loose, dark green glauconite; sand is medium to coarse-grained, subangular to subrounded, poorly sorted; minor phosphate, trace pyrite; based upon the geophysical log signature, interpreted to be interbedded with gray, very silty, calcareous, medium-grained quartz sand. High gamma ray peak at 473 feet represents abundant glauconite.

Peedee Formation (Upper Cretaceous) 483/600 feet (117, thick) Top = -470 feet MSL, (tentative call based upon first occurrence of gray claystone)

483/525 Sand; quartz; very silty; calcareous; medium-grained; subangular to subrounded, poor to moderate sorted, abundant glauconite; common brown phosphate. Interpreted to be interbedded with gray phosphatic shale and glauconitic micrite.

525/552 Sand, quartz; silty; calcareous; dark gray, medium- to coarse-grained; subangular to subrounded; poor to moderate sorting; abundant glauconite and brown phosphate; trace pyrite; fauna includes teeth fragments and ostracods. Based upon the geophysical log signature, interpreted to be interbedded with glauconitic micrite and gray phosphatic shale.

552/588 Sand, quartz; very silty; calcareous; dark gray, medium-grained with coarse sand interbeds; subangular to subrounded; moderate sorting; common glauconite and brown phosphate; trace pyrite; trace heavy minerals; fauna includes ostracods and calcareous worm tubes.

588/600 Sandstone; calcite cemented, light gray; fine to coarse grained; subangular; poorly sorted; common glauconite; common phosphate; minor muscovite; fauna consists of chalky shell and molds partially filled with calcite spar. Good correlation to high resistivity peak at 592 feet.

Black Creek Formation (Upper Cretaceous) 600/766 feet (166 feet thick) Top = -587 feet MSL, (tentative call based upon first major occurrence of pyritized wood fragments and common muscovite)

600/684 Sand, quartz, silty; light gray; fine-grained; subangular; moderately well sorted; minor fine grained muscovite, minor pyrite; minor pyritized wood, trace heavy minerals, minor amethyst, trace green-stained feldspar from 660/684 feet, trace *Inoceramis* prisms. Geophysical log suggests numerous shale interbeds that were not present in the samples.

684/711 Sand, quartz,silty to very silty; light gray; fine-to medium-grained; subangular; moderately sorted; trace fine grained muscovite, trace pyrite; minor pyritized wood, trace heavy minerals, trace amethyst, trace *Inoceramis* prisms.

711/737 Sand, quartz, silty; light gray; medium-to coarse-grained; subangular; moderately sorted; trace fine grained muscovite, trace pyrite; minor pyritized wood, trace heavy minerals, trace amethyst; trace white feldspar.

737/766 Sand, quartz; clean; white; coarse-grained; subangular to subrounded; moderately well to well sorted; trace amethyst; trace rose quartz; first appearance of milky quartz. The forams *Nodosaria* and *Neoflabella* are present.

Cape Fear Formation equivalent (?) (Upper Cretaceous) 766/1140 feet (>407 feet thick) Top = -781 feet MSL; (tentative call based upon first occurrence of hematitic siltstone aggregates and abundant coarse-grained oxidized quartz grains) NOTE: Severe contamination from 940/1140: whole Tertiary mollusk shells, shell fragments, glauconite, and quartz grains.

766/780	Sand; slightly clayey; tan; and silt stone, orange, micaceous; inferred to be inter bedded; first occurrence of hematitic clayey sand aggregates (rare); quartz sand is medium- to coarse-grained, subangular to subrounded, moderately sorted; minor white and gray feldspar, trace heavy minerals; minor amount of oxidized (yellow, red, and green) quartz sand.
780/797	Sand; quartz; very slightly silty; tan; medium- to coarse-grained; subangular to subrounded; poor to moderately sorted; trace muscovite; trace amethyst, trace rose quartz; trace heavy minerals; trace white and gray feldspar; minor amount of oxidized (yellow, red, and green) quartz sand; rare ferrugenous siltstone.
797/821	Sand; quartz; gravelly; tan; medium to very coarse grained inter bedded quartz sands; subangular to subrounded; poorly sorted; trace muscovite, trace amethyst, trace rose quartz, minor to trace white and gray feldspar, trace heavy minerals; common oxidized (yellow, red, and green) quartz sand.
821/844	Sand; quartz; very gravelly; tan and gray; coarse to very coarse grained, subrounded, moderately well sorted; trace to minor muscovite, trace amethyst, trace rose quartz, trace to minor white and gray feldspar; trace heavy minerals. Noticeable decrease in amount of oxidized quartz and fine- to medium-grained sand fraction.
844/873	Sand; quartz; silty; gray and red; medium- to coarse-grained, fines downward over this interval; subangular to subrounded; moderately sorted; trace gray feldspar, minor rose quartz, trace amethyst, trace to minor muscovite, rare heavy minerals.
873/891	Siltstone; micaceous, ferrugenous, red with interbedded sand. Quartz sand is fine- to medium-grained; subangular to subrounded; poorly sorted; trace of quartz gravel at base; trace gray feldspar, trace rose quartz, trace amethyst, trace to minor muscovite, rare heavy minerals.
891/906	Sand; quartz; silty; gray; medium-grained; subangular to subrounded; poorly sorted; trace white feldspar,trace rose quartz, trace amethyst, trace to minor muscovite, rare heavy minerals, common oxidized (yellow, red, and green) quartz sand.
906/980	Sand; quartz; silty; gray and red; medium-grained, subangular to subrounded, moderately sorted; interbedded with red and yellow micaceous sandy siltstone; minor gray and white feldspar; trace to minor muscovite; trace hematitic aggregates; trace amethyst; a lot of the coarse grains are oxidized (yellow); contamination prevalent (shell fragments, glauconite) from 940 feet. The cause for the high gamma-ray peak on the geophysical log at 920 feet was not evident in the cuttings. (The gamma ray curve suggests that this is a "shalely" section with minor sand packages at 942/954 feet and 963/973 feet, the cuttings did not reflect this.)
980/1021	Interval interpreted to be: Sand; quartz; silty; gray and red; medium-grained, subangular, moderately well to well sorted; interbedded with red and yellow micaceous sandy siltstone; minor gray and white feldspar; trace to minor muscovite; trace hematitic aggregates; trace amethyst; a lot of the coarse grains are oxidized (yellow and red); contamination prevalent (shell fragments, glauconite).
1021/1054	Interval interpreted to be: Sand; quartz; silty; gray, yellow and red; medium-grained, subangular, moderately well to well sorted; interbedded with red and yellow

micaceous sandy siltstone; yellow and light gray claystone; and dense brown dolostone (high resistivity peak 1042/1046). Contains: minor gray and white feldspar; trace to minor muscovite; trace hematitic aggregates; trace amethyst; a lot of the coarse grains are oxidized (yellow and red); contamination prevalent (shell fragments, glauconite).

1054/1140 Interval interpreted to be: Sand; quartz; silty; gray, and red; medium-grained, subangular to subrounded, moderately well sorted; interbedded with red and yellow micaceous sandy siltstone; yellow and red claystone; and dense brown dolostone (high resistivity peaks 1051/1062 feet, 1068/1073 feet, 1088/1092 feet, and 1116/1120 feet). Contains: minor gray and white feldspar; trace to minor muscovite; trace hematitic aggregates; trace amethyst; a lot of the coarse grains are oxidized (yellow and red); contamination prevalent (shell fragments, glauconite).

Report A-3: DWR Moyock Test-Stratigraphic Log

(by John Nickerson-North Carolina Geological Survey)

Discussion

General

This well is located in Currituck County, North Carolina, about 2 miles southwest of Moyock, along SR 1227 and approximately 1100 feet north of SR 1227, latitude: 36° 31' 19", and longitude: 76° 12' 20", elevation of ground level is about 12 feet. The hole is on private property, and was drilled and logged by the Groundwater Section of EHNR-DEM for the N.C. Division of Water Resources (DWR). Cuttings from the well delivered to the N.C. Geological Survey's Coastal Plain Office were very complete (0'/280'; 290'/1200'). This hole has been incorporated into the NCGS Repository, and has been assigned the well code CK-T-1-95; NCDWR code is CU-T1-95.

The well is located on the northern fringe of the Albemarle embayment. This portion of the embayment has received sediments from Late Cretaceous to recent (the past 100 million years or so).

Sample Examination

Samples from the well were washed over a 200 mesh screen (3.75 phi; 0.074 mm)) to remove drilling mud, and then dried. They were examined under a stereo-binocular microscope at low-power magnifications (typically 6x to 12x). Dominant components, sediment color, sediment texture (grain size, grain shape and sorting), and accessories were noted. No biostratigraphic information is presented; formational correlation is strictly lithologic. The sample data and geophysical logs were both used to develop the lithologic log.

The lack of an appropriately-scaled geophysical log for the upper +/- 500 feet restricted sample-to-log correlations. The log response over this interval was relatively flat and provided little information. Requests to obtain a rescaled geophysical log for this interval were not granted.

Sample contamination

Efforts by the drill crew and the personnel of the DWR to reduce the amount of sample contamination in this well were, for the most part, successful. Although moderate contamination was detected from about 530 feet to the bottom of the hole, sample quality was much improved over the last hole drilled, GA-T-1-95. Contamination usually consisted of glauconite, limestone fragments, shell fragments, and quartz sand.

Stratigraphy

Six (6) stratigraphic packages were determined from the above process. Tentative formational calls are listed below. As in the Gates County Prison well report (GA-T-1-94), it is essential to explain and qualify the stratigraphy here. The units used in this report are those that are generally recognized by the NCGS and numerous other workers on a regional (Northeastern N.C.) basis. Various workers have defined or recognized other units locally throughout this region and in southeastern Virginia. Examples of these other units include the upper Pliocene to early Pleistocene Chowan River, Bacons Castle, and James City formations, the upper Miocene Eastover and St. Marys Formations, other Paleocene units, and various upper Cretaceous units. The problem is that these units are either: 1) not correlated between the outcrop and subsurface sections or visa versa, 2) not recognizable or distinguishable in well cuttings, or 3) a matter of conflict between different studies and not resolvable without considerable additional work. Several of these other units very likely occur within this borehole and it may be that subsequent data and correlations will permit us to revise this preliminary stratigraphy toward a higher resolution.

From the surface, the seven stratigraphic packages are identified:

- an unnamed (Pleistocene or upper Pliocene ?) sand unit - fine-grained to pebbly, slightly silty and shelly sands; top = +12 feet (reference MSL); 88 feet thick.

- Yorktown Formation (?) (lower Pliocene) - shelly, glauconitic, silty sands; top = -76 feet (reference MSL); 408 feet thick. (note: there are most likely two or more units within this interval; however, without further detailed biostratigraphic work, these cannot be subdivided).

- Pungo River Formation (?) (early to middle Miocene) - slightly phosphatic quartz sands; top = -484 feet (reference MSL); 32 feet thick.(note: this formation is substantially thicker in nearby wells, (see correlation table) the interval in this well from +/- 300 feet to 528 feet could represent the Pungo River Formation; however, further work is needed).

- Castle Hayne Formation (?) (middle Eocene) - glauconitic sandy limestone and dolomite; top = -516 feet (reference MSL); 40 feet thick.

- Beaufort Formation (upper Paleocene) - highly glauconitic slightly shelly sands and sandy biomicrite; top = -556 feet (reference MSL); 60 feet thick.

- Black Creek Formation equivalent (?) (Upper Cretaceous) - medium-grained to pebbly sands and glauconitic, shelly, silty sands; top = -616 feet (reference MSL); 165 feet thick.

- Cape Fear Formation equivalent (?) (Upper Cretaceous) - Inter bedded clayey sands, silt stones, and coarse feldspathic sands; top = -781 (reference MSL); 407 feet thick.

A graphic lithologic log, at a scale of 1 inch equals 10 feet, was prepared for the hole. A listing of lithologic symbols is attached for reference.

Correlations

The nearest interpreted wells are CK-T-2-84 (Maple Research Station, TD=1502'), about 13 miles southeast of CK-T-1-95; and CM-OT-1-65 (Blair #1, TD=3750'), about 8 miles south-southeast of CK-T-1-95. Correlations are summarized below.

	Unit	CK-T-2-84	CK-T-1-95		CM-OT-1-65	
	Top	*Thickness*	*Top*	*Thickness*	*Top*	*Thickness*
Holocene/Pleistocene undivided	+13	73	+12	88	+8	100
Pliocene Yorktown Fm.	-60	256	-76	408	-92	268
middle Miocene Pungo River Fm.	-316	378	-484	32	-360	165
middle Eocene Castle Hayne Fm.	-694	118	-516	40	-525	74
lower Eocene unnamed unit	-812	56	NR	NR	-599	25

Paleocene Beaufort Fm.	-868	85	-556	60	-624	55
Upper Cretaceous Peedee Fm	-953	106	NR	NR	NR	NR
Upper Cretaceous Black Creek Fm	-1059	175	-616	165	-679	131
Upper Cretaceous Black Creek Fm	-1234	83	?	?	-810	74
Upper Cretaceous Cape Fear eq	-1317	183	-781	>407	-884	268

Tops are in feet, reference mean sea-level; thicknesses are in feet.
NR = not present or not recognized.
? indicates material combined with Black Creek Formation.

