

**APPENDIX 4.17-1**  
**HYDROLOGY AND WATER QUALITY SUPPLEMENTAL INFORMATION**

**1.0 GROUNDWATER**

Brief descriptions of the geological formations of the aquifers and confining units in the lower Coastal Plain are provided in the following paragraphs

**Surficial Aquifer System**

The Surficial aquifer is composed of Quaternary unconsolidated sands of one or more of the following five geological formations: Halocene deposits, Wando Formation, Ten Mile Hill beds, Penholoway Formation, and Daniel Island beds. These deposits, which formed during interglacial ages, represent partially filled-backbarrier, barrier island, and shallow-marine-shelf deposits. Each barrier island deposit represents the position of the Atlantic shoreline at the time it was formed. These deposits are similar to those forming along the present-day shoreline.

The Surficial aquifer consists of sandy marine terrace and alluvial deposits that are approximately 50 feet thick along the Atlantic Coast, and gradually pinches out at the boundary of the upper and lower Coastal Plain. Groundwater in the Surficial aquifer occurs under unconfined conditions, and the water table is about 10- to 20 feet below land surface. This aquifer may be locally truncated by major riverbeds. The aquifer receives recharge from precipitation, which can leak vertically into lower aquifers or move horizontally into the nearest surface-water body. The Surficial aquifer also functions as a sink for deeper aquifers in areas with an upward, vertical hydraulic gradient. Few reliable estimates of aquifer properties are available for the Surficial aquifer system. (USGS (a), 1996)

**Tertiary Aquifer System**

The Tertiary aquifer system is composed of the dense low permeability sediments of the Tertiary Sand, Santee Limestone/Black Mingo (Floridan) confining unit underlain by clastic sediments of the Tertiary Sand aquifer unit and carbonate system of the Santee Limestone/Black Mingo aquifer unit (Floridan aquifer). The Tertiary Sand and Santee Limestone/Black Mingo aquifer unit (Floridan aquifer) grade laterally into one another from northeast to southeast and form the most productive aquifer in the South Carolina Coastal Plain. (USGS (a), 1996) No distinctive water-level or water quality differences exist between these two aquifer units, so they are combined into one aquifer.

**Tertiary Sand, Santee Limestone/Black Mingo and Floridan confining unit**

The Tertiary Sand, Santee Limestone/Black Mingo and Floridan confining unit is composed of dense low permeability tertiary deposits of the Marks Head Formation following three Cooper Group formations: Ashley Formation, Parkers Ferry Formation, and Harleyville Formation; and a Cross Formation. These formations are approximately 342 feet thick beneath Charleston, South Carolina and comprise a highly effective confining unit. Few vertical hydraulic conductivity measurements are available for the Cooper Group sediments. Chester Environmental, Inc. (1994) reported laboratory-derived vertical hydraulic conductivities of  $1.5 \times 10^{-7}$  to  $2.0 \times 10^{-7}$  cm/s ( $4.3 \times 10^{-4}$  to  $5.7 \times 10^{-4}$  ft/d) for Ashley Formation sediments of the Cooper

Group in Calhoun Park near downtown Charleston. A qualitative measure of the low permeability of the Ashley Formation sediments were made during the construction of the water-supply tunnel from the Edisto River to Charleston in 1936-37. Observed infiltration rates into the tunnel during construction were 0.5 (gal/d) per feet of length of the 7-foot diameter tunnel. (USGS (b), 1996)

### **Tertiary Sand, Santee Limestone/Black Mingo aquifer (Floridan aquifer)**

The Tertiary Sand aquifer and the Santee Limestone/Black Mingo aquifer (Floridan aquifer) were both formed during the Eocene geological age. They occur at the same stratigraphic level. The Santee Limestone/Black Mingo aquifer (Floridan aquifer) system gradually grades into the Tertiary Sand aquifer toward the northwest. The Santee Limestone/Black Mingo aquifer and the Floridan aquifer system are one of the same because the Santee Limestone/Black Mingo aquifer is the northern extension of the Floridan aquifer system. The Santee Limestone/Black Mingo aquifer (Floridan aquifer) consists of Santee limestone underlain by Black Mingo sand and sediments. The underlying Black Mingo sand and clay sediments are usually hydraulically connected to the Santee Limestone and form a single aquifer. The Santee Limestone/Black Mingo aquifer (Floridan aquifer) will be referred to as the Floridan aquifer for the rest of this discussion.