Lithologic Description

Total sample depth = 1200 feet; Elevation = about 12 feet.

Log Depths — Sample Description

Unnamed Surficial deposits (Holocene ?) 0/88' thick ; Top = +12', reference MSL

0/22 — Sand; quartz; medium-grained; silty; subangular to subrounded; poorly sorted; light-tan in color; trace of ilmenite; trace organics; minor amount of shells in lower part, conus, mulinia; significant gravelly section 9-11 feet.

22/29 — Sand; quartz; fine-grained; silty; very well sorted; light-grey in color; angular to subangular; minor amount of medium grey oyster shells; rare turritella.

29/88 — Sand; quartz; medium-grained to gravelly; moderately sorted; typically finer grains are subangular to angular while coarser grains are rounded to well rounded; basal 20 feet has >50% of coarser grains well rounded.

Yorktown Formation (?) (lower Pliocene) 88/496' (408' thick) ; Top = -76', reference MSL; (note: tentative formational call; there are most likely two or more units within this interval; however, without further detailed biostratigraphic work, these cannot be subdivided).

88/146 — Shell hash; sandy,with predominantly abraded and rounded shell fragments; Geophysical log curves are generally flat throughout this section. Significant Gamma-ray and SP curve positive deflection at 146 feet.

146/189 — Silt stone; glauconitic, shelly, micaceous, trace of phosphate; with fine-grained, angular to subangular quartz sand; common to abundant glauconite.

189/282 — Sand; quartz; fine- to medium-grained; shelly; silty; moderately well to well sorted; angular to subrounded; common glauconite; trace mica; rare sandy micrite.

282/496 — Silt stone; glauconitic; slightly shelly; micaceous; trace of phosphate; sandy - very fine to medium grained, angular to subangular, moderately well to well sorted; fairly homogeneous overall.

Pungo River Formation (early to middle Miocene) 496/528' (32' thick) Top = -484', reference MSL; (tentative call based upon occurrence of water polished quartz grains, trace amounts of brown phosphate, and high Gamma kick at 522-528'; please refer to note above regarding this formation).

496/528 Sand; silty; mostly medium-grained; angular to subangular; coarser grains are rounded and show evidence of water polishing; poor to moderate sorting; slightly shelly; common to abundant glauconite; common brown phosphate and mica; minor amount of pyrite; trace of micritic limestone; shells are mostly molluscan shell fragments, light grey and white.

Castle Hayne Formation (middle Eocene) 528/568 (40' thick) Top = -516', reference MSL; (tentative call based upon occurrence of glauconitic sandy limestone and pale green dolomite.) Good log response - Gamma and SP decrease with coincident SPR increase over this interval. Geologist-on-site noted considerable chatter during this interval; note resistive streaks on SPR between 550 and 560 feet.

528/538 Limestone; biomicrite; very sandy, shelly; light grey; glauconitic; thick mollusc shell fragments; probably a shell limestone with micritic matrix.

538/548 Sand; quartz; clean; medium-grained; very well sorted; subangular to subrounded; trace of glauconite, shell fragments, and phosphate.

548/568 Limestone; biomicrite to biosparrite; sandy; dark green, fine-grained glauconite (increases toward base) inter bedded with pale green dolomite.

Beaufort Formation (upper Paleocene) 568/628' (60' thick) Top = -556', reference MSL; (based upon first occurrence of abundant dark green glauconite)

568/597 Sand, quartz, angular to subangular; moderately well sorted; very abundant medium- to coarse-grained dark-green glauconite (>50%); trace black phosphate.

597/612 Limestone; glauconitic, sandy biomicrite; sandy; abundant loose, dark green glauconite. Abundant weathered (iridescent medium brown) glauconite or phosphate, this occurs as loose grains and in the micrite matrix - could represent significant subaerial exposure of this limestone. Top of biomicrite occurs coincident with a Gamma-ray low and an SPR high (597').

612/628 Sand, quartz, medium- to coarse-grained; subangular to subrounded; moderately sorted; common tan-colored shell fragments; minor amount of oxidized (orange) quartz sand; Abundant weathered(iridescent medium brown) glauconite or phosphate.

Black Creek Formation ? (Upper Cretaceous) 628/793' (165' thick) Top = -616', reference MSL; (tentative call based upon first major occurrence of coarse-grained amethyst) Moderate contamination throughout this section: sandy biomicrite, glauconite, shell fragments, and quartz grains.

628/651 Sand, quartz,clean; medium- to coarse-grained; angular to subangular; moderate sorting; minor to common amethyst; trace of rose quartz. (note: log scale is off by 1 foot between 620 and 630 feet).

651/708 Silt stone; glauconitic; with fine-grained clayey quartz sand, inferred to be inter bedded, angular to subangular; very well sorted; common mica; trace of mollusc shells.

708/711 Gravel; quartz; well rounded.

711/742 Silt stone; glauconitic; with fine- to medium-grained clayey quartz sand, probably inter bedded, angular to subangular; very well sorted; fine-grained medium green glauconite; common mica; trace of mollusc shells.

742/756 Sand; medium- to coarse-grained; angular to subangular.

756/782 Sand; clayey; and silt stone, inferred to be inter bedded; very pale green to light grey; quartz sand is fine- to medium-grained, angular to subangular, moderately sorted, common glauconite and trace shell fragments.

782/793 Sand; medium- to coarse-grained; angular to subangular.

Cape Fear Formation equivalent (?) (Upper Cretaceous) 793/1200' (?) (407' thick) Top = -781', reference MSL; (tentative call based upon first occurrence of hematitic clayey sand aggregates (rare), and grey feldspar) Increasing contamination throughout this section: sandy biomicrite, glauconite, shell fragments, and quartz grains.

793/804 Sand; clayey; and silt stone, inferred to be inter bedded; very pale green to light grey; first occurrence of hematitic clayey sand aggregates (rare); quartz sand is fine- to medium-grained, angular to subangular, moderately sorted, common glauconite and trace shell fragments.

804/847 Sand; coarse to gravelly; clean; trace amethyst, rose quartz and pyrite; rare grey feldspar; coarsens downward.

847/880 Sand; clayey with coarse to very coarse grained inter bedded quartz sands; trace white feldspar.

880/918 Sand; coarse to very coarse grained quartz sand, subangular to subrounded, generally poorly sorted; common white and grey feldspar; contamination prevalent.

918/922 Sand, slightly silty; fine-grained, angular to subangular, very well sorted; minor fine to coarse mica and trace brown gel-like phosphate and black rounded phosphate pebble. (note coarse to pebbly black, rounded phosphate was observed in the 960/970 sample and is most likely from this interval given the intensity of the Gamma peak); possible formational break here.

922/934 Sand; medium- to coarse-grained, rounded to well rounded, well sorted; increase in oyster (?) and molluscan shell fragments - some with a fibrous nature to them (aragonitic (?)); rare siderite; trace mica; minor feldspar.

934/982 Sand; quartz, clayey and silt stone, probably inter bedded, sand is mostly medium- to coarse-grained (contamination present makes it difficult to determine in situ material); trace mica and siderite.

982/1010 Limestone; inter bedded shell limestone, dolomite,clayey sand, and coarse-grained to pebbly well rounded quartz grains; increase in medium grey oyster shell fragments and whitish weathered gastropod fragments; thin, resistive zones on SPR log over this interval most likely are related to the shell limestone, dolomite, and pebbly sands.

1010/1116	Sands, and clayey sands, inferred inter bedded sands and clayey sands based upon log responses, sands are mostly medium- to coarse-grained and angular to subangular, common white and grey pebbly unweathered feldspar; trace mica.
1116/1146	Sand; coarse to very coarse grained, subrounded, minor grey and white feldspar; trace siderite; trace hematitic aggregates; trace amethyst; a lot of the coarse grains are oxidized (yellow); contamination prevalent (biomicrite, shell fragments, glauconite).
1146/1200	Sands, and clayey sands, inferred inter bedded sands and clayey sands based upon log responses, sands are mostly medium- to coarse-grained and angular to subangular, common white and grey pebbly unweathered feldspar; trace mica.

Table A-1: Aquifer Test Analyses-North Albemarle Study Wells

Well or Research Station	Single Well or Multi Well Test	Screened Interval (in feet)	Pumping Rate (Q) gpm	Well Diam. (in inches)	Test Duration (in minutes)	Aquifer	T ft2/day	K ft/day	K' ft/day	S	Yield gpm	Specific Capacity gpm/ft
DWR Perquimans Co. Test	SWT	45-55	15.7	4	90	Yorktown	30.34	0.226	*	*	20 air lift	2.11
		102-112	5.5	2.5	180	Yorktown	*	*	*	*	8 air lift	0.412
		330-340	6.4	2.5	90	C. Hayne	*	*	*	*	25 air lift	3.92
		995-1005	5	2.5	90	L.Cape Fear	1.56	0.018	*	*	7.89 air lift	0.118
DWR Moyock Test	SWT	40-50	17	4	60	Surficial	26	0.26	*	*	24 air lift	0.666
		100-110	6.5	2.5	150	Yorktown	*	*	*	*	37.5 air lift	36.1
		630-640	7.5	2.5	150	Beaufort	*	*	*	*	33 air lift	2.25
		830-840	5.5	2.5	180	U.Cape Fear	*	*	*	*	43 air lift	10.18
		885-895	6	2.5	180	U.Cape Fear	*	*	*	*	33 air lift	18.33
		1125-1135	7.1	2.5	240	L.Cape Fear	*	*	*	*	17 air lift	4.9
DWR Gates Co. Test	SWT	40-50	16.6	4	150	Surficial	*	*	*	*	50 air lift	9.36
		211-221	6	2.5	180	Beaufort	11.77	0.09	*	*	11.5 air lift	0.46
		290-300	6	2.5	240	Beaufort	*	*	*	*	25 air lift	0.305
		642-652	3.5	2.5	107	U. Cape F.	*	*	*	*	13.6 air lift	0.56
		732-742	5	2.5	26	L.Cape Fear	*	*	*	*	25 air lift	6.57
		869-879	3.7	2.5	166	L.Cape Fear	*	*	*	*	20 air lift	2.85
		992-1002	3.1	2.5	154	L.Cape Fear	5.14	0.075	*	*	*	0.18
EHNR Big Flatty Creek	MWT obs	46-56		2.5	1110	Surficial					43 pump	
	p	90-100	123	4	1110	Yorktown					150 pump	3.54
	obs	90-100		4	1110	Yorktown	2352.37	98	0.0005	0.000148	150 pump	
	obs	579-622		4	1110	C. Hayne					175 pump	
EHNR Halls Creek Res. Station	MWT p	60-70	60	4	300	Yorktown					35 pump	16.71
	obs	60-70		2.5	300	Yorktown	2038.8	30	*	0.00026	20 pump	
EHNR Okiska Res. Station	MWT obs	76-86		2.5	360	Yorktown	501.67	4.25	*	0.00024	8 pump	
EHNR NC Forestry Hdqtrs.	MWT obs	120-130		4	240	Yorktown	79.13	1.41	0.02	0.00015	20 pump	
	p	120-130	30	4	178	Yorktown					30 pump	0.75
EHNR Como Res. Station	MWT p	250-260	41.6	4	2000	U.Cape Fear	922.43				31 pump	6.92
	obs	250-260		2.5	2000	U.Cape Fear					*	
	obs	490-500		2.5	2400	L.Cape Fear					10 pump	
	obs	560-570		4	2400	L.Cape Fear					15 pump	
EHNR Morgans Corner Res. Sta.	MWT obs	27-37	17.15	2.5	240	Surficial	2487	124.3		0.000054	30 air lift	
Town of Elizabeth City RO Test												
		232-252	8		465	Yorktown						0.12
		459-484	52.9		1442	C. Hayne						3.3
		582-613	33.7		1440	Beaufort						0.5
		696-757	43.5		480	U.Cape F.						1.5
Elizabeth City Well Field												
Well No. 1		65-105	405	6	1276	Yorktown					626 pump	30
Well No. 2		57-87	168	10	2677	Yorktown					264 pump	8
Well No. 3		94-120	450	18	1396	Yorktown					654 pump	16
Well No. 4		94-120	350	14	4314	Yorktown					503 pump	10
Well No. 5		68-78	36	12	1352	Yorktown					140 pump	2.9
Well No. 6		77-87	30	12	1607	Yorktown					50 pump	1.6
Well No. 7		56-66	136	12	1313	Yorktown					140 pump	3.2
South Camden Water and Sewer	SWT	675-95		6	180	C. Hayne						1.96