The presence of the Floridan aquifer system in South Carolina represents the northernmost extent of limestone deposits that occur from south Florida through Alabama, Georgia, and South Carolina. Its maximum thickness in South Carolina is approximately 700 feet at the intersection of the Georgia-South Carolina border and the Atlantic coast. Toward the northeast it gradually thins and outcrops along the lower Santee River.

The Tertiary Sand aquifer consists of deltaic sands, which were deposited in the southwestern part of the Coastal Plain in South Carolina above the Cretaceous deposits. The aquifer is unconfined in the upper Coastal Plain and is confined in the lower Coastal Plain. The aquifer gradually merges into its carbonate equivalent in the Floridan aquifer system.

The geologic formations consist of tertiary Santee Limestone and Black Mingo clays and sands of the Williams and Rhems Formations in the upper and lower layers of the Floridan aquifer, respectively. The Black Mingo Williams and Rhems Formations also constitute the geological formations of the Tertiary Sand aquifer. The Floridan aquifer system is the only major limestone aquifer in the State of South Carolina. The Tertiary Sand aquifer and Floridan aquifer are effectively confined by the low permeability, phosphatic clayey sand, and phosphatic sandy clay of the overlying Cooper Group sediments. However, these clays are discontinuous in many areas and allow high leakage rates between the Tertiary Sand/Floridan and surficial aquifers aquifer systems.

### **Cretaceous Aquifer System**

The Cretaceous aquifer system is the most extensive and heavily pumped group of aquifers in the South Carolina Coastal Plain. This aquifer system provides water for a variety of uses across most of the Coastal Plain, including potable supply, industrial supply, and irrigation (USGS (a), 1996). The Cretaceous aquifer system is composed of the following three aquifer units and three confining units in descending order from

the land surface: Black Creek confining unit; Black Creek aquifer; Middendorf confining unit; Middendorf aquifer; Cape Fear confining unit; and Cape Fear aquifer.

The aquifer names are derived from the geological formations of the same names; however, the aquifer units do not always coincide with formations names. Division by aquifer unit is on the basis of relative permeability. Higher permeability units in the top or bottom of the geologic units may combine to form an aquifer unit that crosses the geologic formation boundaries. (USGS (a), 1996)

### **Black Creek Confining Unit**

The Black Creek confining unit separates the upper Tertiary Sand and Floridan aquifer systems from the lower cretaceous Black Creek aquifer system. The low permeability sediments of the Pee Dee Formation and other clayey sediments make the Black Creek confining unit the most effective confining unit in the Coastal Plain. The effectiveness of the Black Creek confining unit is demonstrated by different flow systems and water quality between the Black Creek aquifer and Floridan and Tertiary Sand aquifer (USGS (a), 1996).

The Black Creek confining unit is composed of the tertiary Black Mingo, Williams and Rhems Formations in the upper part and cretaceous PeeDee Formation in the lower part.

### **Black Creek Aquifer**

The Black Creek aquifer is the uppermost regionally extensive Cretaceous-age aquifer in the southern South Carolina Coastal Plain (USGS (a), 1996). The Black Creek aquifer lies stratigraphically below the Black Creek confining unit and above the Middendorf confining unit. The Black Creek aquifer out crops and is unconfined in the northeastern part of the upper Coastal Plain north of Berkeley County and is confined elsewhere. The Black Creek aquifer system gradually thickens from a feather-edge at the fall line to approximately 900 feet near the Atlantic coast. The aquifer system is the major source of groundwater in the Myrtle Beach, S.C., area (USGS (b), 1996).

The geological formations of the Black Creek aquifer consist of the following four Cretaceous age sand formations of the Black Creek Group: Donoho Creek Formation, Bladen Formation, Coachman Formation, and Cane Acre Formation. The four formations were deposited in non-marine, delta-plain environments in the southwest that grade through transitional to marine environments along the coast. In the southern end, the four Black Creek Formations were deposited in environments grading from marginal marine to marine as evidenced by the abundance of sharks teeth In the sediments. Sediments in the southern end have a high clay content. In the southwestern part of the upper Coastal Plain, sediments of the Black Creek Formation were deposited in nonmarine and transitional delta-plain environments and contain less clay, little if any calcite, and more coarse grained sand (USGS (c), 1996).