Table A-1 continued

Well or Research Station	Single Well or Multi Well Test	Screened Interval	Pumping Rate (Q)	Well Diam.	Test Duration	Aquifer	T	K	K'	S	Yield	Specific Capacity
		(in feet)	gpm	(in inches)	(in minutes)		ft2/day	ft/day	ft/day		gpm	gpm/ft
Lloyd, 1968, Ground Water												
Resources of Chowan County						C. Hayne	4010	100		0.0001		
Average Values Based on 22						Beaufort	1604	29		0.0001		
Aquifer Tests												
Jacobs Distance Drawdown	MWT		45 MGD			L. Cape Fea	22,386	56		0.00319		
Analysis of EHNR Sunbury,												
Parkville, and Como Res.												
in response to pumping from												
Union Camp Corp. and vicinity												
Hantush Jacobs Time	MWT	880-890	45 MGD	2.5	10,000 days	L.Cape Fear	19,130	48		0.0025		
Drawdown Analysis of EHNR-												
Sunbury R.S. in response to												
pumping from Union Camp												
Corp. and vicinity												

TABLE A-2: WELL DATA-FRAMEWORK WELLS

State	NC		**County**	Gates	
Well Name	DWR Gates County Prison Test				
Well Depth	1080'	**Well No.**		**Top Basement**	nd
Land Surface Elev.	36'			**Latitude**	36.434444
				Longitude	76.728889

Top Yrktwn CU	+18'	**Top Beaufort Aquifer**	-172'
Top Yrktown Aq.	+12'	**Top Upper Cape Fear CU**	-304'
Top C. Hayne CU	-93'	**Top Upper Cape Fear Aq.**	-348'
Top C. Hayne Aq.	-124'	**Top Lower Cape Fear CU**	-531'
Top Beaufort CU	-154'	**Top Lower Cape Fear Aq.**	-562'

State	NC		**County**	Gates	
Well Name	NCDENR Sunbury Research Station				
Well Depth	953'	**Well No.**	C15s4	**Top Basement**	nd
Land Surface Elev.	37'			**Latitude**	36.446293
				Longitude	76.603281

Top Yrktwn CU	+13'	**Top Beaufort Aquifer**	-251'
Top Yrktown Aq.	+3'	**Top Upper Cape Fear CU**	-339'
Top C. Hayne CU	-201'	**Top Upper Cape Fear Aq.**	-386'
Top C. Hayne Aq.	-207'	**Top Lower Cape Fear CU**	-661'
Top Beaufort CU	-227'	**Top Lower Cape Fear Aq.**	-688'

State	NC		**County**	Gates	
Well Name	S.E. Cullinan Weyerhauser				
Well Depth	2140'	**Well No.**	1	**Top Basement**	-2088'
Land Surface Elev.	15'			**Latitude**	36.436111
				Longitude	76.501389

Top Yrktwn CU	nd	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	-427'
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	-449'
Top C. Hayne Aq.	nd	**Top Lower Cape Fear CU**	-770'
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	-809'

nd = no data

State	NC	**County**	Gates
Well Name	Kittrell Farm		
Well Depth	417'	**Well No.**	
Top Basement	nd		
Land Surface Elev.	42'		
Latitude	36.515833	**Longitude**	76.596111
Top Yrktwn CU	nd	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	-207'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Hertford
Well Name	NCDENR Como Research Station		
Well Depth	818'	**Well No.**	B20u6
Top Basement	-752'		
Land Surface Elev.	69'		
Latitude	36.507222	**Longitude**	77.005833
Top Yrktwn CU	missing	**Top Beaufort Aquifer**	-9'
Top Yrktown Aq.		**Top Upper Cape Fear CU**	-38'
Top C. Hayne CU	missing	**Top Upper Cape Fear Aq.**	-85'
Top C. Hayne Aq.	missing	**Top Lower Cape Fear CU**	-275'
Top Beaufort CU	+9'	**Top Lower Cape Fear Aq.**	-339'

State	NC	**County**	Hertford
Well Name	NCDENR Tunis Research Station		
Well Depth	940'	**Well No.**	D18m3
Top Basement	-902'		
Land Surface Elev.	38'		
Latitude	36.380000	**Longitude**	76.890833
Top Yrktwn CU	missing	**Top Beaufort Aquifer**	-62'
Top Yrktown Aq.	missing	**Top Upper Cape Fear CU**	-114'
Top C. Hayne CU	missing	**Top Upper Cape Fear Aq.**	-170'
Top C. Hayne Aq.	missing	**Top Lower Cape Fear CU**	-270'
Top Beaufort CU	-50'	**Top Lower Cape Fear Aq.**	-302'

nd = no data

State	NC	**County**	Bertie
Well Name	NCDENR Cremo Research Station		
Well Depth	1192'	**Well No.** G19b3	**Top Basement** -1033'
Land Surface Elev.	65'	**Latitude** 36.164722	**Longitude** 76.937500

Top Yrktwn CU	+37'	**Top Beaufort Aquifer**	-71'
Top Yrktown Aq.	+1'	**Top Upper Cape Fear CU**	-109'
Top C. Hayne CU	missing	**Top Upper Cape Fear Aq.**	-145'
Top C. Hayne Aq.	missing	**Top Lower Cape Fear CU**	-363'
Top Beaufort CU	-55'	**Top Lower Cape Fear Aq.**	-451'

State	NC	**County**	Chowan
Well Name	USGS Glidden Test		
Well Depth	940'	**Well No.**	**Top Basement** nd
Land Surface Elev.	36'	**Latitude** 36.317222	**Longitude** 76.609444

Top Yrktwn CU	+22'	**Top Beaufort Aquifer**	-267'
Top Yrktown Aq.	+2'	**Top Upper Cape Fear CU**	-323'
Top C. Hayne CU	-109'	**Top Upper Cape Fear Aq.**	-347'
Top C. Hayne Aq.	-194'	**Top Lower Cape Fear CU**	-747'
Top Beaufort CU	-230'	**Top Lower Cape Fear Aq.**	-800'

State	NC	**County**	Chowan
Well Name	USGS Valhalla Test		
Well Depth	528'	**Well No.**	**Top Basement** nd
Land Surface Elev.	39'	**Latitude** 36.143333	**Longitude** 76.656667

Top Yrktwn CU	+4'	**Top Beaufort Aquifer**	-255'
Top Yrktown Aq.	-13'	**Top Upper Cape Fear CU**	-319'
Top C. Hayne CU	-133'	**Top Upper Cape Fear Aq.**	-357'
Top C. Hayne Aq.	-163'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-214'	**Top Lower Cape Fear Aq.**	nd

nd = no data

State	NC	**County**	Chowan
Well Name	USGS Edenton Airport Test		
Well Depth	857'	**Well No.**	
Top Basement	nd		
Land Surface Elev.	8'		
Latitude	36.016667	**Longitude**	76.577222

Top Yrktwn CU	-34'	**Top Beaufort Aquifer**	missing
Top Yrktown Aq.	-44'	**Top Upper Cape Fear CU**	-424'
Top C. Hayne CU	-146'	**Top Upper Cape Fear Aq.**	-544'
Top C. Hayne Aq.	-207'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	missing	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Perquimans
Well Name	DEHNR Parkville Research Station		
Well Depth	1210'	**Well No.**	E13m2
Top Basement	nd		
Land Surface Elev.	18'		
Latitude	36.295645	**Longitude**	76.463015

Top Yrktwn CU	+8'	**Top Beaufort Aquifer**	-380'
Top Yrktown Aq.	+1'	**Top Upper Cape Fear CU**	-439'
Top C. Hayne CU	-246'	**Top Upper Cape Fear Aq.**	-469'
Top C. Hayne Aq.	-302'	**Top Lower Cape Fear CU**	-928'
Top Beaufort CU	-349'	**Top Lower Cape Fear Aq.**	-976'

State	NC	**County**	Perquimans
Well Name	DWR Perquimans Test		
Well Depth	1143'	**Well No.**	
Top Basement	nd		
Land Surface Elev.	13'		
Latitude	36.169167	**Longitude**	76.451667

Top Yrktwn CU	-19'	**Top Beaufort Aquifer**	-423'
Top Yrktown Aq.	-26'	**Top Upper Cape Fear CU**	-470'
Top C. Hayne CU	-239'	**Top Upper Cape Fear Aq.**	-497'
Top C. Hayne Aq.	-312'	**Top Lower Cape Fear CU**	-679'
Top Beaufort CU	-385'	**Top Lower Cape Fear Aq.**	-694'

nd = no data

State	NC	**County**	Pasquotank
Well Name	USGS PA-T1-62		
Well Depth	700'	**Well No.**	**Top Basement** nd
Land Surface Elev.	14'	**Latitude**	36.437499
		Longitude	76.412498
Top Yrktwn CU	-4 '	**Top Beaufort Aquifer**	-412'
Top Yrktown Aq.	-14'	**Top Upper Cape Fear CU**	-480'
Top C. Hayne CU	-286'	**Top Upper Cape Fear Aq.**	-556'
Top C. Hayne Aq.	-339'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-372'	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	USGS PA-T2-62		
Well Depth	704'	**Well No.**	**Top Basement** nd
Land Surface Elev.	3'	**Latitude**	36.191665
		Longitude	76.233335
Top Yrktwn CU	-69'	**Top Beaufort Aquifer**	-620'
Top Yrktown Aq.	-88'	**Top Upper Cape Fear CU**	-661'
Top C. Hayne CU	-389'	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	-461'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-579'	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	NCDENR Morgans Corner Research Station		
Well Depth	1530'	**Well No.** C12r3	**Top Basement** nd
Land Surface Elev.	10'	**Latitude**	36.431549
		Longitude	76.375628
Top Yrktwn CU	-5'	**Top Beaufort Aquifer**	-448'
Top Yrktown Aq.	-15'	**Top Upper Cape Fear CU**	-570'
Top C. Hayne CU	-292'	**Top Upper Cape Fear Aq.**	-628'
Top C. Hayne Aq.	-363'	**Top Lower Cape Fear CU**	-714'
Top Beaufort CU	-412'	**Top Lower Cape Fear Aq.**	-755'

nd = no data

State	NC	**County**	Pasquotank
Well Name	NCDENR Forest Service Research Station		
Well Depth	500'	**Well No.** D11v5	**Top Basement** nd
Land Surface Elev.	7'	**Latitude**	36.347527
		Longitude	76.277474
Top Yrktwn CU	-21'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-41'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	-379'	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	-437'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	Elizabeth City RO Test		
Well Depth	898'	**Well No.**	**Top Basement** nd
Land Surface Elev.	5'	**Latitude**	36.306944
		Longitude	76.271667
Top Yrktwn CU	nd	**Top Beaufort Aquifer**	-573'
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	-619
Top C. Hayne CU	-417'	**Top Upper Cape Fear Aq.**	-676'
Top C. Hayne Aq.	-441'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-537'	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	Cullinan, Waldorf		
Well Depth	2714'	**Well No.** 1	**Top Basement** -2605
Land Surface Elev.	15'	**Latitude**	36.333333
		Longitude	76.366667
Top Yrktwn CU	nd	**Top Beaufort Aquifer**	-475'
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	-524'
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	-577'
Top C. Hayne Aq.	nd	**Top Lower Cape Fear CU**	-1209
Top Beaufort CU	-449'	**Top Lower Cape Fear Aq.**	-1271'

nd = no data

State	NC	**County**	Pasquotank
Well Name	NCDENR Okiska Research Station		
Well Depth	200'	**Well No.**	E11q5
Top Basement	nd		
Land Surface Elev.	11'		
Latitude	36.268972	**Longitude**	76.316238
Top Yrktwn CU	-13'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-19'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	nd	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	NCDENR Halls Creek Research Station		
Well Depth	199'	**Well No.**	F11i3
Top Basement	nd		
Land Surface Elev.	4'		
Latitude	36.219541	**Longitude**	76.276379
Top Yrktwn CU	-20'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-48'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	nd	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	NCDENR Weeksville Research Station		
Well Depth	221'	**Well No.**	F10k4
Top Basement	nd		
Land Surface Elev.	4'		
Latitude	36.205757	**Longitude**	76.166895
Top Yrktwn CU	-52'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-60'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	nd	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

nd = no data

State	NC	**County**	Pasquotank
Well Name	NCDENR Big Flatty Creek Research Station		
Well Depth	731'	**Well No.** G9c4	**Top Basement** nd
Land Surface Elev.	3'	**Latitude** 36.150033	**Longitude** 76.132485
Top Yrktwn CU	-97'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-120'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	-473'	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	-545'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-701'	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Pasquotank
Well Name	NCDENR Eliz. City CG Research Station		
Well Depth	200'	**Well No.** F10a3	**Top Basement** nd
Land Surface Elev.	10'	**Latitude** 36.250825	**Longitude** 76.177299
Top Yrktwn CU	-11'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-26'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	nd	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Camden
Well Name	Sydnor Hydrodynamics Sawyer Aquafarm Test		
Well Depth	1014'	**Well No.** 2	**Top Basement** nd
Land Surface Elev.	3'	**Latitude** 36.451389	**Longitude** 76.312500
Top Yrktwn CU	-7'	**Top Beaufort Aquifer**	-501'
Top Yrktown Aq.	-25'	**Top Upper Cape Fear CU**	-595'
Top C. Hayne CU	-277'	**Top Upper Cape Fear Aq.**	-657'
Top C. Hayne Aq.	-425'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-477'	**Top Lower Cape Fear Aq.**	nd

nd = no data

State	NC	**County**	Camden
Well Name	Blair Oil Company, Weyerhaueser		
Well Depth	3742'	**Well No.** 1	**Top Basement** -2814'
Land Surface Elev.	8'	**Latitude** 36.411111	**Longitude** 76.175000