### **Middendorf Confining Unit**

The Middendorf aquifer confining unit separates the upper Black Creek aquifer and lower Middendorf aquifer. The Middendorf confining unit consists of low permeability sediments of the lower silt-clay members of the Cane Acre and Caddin Formations. The lithology is a medium to light gray, calcareous, silty, and

sandy clay. In the Florence area, the confining unit consists of sandy clay in the lower part of the Black Creek Group (USGS (a), 1996).

### **Middendorf Aquifer**

The Middendorf aquifer is the middle of the three regional aquifers in Cretaceous sediments. The Middendorf aquifer extends from the Fall Line to the coast and is the most extensive aquifer in the South Carolina Coastal Plain. In the upper Coastal Plain, the Middendorf aquifer is unconfined, but where the Black Creek aquifer is present, the Middendorf aquifer is confined. The Middendorf aquifer is thinner in the lower than in the upper Coastal Plain. The maximum thickness of the aquifer is approximately 300 feet near the Atlantic coast (USGS (a), 1996).

The geological formations of the Middendorf aquifer consist of Cretaceous-age sands of the Shepard Grove and Middendorf formations and the top portion of the Cape Fear Formation. In the Florence area, the Middendorf aquifer is composed of the Middendorf formation only. Sand and clay sediments of the Shepard, Middendorf, and Cape Fear formations were deposited in fluvial to upper-delta-plain environments. Sediments generally may be coarse grained throughout most of the thickness of the Middendorf aquifer in the upper Coastal Plain, but may have a coarsening-upward sequence farther down gradient. The thick layer of the coarse-grained sediment is characteristic of deposition by a braided stream in a fluvial environment. Sand layers are thinner and clay layers are thicker in the lower Coastal Plain than in the upper Coastal Plain (USGS (a), 1996).

### **Cape Fear Confining Unit**

The Cape Fear confining unit separates the upper Middendorf aquifer from the lower Cape Fear aquifer. The Cape Fear confining unit consists of a grayish yellow to dusky yellow, massive, non-calcareous clay of the Cape Fear Formation. Large water-level and water-quality differences between the Middendorf and Cape Fear aquifers indicates that the upper part of the Cape Fear Formation is an effective confining unit between the two aquifers (USGS (a), 1996).

### **Cape Fear Aquifer**

The Cape Fear aquifer forms the lowermost aquifer in the Coastal Plain of South Carolina. The Cape Fear aquifer is thickest near the coast, and gradually thins and disappears in South Carolina toward the fall line. The Cape Fear Aquifer is present throughout the lower Coastal Plain and the northeastern part of the upper Coastal Plain, but probably does not crop out in South Carolina. Less is known about the Cape Fear aquifer than other aquifers in Cretaceous sediments because of its depth, poor water quality, and low permeability (USGS (a), 1996).

The geological formations of the Middendorf aquifer consist of Cretaceous-age sediments of the Cape Fear Formation. Sediments of the Cape Fear aquifer were deposited in nonmarine, fluvial to upper-delta-plain environments. The sediments consist primarily of thick red clays with immature, poorly developed sorted quartz and feldspar rich sands.

The Cape Fear aquifer is underlain by a confining unit of clays, clayey sands, silts and silty clays overlying pre-Cretaceous crystalline rock.

## **2.0 WATER QUALITY**

Results for the SCDHEC water quality monitoring stations listed in the EIS in Table 4.17.2-7 and shown on Figure 4.17-2-2 conducted during SCDHEC's assessment of the Catawba-Santee Watershed are shown in Tables 1, 2, 3, and 4 of this Appendix. Results for the USGS water quality monitoring stations listed in the EIS in Table 4.17.2-8 and shown on Figure 4.17-2-2 for the 1997 water year are shown in Tables 5 and 6 of this Appendix.

At the majority of the SCDHEC's monitoring stations, samples for analysis were collected as single grab samples once per month, quarter, or year, depending on the parameter. Water was sampled as a water column profile, with measurements being made at a depth of 0.3 meters below the water surface and at one-meter intervals to the bottom or as a single surface grab sample at 0.3 meters below the surface. Water column samples and macro invertebrate community structure were analyzed for various water quality parameters. Macro invertebrate community structure was analyzed routinely at selected stations as a means of detecting adverse biological impacts on the aquatic fauna of the state's waters due to water quality conditions which may not be readily detectable in the water column chemistry. Results from the water quality samples were compared to State Standards and USEPA criteria. For the standards comparisons, columns headed with "EXC" are the number of values exceeding the standard. Columns headed "N" are the total number of surface samples considered in the 1989-1993 time period. The "%" columns are the percentage of values exceeding the standard. An excursion is a value outside of the appropriate range established by the SCDHEC.