Top Yrktwn CU	nd	**Top Beaufort Aquifer**	-646'
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	-817'
Top C. Hayne CU	-410'	**Top Upper Cape Fear Aq.**	-862'
Top C. Hayne Aq.	-544'	**Top Lower Cape Fear CU**	-1104'
Top Beaufort CU	-624'	**Top Lower Cape Fear Aq.**	-1327'

State	NC	**County**	Camden
Well Name	South Camden Water and Sewer District		
Well Depth	712'	**Well No.**	**Top Basement** nd
Land Surface Elev.	1'	**Latitude** 36.221111	**Longitude** 76.031667

Top Yrktwn CU	-69'	**Top Beaufort Aquifer**	nd
Top Yrktown Aq.	-93'	**Top Upper Cape Fear CU**	nd
Top C. Hayne CU	-575'	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	-657'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	nd	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Currituck
Well Name	Blair Oil Company, Twiford		
Well Depth	4547'	**Well No.** 1	**Top Basement** -4516'
Land Surface Elev.	5'	**Latitude** 36.302778	**Longitude** 75.925000

Top Yrktwn CU	nd	**Top Beaufort Aquifer**	-1002'
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	-1058'
Top C. Hayne CU	nd	**Top Upper Cape Fear Aq.**	-1222'
Top C. Hayne Aq.	-763'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-965'	**Top Lower Cape Fear Aq.**	nd

nd = no data

State	NC	**County**	Currituck
Well Name	NCDENR Maple Prison Research Station		
Well Depth	1502'	**Well No.**	D8i6
Top Basement	nd		
Land Surface Elev.	13'		

Latitude	36.404167
Longitude	76.021667

Top Yrktwn CU	-35'	**Top Beaufort Aquifer**	-821'
Top Yrktown Aq.	-110'	**Top Upper Cape Fear CU**	-977'
Top C. Hayne CU	-608'	**Top Upper Cape Fear Aq.**	-1045'
Top C. Hayne Aq.	-676'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-803'	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Currituck
Well Name	DWR Moyock Test		
Well Depth	1201'	**Well No.**	
Top Basement	nd		
Land Surface Elev.	15'		

Latitude	36.523611
Longitude	76.206944

Top Yrktwn CU	-152'	**Top Beaufort Aquifer**	-585'
Top Yrktown Aq.	-173'	**Top Upper Cape Fear CU**	-643'
Top C. Hayne CU	-491'	**Top Upper Cape Fear Aq.**	-715'
Top C. Hayne Aq.	-509'	**Top Lower Cape Fear CU**	-1014'
Top Beaufort CU	-562'	**Top Lower Cape Fear Aq.**	-1052'

State	NC	**County**	Currituck
Well Name	Rapp Oil Company, Kellog		
Well Depth	5140'	**Well No.**	1
Top Basement	-5055'		
Land Surface Elev.	10'		

Latitude	36.117222
Longitude	75.852778

Top Yrktwn CU	nd	**Top Beaufort Aquifer**	-1160'
Top Yrktown Aq.	nd	**Top Upper Cape Fear CU**	-1310'
Top C. Hayne CU	-660'	**Top Upper Cape Fear Aq.**	-1500'
Top C. Hayne Aq.	-830'	**Top Lower Cape Fear CU**	-2165'
Top Beaufort CU	-1060'	**Top Lower Cape Fear Aq.**	-2325'

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nd = no data

State	NC	**County**	Curritcuk
Well Name	Currituck Co. Sanderling Beach Test		
Well Depth	1500'	**Well No.**	
Top Basement	nd		
Land Surface Elev.	10'		
Latitude	36.3000000	**Longitude**	75.811388
Top Yrktwn CU	-53'	**Top Beaufort Aquifer**	-1322'
Top Yrktown Aq.	-85'	**Top Upper Cape Fear CU**	-1450'
Top C. Hayne CU	-794'	**Top Upper Cape Fear Aq.**	nd
Top C. Hayne Aq.	-870'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-1120'	**Top Lower Cape Fear Aq.**	nd

State	NC	**County**	Washington
Well Name	NCDENR Scuppernong Research Station		
Well Depth	1312'	**Well No.**	
Top Basement	nd		
Land Surface Elev.	12'		
Latitude	35.916389	**Longitude**	76.470556
Top Yrktwn CU	-26'	**Top Beaufort Aquifer**	-494'
Top Yrktown Aq.	-50'	**Top Upper Cape Fear CU**	-594'
Top C. Hayne CU	-258'	**Top Upper Cape Fear Aq.**	-767
Top C. Hayne Aq.	-290'	**Top Lower Cape Fear CU**	-990'
Top Beaufort CU	-452'	**Top Lower Cape Fear Aq.**	-1008'

State	VA	**County**	Isle of Wight
Well Name	Union Camp		
Well Depth	710'	**Well No.**	55B63
Top Basement	nd		
Land Surface Elev.	30'		
Latitude	36.689167	**Longitude**	76.914167
Top Yrktwn CU	missing	**Top Beaufort Aquifer**	-62'
Top Yrktown Aq.		**Top Upper Cape Fear CU**	missing
Top C. Hayne CU	missing	**Top Upper Cape Fear Aq.**	missing
Top C. Hayne Aq.	missing	**Top Lower Cape Fear CU**	-150'
Top Beaufort CU	-46'	**Top Lower Cape Fear Aq.**	-240'

nd = no data

State	VA	**County**	Cty of Suffolk
Well Name	Forest Glow School		
Well Depth	693'	**Well No.** 57B6	**Top Basement** nd
Land Surface Elev.	55'	**Latitude**	36.713333
		Longitude	76.653611
Top Yrktwn CU	+43'	**Top Beaufort Aquifer**	-236'
Top Yrktown Aq.	+31'	**Top Upper Cape Fear CU**	missing
Top C. Hayne CU	-114'	**Top Upper Cape Fear Aq.**	missing
Top C. Hayne Aq.	-155'	**Top Lower Cape Fear CU**	-267'
Top Beaufort CU	-205'	**Top Lower Cape Fear Aq.**	-297'

State	VA	**County**	Cty of Suffolk
Well Name	VA Dept. of Highways		
Well Depth	620'	**Well No.** 57A1	**Top Basement** nd
Land Surface Elev.	70'	**Latitude**	36.602222
		Longitude	76.668661
Top Yrktwn CU	+28'	**Top Beaufort Aquifer**	-170'
Top Yrktown Aq.	+2'	**Top Upper Cape Fear CU**	-251'
Top C. Hayne CU	-90'	**Top Upper Cape Fear Aq.**	-272'
Top C. Hayne Aq.	-114'	**Top Lower Cape Fear CU**	-290'
Top Beaufort CU	-156'	**Top Lower Cape Fear Aq.**	-320'

State	VA	**County**	Cty of Suffolk
Well Name	VDEQ Sommerton Swamp Research Sta.		
Well Depth	1200'	**Well No.** 56A10	**Top Basement** nd
Land Surface Elev.	45'	**Latitude**	36.562500
		Longitude	76.783889
Top Yrktwn CU	+25'	**Top Beaufort Aquifer**	-135'
Top Yrktown Aq.	+5'	**Top Upper Cape Fear CU**	-185'
Top C. Hayne CU	-43'	**Top Upper Cape Fear Aq.**	-224'
Top C. Hayne Aq.	-71'	**Top Lower Cape Fear CU**	-303'
Top Beaufort CU	-122'	**Top Lower Cape Fear Aq.**	-383'

nd = no data

State	VA	**County**	Cty of Suffolk
Well Name	Virginia Dept. of Water Resources		
Well Depth	2017'	**Well No.** 58A2	**Top Basement** nd
Land Surface Elev.	60'	**Latitude** 36.569444	**Longitude** 76.584722

Top Yrktwn CU	+40'	**Top Beaufort Aquifer**	-278'
Top Yrktown Aq.	+30'	**Top Upper Cape Fear CU**	-361'
Top C. Hayne CU	-184'	**Top Upper Cape Fear Aq.**	-414'
Top C. Hayne Aq.	-218'	**Top Lower Cape Fear CU**	-470'
Top Beaufort CU	-264'	**Top Lower Cape Fear Aq.**	-506'

State	VA	**County**	Cty of Suffolk
Well Name	VDEQ State Line Research Station		
Well Depth	782'	**Well No.** 58A75	**Top Basement** nd
Land Surface Elev.	40'	**Latitude** 36.550833	**Longitude** 76.550556

Top Yrktwn CU	+10'	**Top Beaufort Aquifer**	-307'
Top Yrktown Aq.	-2'	**Top Upper Cape Fear CU**	-412'
Top C. Hayne CU	-202'	**Top Upper Cape Fear Aq.**	-465'
Top C. Hayne Aq.	-254'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-298'	**Top Lower Cape Fear Aq.**	nd

State	VA	**County**	Cty of Suffolk
Well Name	VDEQ Dismal Swamp Research Station		
Well Depth	1862'	**Well No.** 58A76	**Top Basement** -1853'
Land Surface Elev.	33'	**Latitude** 36.615278	**Longitude** 76.555556

Top Yrktwn CU	-67'	**Top Beaufort Aquifer**	-289'
Top Yrktown Aq.	-113'	**Top Upper Cape Fear CU**	-359
Top C. Hayne CU	-189'	**Top Upper Cape Fear Aq.**	-393'
Top C. Hayne Aq.	-251'	**Top Lower Cape Fear CU**	-437'
Top Beaufort CU	-281'	**Top Lower Cape Fear Aq.**	-489'

---

nd = no data

State	VA	**County**	Cty of Chesapeake
Well Name	VDEQ		
Well Depth	701'	**Well No.** 61A2	**Top Basement** nd
Land Surface Elev.	10'		

Latitude	36.580000
Longitude	76.203333

Top Yrktwn CU	-194'	**Top Beaufort Aquifer**	-590'
Top Yrktown Aq.	-222'	**Top Upper Cape Fear CU**	-644'
Top C. Hayne CU	-486'	**Top Upper Cape Fear Aq.**	-675'
Top C. Hayne Aq.	-536'	**Top Lower Cape Fear CU**	nd
Top Beaufort CU	-580'	**Top Lower Cape Fear Aq.**	nd

nd = no data

Table A-3: Division of Water Resources-Gates County Prison Test
Lab Analysis Data

Collection date	12/14/94	12/14/94	12/08/94	11/21/94	11/02/94	10/27/94	11/18/94
Sampling Method	Sub Pump	Sub Pump	Sub Pump	Sub Pump	Sub Pump	Sub Pump	Sub Pump
Screened Interval	40-50	211-221	290-300	642-652	732-742	869-879	992-1002
Lab Analysis							
pH	8.2	8.1	8.9	8.6	8.5	8.3	8.4
Alkalinity pH4.5*	38	440	430	780	520	500	540
Alkalinity pH8.3*	<1	<1			<1	<1	
Carbonate*	<1	29	31	<1	12	<1	31
Bicarbonate*	46	480	470	910	620	610	600
Chloride*	8	16	54	250	230	440	1700
Diss. Solids*	100	680	550	1200	1200	1600	3600
Flouride*	0.1	2.8	3.3	1.1	1.6	1.1	0.1
Hardness: total*	33	14	<1	20	24	30	130
Hardness: noncarb*	<1	<1	<1	<1	<1	<1	<1
Specific Cond.	140uMhos	910uMhos	1300uMhos	2000uMhos	2000uMhos	3400uMhos	6100uMhos
Sulfate*	<5	7	37	26	46	56	200
NH as N*	0.25	0.75	0.075	0.41	0.44	0.37	0.63
TKN as N*	0.3	0.9	0.8	0.5	0.6	0.4	0.7
NO + NO as N*	<0.01	0.01	0.01	0.01	<.01	0.04	0.01
P: Total as P*	0.16	0.05	0.18	0.07	0.14	0.12	0.08
Al+	<100	<100	<100	<100	<100	<100	<100
Ca*	4.5	3.4	2.2	4.1	3.4	4.5	22
Cu+	7.7	13	5	<2	<2	<2	2.7
Fe+	10000	10000	<100	<100	570	1500	5300
K*	<.5	<.5	12	14	17	20	40
Mg*	2.2	2.2	1.3	1.9	2.1	3.1	14
Mn+	140	140	<20	<20	27	36	150
Na*	12	12	270	430	170	250	1200
Pb+	<10	<10	<10	<10	<10	<10	<10
Zn+	84	84	<20	32	74	160	1100

* ppm
+ppb

Table A-4: Division of Water Resources-Perquimons Test
Lab Analysis Data

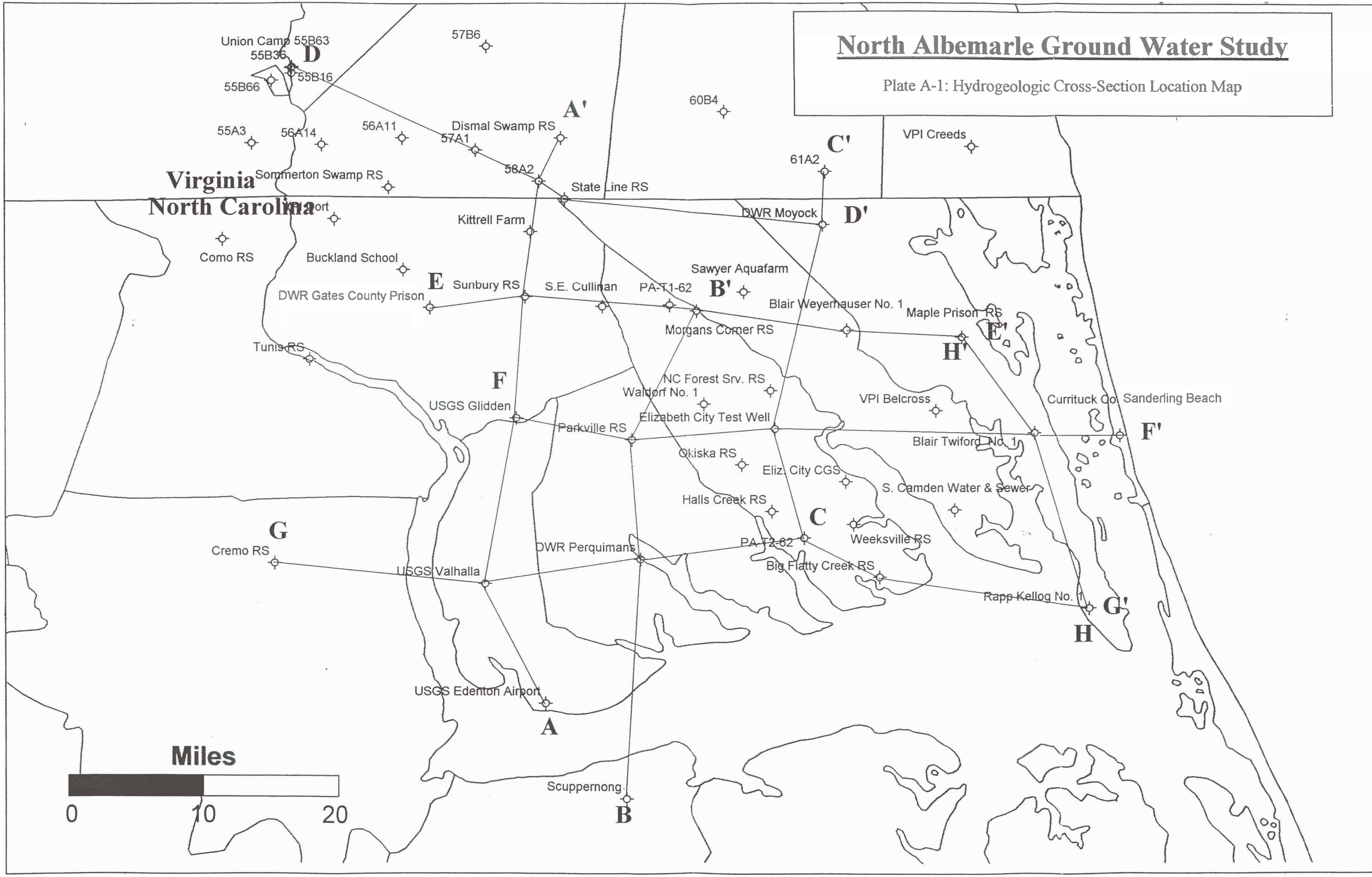
Sampling Method: Sub Pump						
Screened Interval	995' - 1005'	796' - 806'	739' - 749'	330' - 340'	102' - 112'	45' - 55'
Yield (air lift, gpm)	7.8 gpm	4.05 gpm	4.1 gpm	25 gpm		20 gpm
Lab Analysis						
pH	8.0	8.2	8	8	7.6	6.5
Alkalinity to pH4.5*	470	440	460	450	160	80
Alkalinity to pH8.3*	< 1	<1	<1	<1	<1	< 1
Carbonate*	<1	<1	<1	<1	<1	< 1
Bicarbonate*	580	540	560	550	190	98
Chloride*	3000	3100	3100	3200	15	15
Diss. Solids*	5900	5300	5400	6500	200	120
Flouride*	0.4	0.4	0.5	1.3	0.1	0.1
Hardness: total*	250	220	290	590	170	71
Hardness: noncarb*	<1		<1	140	10	< 1
Specific Cond.	9900 uMhos	9600 uMhos	10000uMhos	9400 uMhos	400 uMhos	230 uMhos
Sulfate*	300	170	330	380	<5	< 5
NH3 as N*	1.3	1.5	1.7	3.9	0.15	0.16
TKN as N*	1.1	1.6	1.7		0.2	0.5
NO2 + NO3 as N*	<0.01	< 0.01	0.08	<0.01	<0.01	< 0.01
P: Total as P*	0.02	0.03	0.04	0.02	0.16	0.21
Al+	< 50	< 50	110	160	170	< 50
Ca*	33	44	49	not tested	58	22
Cu+	< 2.0	6.2	9.4	not tested	<2.0	< 2.0
Fe+	4600	8100	6800	2200	1800	6000
K*	54	72	85	70	1.7	1.1
Mg*	30	40	49	65	3.9	3.8
Mn+	110	110	77	27	220	200
Na*	2000	1800	2200	2300	16	10
Pb+	< 10	< 10	<10	<10	<10	< 10
Zn+	570	260	310	120	11	71

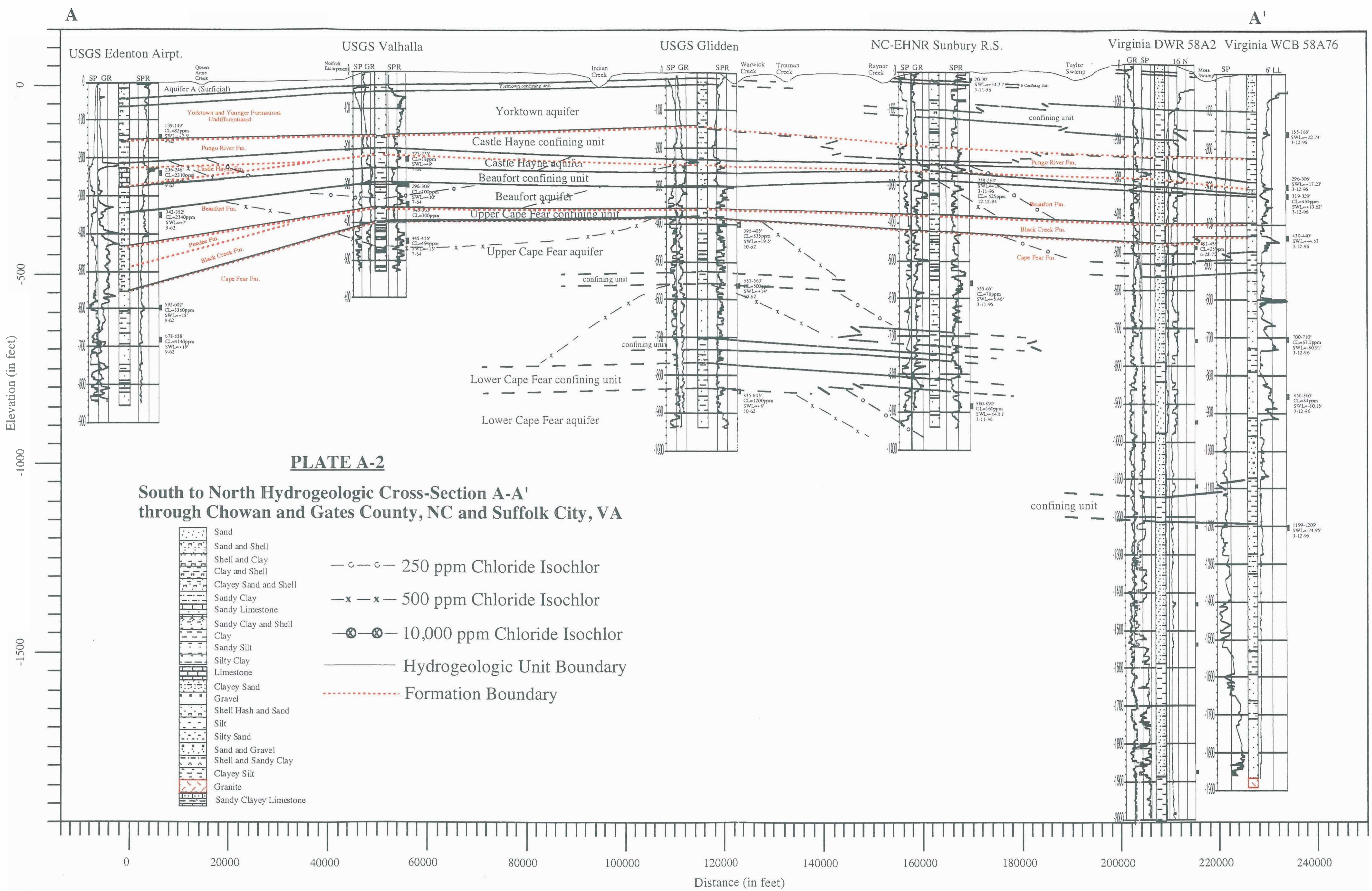
* ppm
+ppb

Table A-5: Division of Water Resources-Moyock Test
Lab Analysis Data

Collect date	05/19/95	05/03/95	05/01/95	04/25/95	04/04/95	03/28/95
Sampling Method	Sub Pump	Sub Pump	Sub Pump	Sub Pump	Sub Pump	Sub Pump
Screened Interval	40-50	100-110	630-640	830-840	885-895	1025-1035
Yield (air lift, gpm)	24	37.5	33	43	33	17
Lab Analysis						
pH	7.8	8	8	8.1	8.6	7.8
Alkalinity pH4.5*	170	700	710	780	800	410
Alkalinity pH8.3*	<1	<1	<1	<1	<1	<1
Carbonate*	<1	<1	<1	<1	29	10
Bicarbonate*	210	850	870	950	920	490
Chloride*	11	21	1500	920	850	2900
Diss. Solids*	180	280	3000	2000	2500	4800
Flouride*	0.2	0.2	1.6	1.6	1.6	0.5
Hardness: total*	170	200	90	48	48	194
Hardness: noncarb*	<1	<1	<1	<1	<1	<1
Specific Cond.	330uMhos	470uMhos	5500uMhos	4200uMhos	4500uMhos	10000uMhos
Sulfate*	<5	<5	41	31	46	6
NH as N*	0.2	0.24	1.7	1.2	1.2	2
TKN as N*	0.3	0.5	1.7	1.4		
NO + NO as N*	<0.01	<0.01	0.02	0.01	<0.01	<0.01
P: Total as P*	0.17	0.13	0.05	0.09	0.08	0.03
Al+	<50	<50	<50	140	<50	<100
Ca*	43	50	12	5.5	6.2	25
Cu+	<2	2.4	6.7	7.3	4.2	8.5
Fe+	210	530	1800	1300	1700	3400
K*	5.8	3.4	41	25	25	100
Mg*	7.4	3.4	12	5.4	5.8	14
Mn+	46	23	15	14	18	44
Na*	8.4	14	1300	740	790	1900
Pb+	<10	<10	<10	<10	<10	<10
Zn+	29	47	42	310	42	410