In general, support of aquatic life uses is determined based on the percentage of DO and pH standard excursions, increases in water temperature due to heated effluents, and impacts to the macro invertebrate community. Support for recreational uses is based on the frequency of fecal coliform bacteria excursions and the occurrence of bathing area closures. Class SFH standards for the consumption of shellfish are more strict than the 400/100 ml figure used to evaluate recreational use support. The decision to close an area to harvesting is made by SCDHEC's Shellfish Sanitation ambient monitoring network. Fish/shellfish consumption use support is determined by the occurrence of advisories or bans on consumption for a waterbody. Fish advisories are derived from the Department's Fish Tissue Monitoring Program and shellfish advisories from the Sanitary Surveys.

Specifically, for dissolved oxygen, pH, and fecal coliform bacteria, a standards excursion percentage less than or equal to 10 percent of samples represents full support of uses. A percentage between 11 and 25 is considered partial support of uses and a percentage greater than 25 is considered to represent nonsupport of uses, unless excursions are due to natural conditions. For aquatic life uses, even if chemical conditions indicate full support, an adversely impacted macro invertebrate community reduces use support to nonsupport status. For the support of fish consumption uses, a fish consumption advisory or conditionally approved shellfish harvesting status indicates partial use support, a consumption ban or shellfish harvesting closure indicates nonsupport of uses.

The SCDHEC did not use concentrations of heavy metals and organic compounds in water and sediment in the determination of use support unless available biological data indicated an impact to biological integrity, or the frequency of occurrence and concentration was extreme. Excursions of heavy metals above standards for the protection of aquatic life are summarized in Table 4, previously referenced. The USEPA criteria for heavy metals to protect aquatic life specifies the four-day average and a one-hour average (see Table 7). The SCDHEC used the one-hour average for the protection of aquatic life in the water quality assessment because of the quarterly sampling frequency. The SCDHEC also used State standards for human health for several heavy metals in the assessment (see Table 7). For metals, columns headed "EXC" in Table 4 contain the number of values in excess of the aquatic life criterion. The column headed "N" is the total number of samples for the particular metal analyzed between 1989 and 1993. For metals with human health criteria, the median of the samples collected during the five-year period is listed in the column headed "MED". A potential human health threat is indicated if the median exceeds the human health criterion. Blank cells for metals indicate no metals were collected at those stations during the period of review.

Brief descriptions of the water quality parameters monitored at the SCDHEC and USGS stations are provided in the following paragraphs.

### **Dissolved Oxygen**

Dissolved oxygen (DO) is one of the primary water quality constituents used as an indicator of the ecological health of a waterbody. Oxygen is essential for the survival and propagation of aquatic organisms. If the amount of oxygen dissolved in water falls below the minimum requirements for survival, aquatic organisms or their eggs and larvae may die. A severe example is a fish kill. Dissolved oxygen varies greatly due to natural phenomena, resulting in daily and seasonal cycles. Different forms of pollution also cause declines in DO. Changes in DO levels can result from temperature changes or the activity of microscopic plants in a waterbody. Dissolved oxygen concentrations are generally lowest in the morning, climbing throughout the day and peaking near dusk, then steadily declining during the hours of darkness. Photosynthesis by phytoplankton releases oxygen during the day, which results in a rise in DO. In the dark, respiration consumes DO and lowers the concentration.

### **Biochemical Oxygen Demand**

Five-day biochemical oxygen demand ( $BOD_5$ ) is a measure of the amount of dissolved oxygen consumed by the decomposition of carbonaceous and nitrogenous matter in water over a five-day period. The  $BOD_5$  test indicates the amount of biologically oxidizable carbon and nitrogen that is present in wastewater or in natural water. Matter containing carbon or nitrogen uses dissolved oxygen from the water as it decomposes, which can result in a dissolved oxygen decline. The quantity of  $BOD_5$  discharged by point sources is limited through the National Pollutant Discharge Elimination System (NPDES) permits issued by the SCDHEC. The discharge of  $BOD_5$  from a point source is restricted by the permits so as to maintain the applicable dissolved oxygen standard.

## **pH**

The hydrogen ion concentration in a water sample is defined as “pH” and is used as a measure of the acidity of the water. The pH scale ranges 0 to 14 standard units (SU). A pH of 7 is considered neutral, with values less than 7 being acidic, and values greater than 7 being basic. The pH may vary from the ranges specified in the standards due to a variety of natural causes. Low pH values are found in natural waters rich in dissolved organic matter, especially in Coastal Plain swamps and black waters. The tannic acid released from the decomposition of vegetation causes the tea coloration of the water and low pHs.