*ppm
+ppb


North Albemarle Ground Water Study
Plate A-1: Hydrogeologic Cross-Section Location Map
Union Camp 55B63
55B36
D
55B16
55B66
57B6
A'
Dismal Swamp RS
57A1
56A11
55A3
56A14
58A2
Sommerton Swamp RS
Virginia
North Carolina
State Line RS
60B4
61A2
C'
VPI Creeds
DWR Moyock
D'
Kittrell Farm
Como RS
Buckland School
E
Sunbury RS
DWR Gates County Prison
S.E. Cullinan
PA-T1-62
B'
Sawyer Aquafarm
Blair Weyerhauser No. 1
Maple Prison RS
Morgans Corner RS
E'
H'
Tunis RS
F
NC Forest Srv. RS
Waldorf No. 1
USGS Glidden
Elizabeth City Test Well
Parkville RS
VPI Belcross
Currituck Co.
Sanderling Beach
F'
Blair Twiford No. 1
Okiska RS
Eliz. City CGS
S. Camden Water & Sewer
Halls Creek RS
C
G
Cremo RS
DWR Perquimans
PA-T2-62
Weeksville RS
USGS Valhalla
Big Flatty Creek RS
Rapp Kellog No. 1
G'
H
USGS Edenton Airport
A
Miles
0
10
20
Scuppernong
B



A
A'
USGS Edenton Airpt.
USGS Valhalla
USGS Glidden
NC-EHNR Sunbury R.S.
Virginia DWR 58A2
Virginia WCB 58A76
Aquifer A (Surficial)
Yorktown and Younger Formations Undifferentiated
Pungo River Fm.
Castle Hayne Fm.
Beaufort Fm.
Peedee Fm.
Black Creek Fm.
Cape Fear Fm.
Yorktown aquifer
Castle Hayne confining unit
Castle Hayne aquifer
Beaufort confining unit
Beaufort aquifer
Upper Cape Fear confining unit
Upper Cape Fear aquifer
confining unit
Lower Cape Fear confining unit
Lower Cape Fear aquifer
Indian Creek
Warwick Creek
Trotman Creek
Raynor Creek
Taylor Swamp
Queen Anne Creek
Norfolk Escarpment
PLATE A-2
South to North Hydrogeologic Cross-Section A-A'
through Chowan and Gates County, NC and Suffolk City, VA
Sand
Sand and Shell
Shell and Clay
Clay and Shell
Clayey Sand and Shell
Sandy Clay
Sandy Limestone
Sandy Clay and Shell
Clay
Sandy Silt
Silty Clay
Limestone
Clayey Sand
Gravel
Shell Hash and Sand
Silt
Silty Sand
Sand and Gravel
Shell and Sandy Clay
Clayey Silt
Granite
Sandy Clayey Limestone
250 ppm Chloride Isochlor
500 ppm Chloride Isochlor
10,000 ppm Chloride Isochlor
Hydrogeologic Unit Boundary
Formation Boundary
Elevation (in feet)
0
-500
-1000
-1500
Distance (in feet)
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000
220000
240000

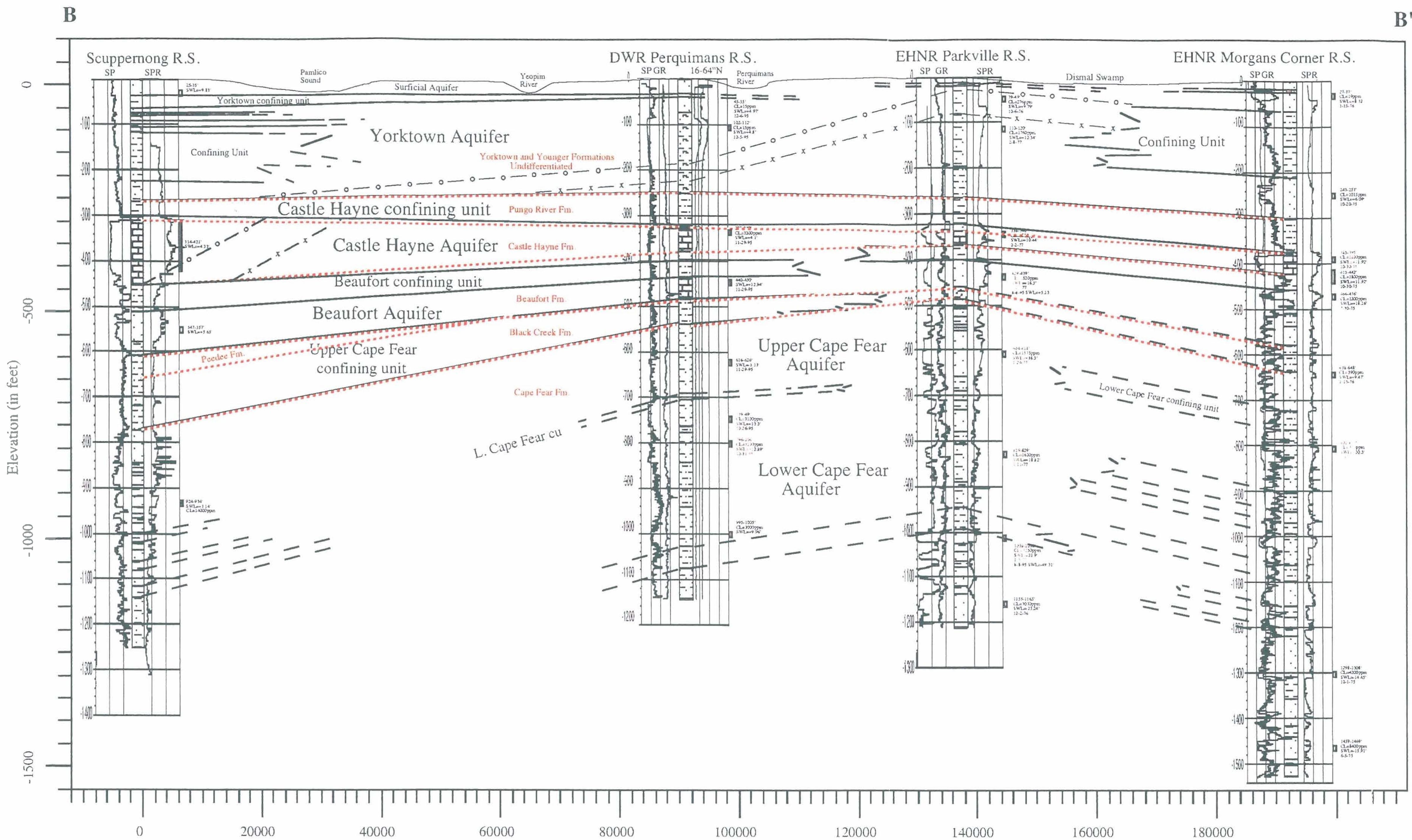


PLATE A-3 **South to North Hydrogeologic Cross-Section B-B' through Chowan, Perquimans, Pasquotank Counties, NC**

- Sand
- Sand and Shell
- Shell and Clay
- Clay and Shell
- Clayey Sand and Shell
- Sandy Clay
- Sandy Limestone
- Sandy Clay and Shell
- Clay
- Sandy Silt
- Silty Clay
- Limestone
- Clayey Sand
- Gravel
- Shell Hash and Sand
- Silt
- Silty Sand
- Sand and Gravel
- Shell and Sandy Clay
- Clayey Silt
- Granite
- Sandy Clayey Limestone

- 250 ppm Chloride Isochlor
- 500 ppm Chloride Isochlor
- 10,000 ppm Chloride Isochlor
- Hydrogeologic Unit Boundary
- Formation Boundary

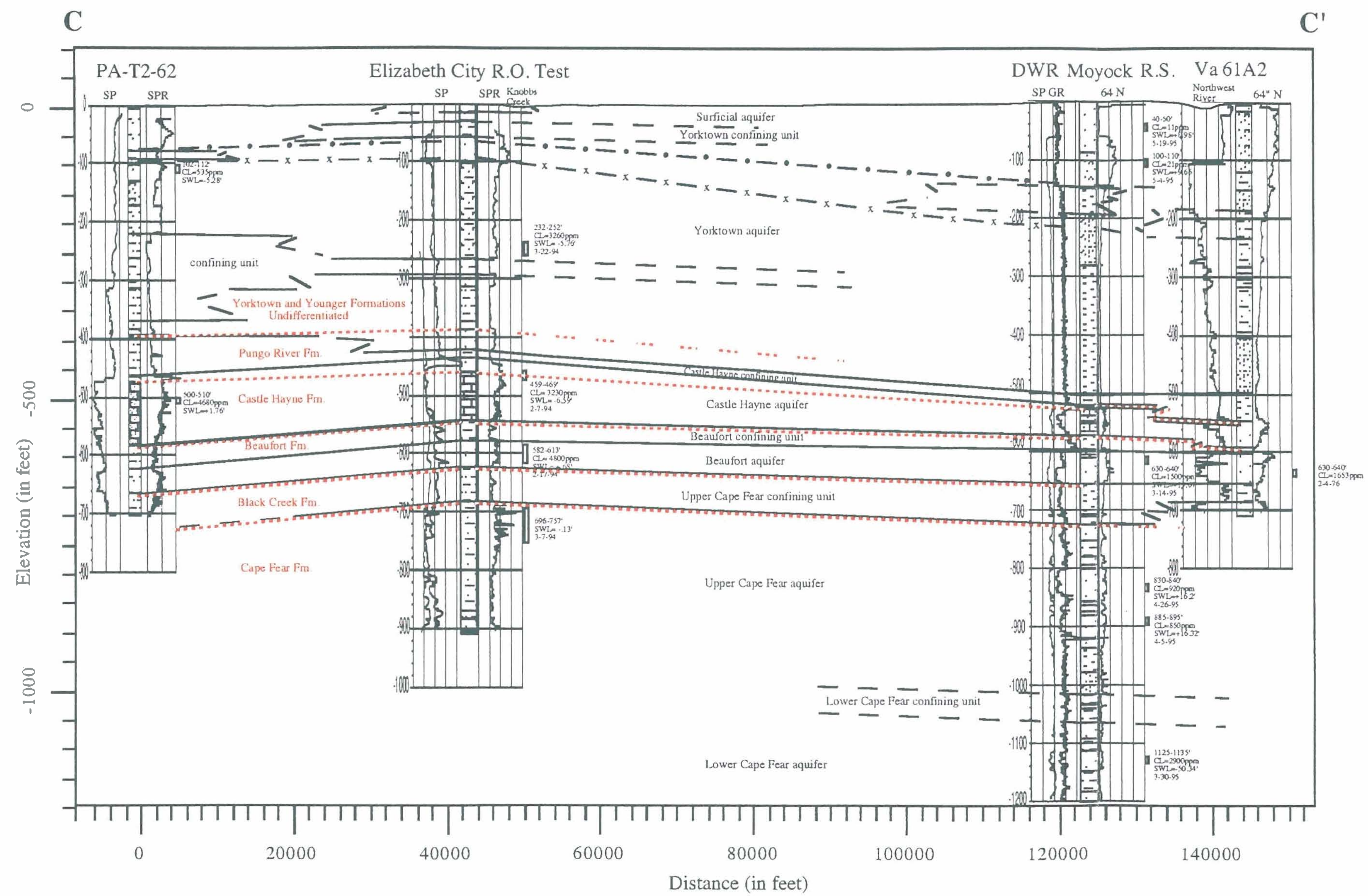
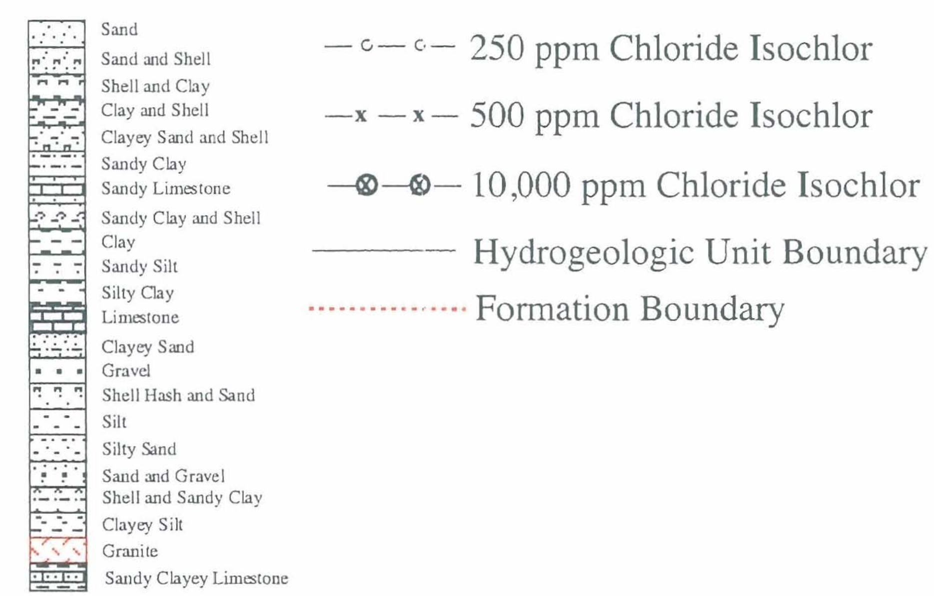


PLATE A-4

South to North Hydrogeologic Cross-Section C-C' through Pasquotank, Camden, and Currituck Counties, NC and Cheaspeake City, VA



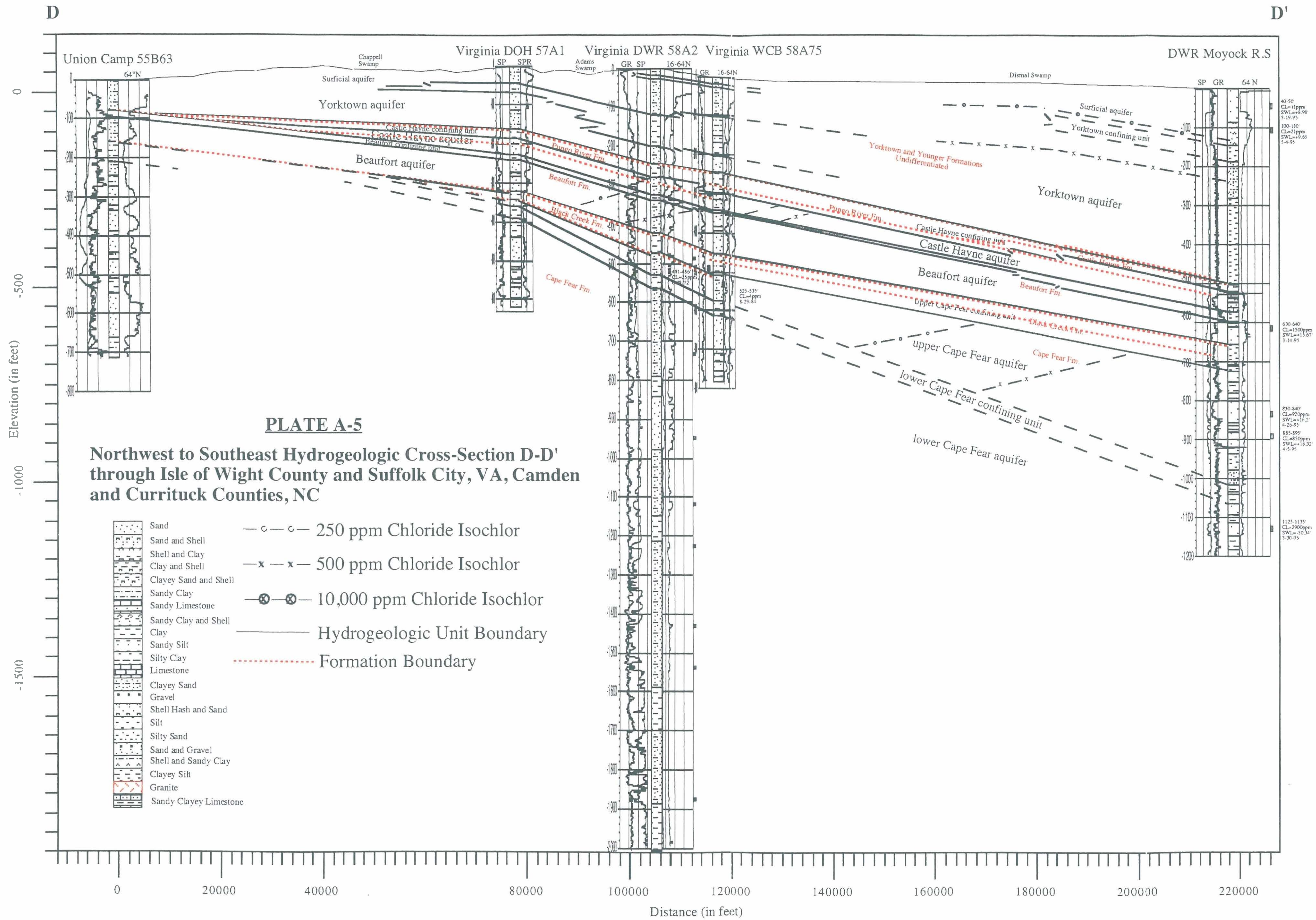
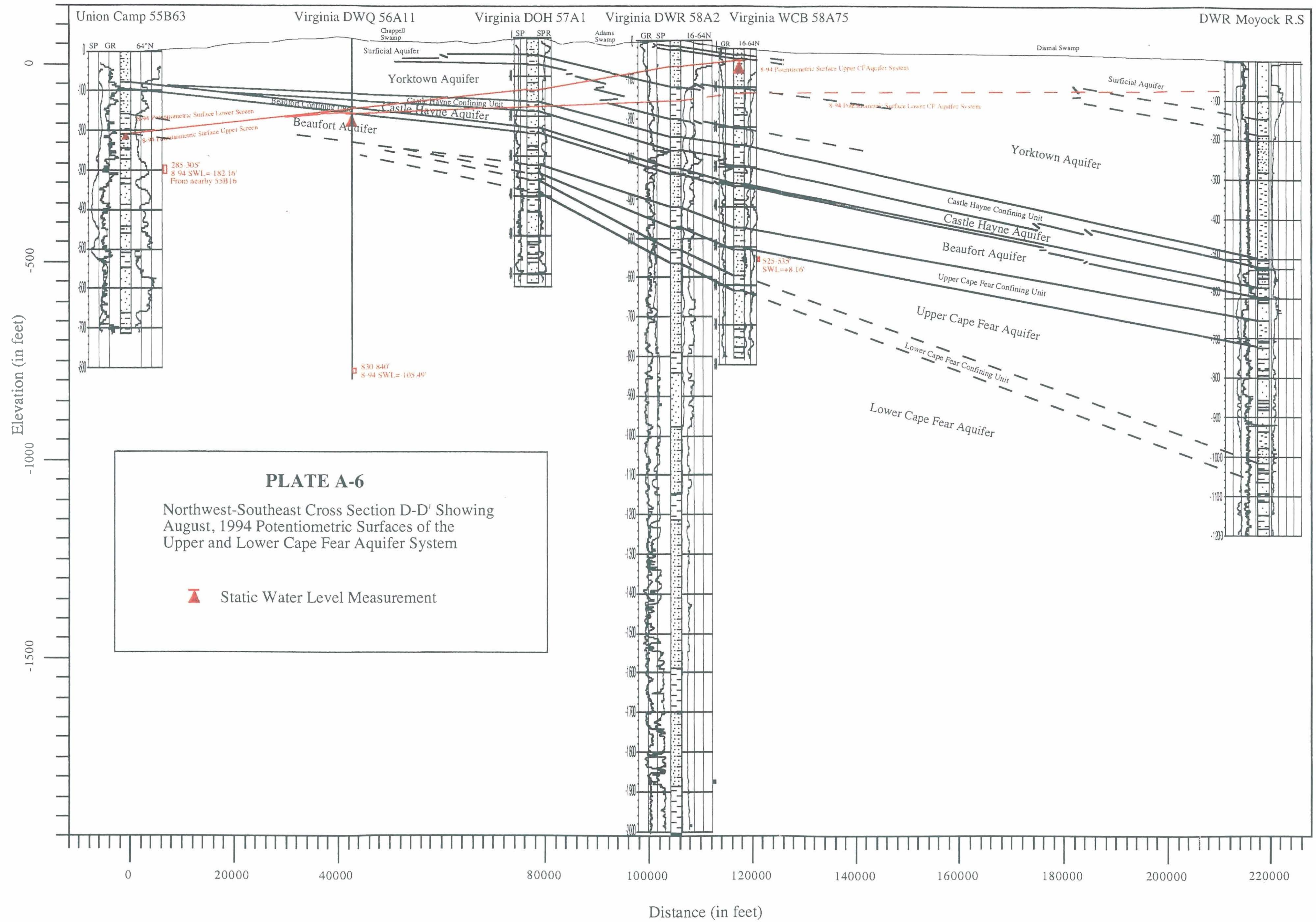


PLATE A-5

Northwest to Southeast Hydrogeologic Cross-Section D-D' through Isle of Wight County and Suffolk City, VA, Camden and Currituck Counties, NC



Union Camp 55B63
Virginia DWQ 56A11
Virginia DOH 57A1
Virginia DWR 58A2
Virginia WCB 58A75
DWR Moyock R.S
Chappell Swamp
Adams Swamp
Dismal Swamp
Surficial Aquifer
Yorktown Aquifer
Castle Hayne Confining Unit
Castle Hayne Aquifer
Beaufort Confining Unit
Beaufort Aquifer
Upper Cape Fear Confining Unit
Upper Cape Fear Aquifer
Lower Cape Fear Confining Unit
Lower Cape Fear Aquifer
285-305'
8-94 SWL= 182.16'
From nearby 55B16
830-840'
8-94 SWL= 105.49'
525-535'
SWL=+8.16'
PLATE A-6
Northwest-Southeast Cross Section D-D' Showing
August, 1994 Potentiometric Surfaces of the
Upper and Lower Cape Fear Aquifer System
Static Water Level Measurement
Elevation (in feet)
0
-500
-1000
-1500
Distance (in feet)
0
20000
40000
80000
100000
120000
140000
160000
180000
200000
220000

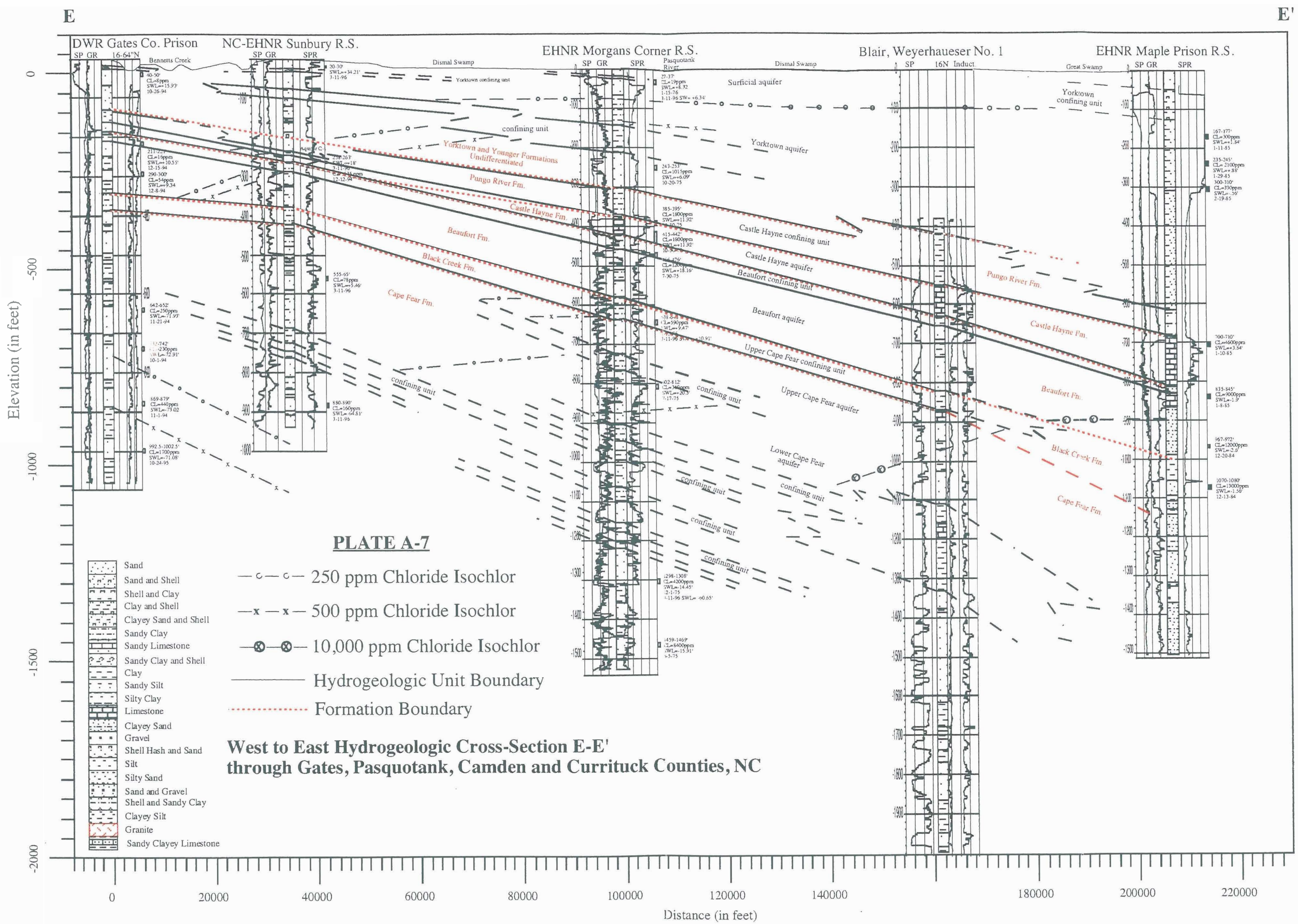


PLATE A-7

West to East Hydrogeologic Cross-Section E-E' through Gates, Pasquotank, Camden and Currituck Counties, NC