## **Fecal Coliform Bacteria**

Coliform bacteria are present in the digestive tract and feces of all warm-blooded animals, including humans, poultry, livestock, and wild game species. Fecal coliform bacteria are themselves generally not harmful, but their presence in surface waters may be serious due to their association with sewage or animal waste which may contain pathogenic microbes. At present, it is difficult to distinguish between waters contaminated by animal wastes and those contaminated by human waste.

Diseases that can be transmitted to humans through water contaminated by human or animal waste are the primary concern. Fecal coliform bacteria are able to survive in water and are usually more numerous than waterborne disease producing organisms (pathogens). Therefore, it is best to test for fecal coliform bacteria as an indicator of possible fecal contamination rather than to try to isolate the relatively few pathogens which may be present in water.

## **Nutrients**

Nutrients, in terms of environmental water quality, usually refer to phosphorous and nitrogen, which are primary requirements for the growth and reproduction of aquatic plants. Oxygen demanding materials and nutrients are the most common constituents discharged to the environment by man’s activities, through wastewater facilities and by agricultural, residential, and stormwater runoff. In general, increasing the nutrient concentrations is undesirable due to the potential for accelerated growth of aquatic vegetation and algal blooms which may, in turn, deplete dissolved oxygen and result in fish kills.

The forms of nitrogen routinely analyzed at SCDHEC and USGS water quality stations are ammonia ( $\text{NH}_3+\text{NH}_4/\text{N}$ ), total Kjeldahl nitrogen (TKN), and nitrite-nitrate nitrogen ( $\text{NO}_2/\text{NO}_3$ ). TKN assays the amount of organic nitrogen and ammonia in a sample. Nitrate is the product of aerobic decomposition of ammonia, and is a primary aquatic plant nutrient. Total phosphorous (TP) is measured to determine the phosphorous concentration of surface waters. This test includes all of the various forms of phosphorous (organic, inorganic, dissolved, and particulate) present in a sample.

There are no official standards or criteria for nutrients in water. However, the USEPA has issued recommendations for total phosphate phosphorous concentrations in order to limit eutrophication. Since these are only recommendations, and not a true criterion for use in evaluating water quality, it is difficult to determine the significance of elevated TP values. Because TP includes all forms of phosphorous, including that incorporated into algal biomass, it would be necessary to consider biological data to properly assess the implications of observed concentrations.

## **Heavy Metals**

The concentrations of some of the heavy metal constituents measured at the water quality stations include cadmium, chromium, copper, lead, mercury, nickel, and zinc. Metal concentrations are based on USEPA derived formulas using a water hardness of 50 mg/l. However, the average hardness of surface waters in the study area is approximately 20 mg/l. The USEPA has expressed reservations about the validity of the formulas when applied to hardness values below 50 mg/l. Based on this opinion, South Carolina's State Standards for metals are based on a hardness of 50 mg/l for waters where hardness is 50 mg/l or less, resulting in several criteria values below the analytical detection limits. Therefore, any detectable concentration of cadmium, copper, or lead is an excursion beyond recommended criteria.

The SCDHEC monitoring data has historically indicated that zinc and copper levels in South Carolina waters are elevated relative to USEPA criteria, apparently a statewide phenomenon in both fresh and salt waters, and possibly resulting from natural conditions or nonpoint sources. These levels do not appear to adversely affect state fisheries, which suggests that the levels are the result of long-term local conditions to which the fauna have adapted, as opposed to point source pollution events. It is difficult to assess the significance of heavy metal excursions due to the questionable applicability of the formulas at low hardness values and the occurrence of calculated criteria below present detection limits. Atmospheric inputs are recognized as important sources of metals to aquatic systems. Metals are released to the atmosphere from the burning of fossil fuels (coal, oil, gasoline), wastes (medical, industrial, municipal), and organic materials. The metals are then deposited on land and in waterways from the atmosphere via rainfall.

## **Specific Conductance**

Specific conductance is a measure of the ability of a water to conduct an electrical current. It is expressed in microsiemens per centimeter at 25° C. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance in (microsiemens). This relation is not constant from stream to stream, and it may vary in the same source with changes in the composition of the water. Salinity values can be calculated from the specific conductance using various algorithms.