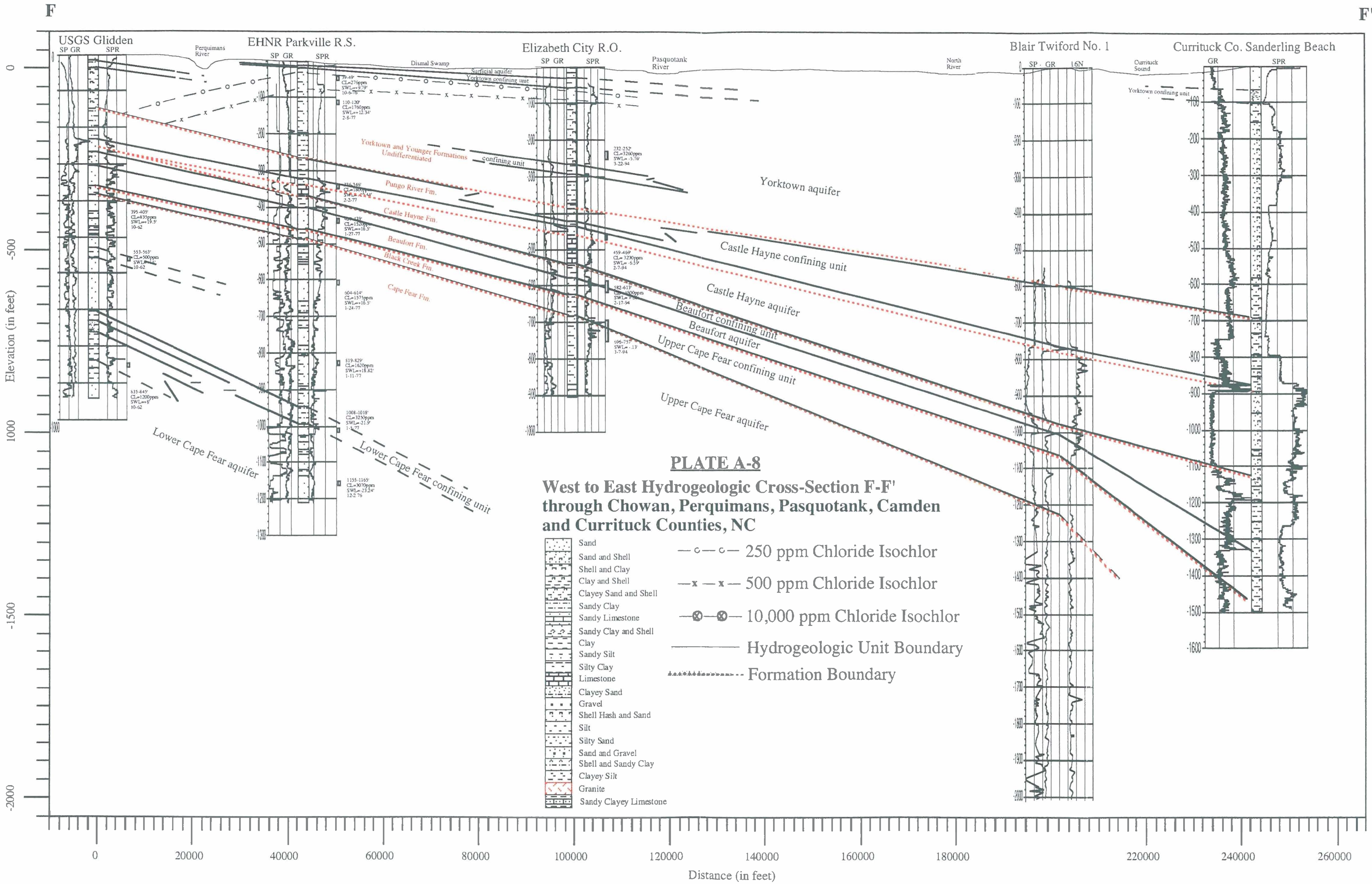


PLATE A-8

West to East Hydrogeologic Cross-Section F-F' through Chowan, Perquimans, Pasquotank, Camden and Currituck Counties, NC

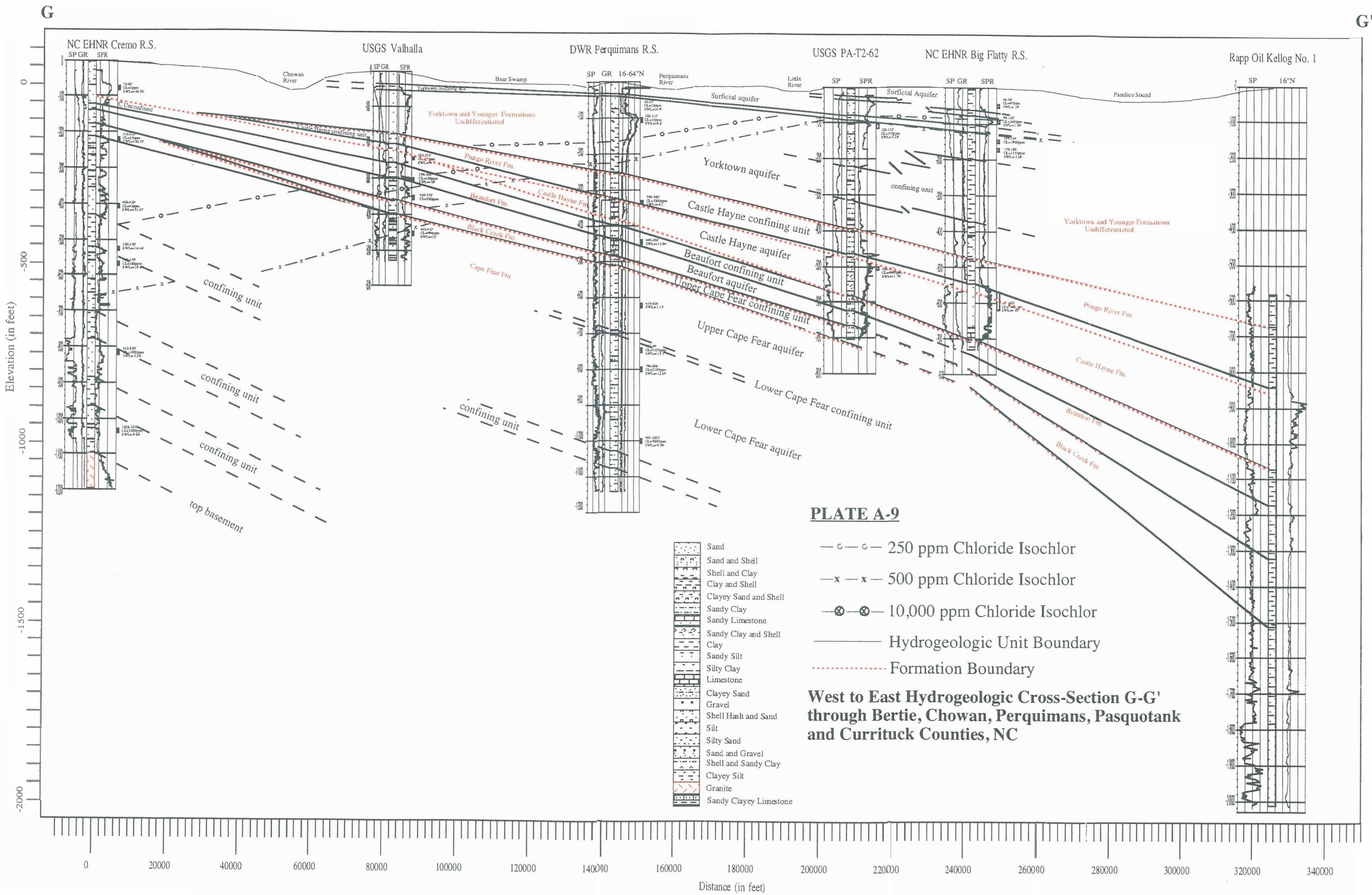


PLATE A-9

West to East Hydrogeologic Cross-Section G-G' through Bertie, Chowan, Perquimans, Pasquotank and Currituck Counties, NC

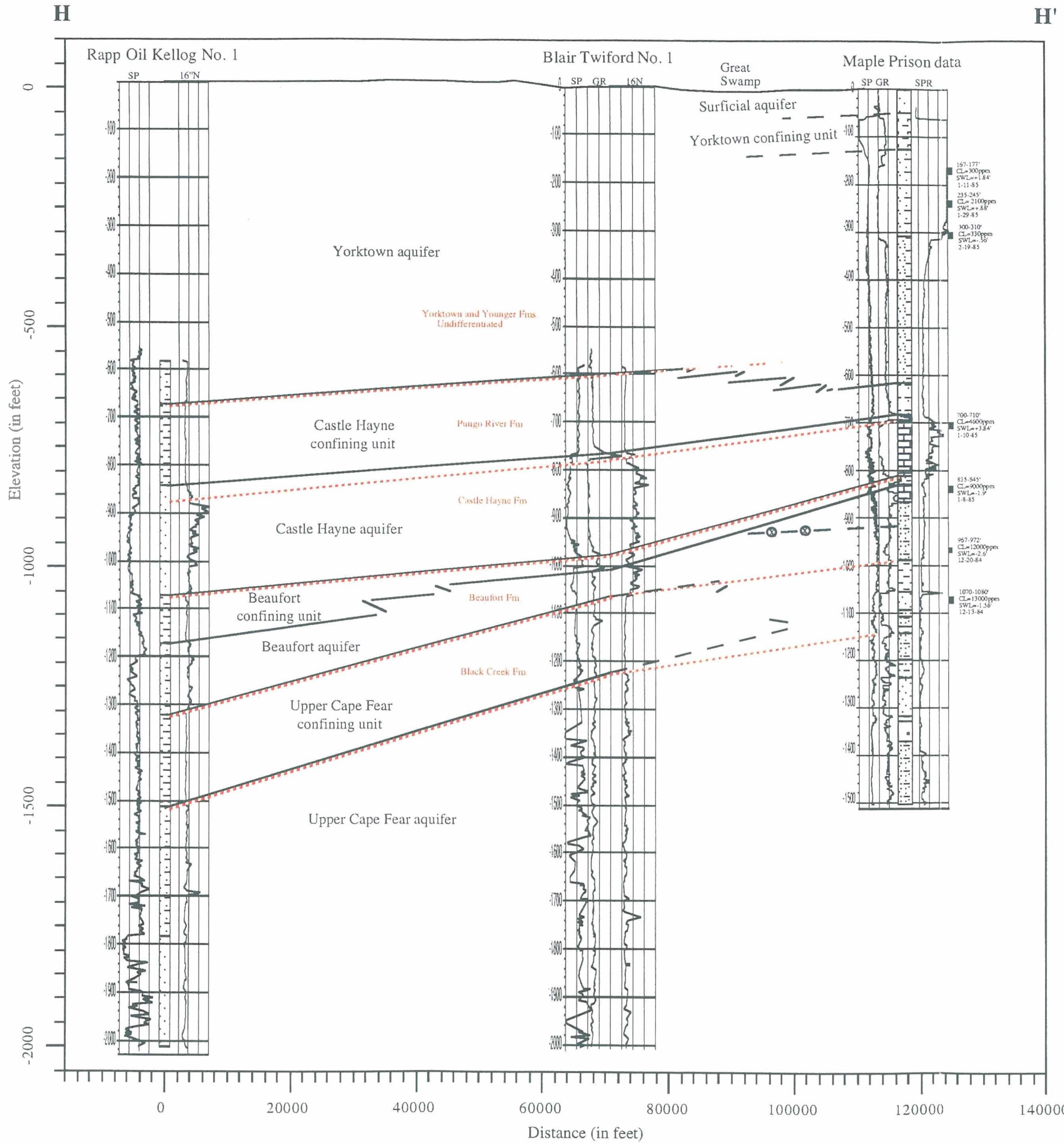


PLATE A-10

South to North Hydrogeologic Cross-Section H-H' through Currituck County, NC