4.3 Water Quality

4.3.1 Historical Water Quality Studies at the Project

Several water quality investigations have been conducted in Lake Tillery, Blewett Falls Lake, and the associated tailwaters over the life of Yadkin-Pee Dee River Project. Some of the initial investigations of the Yadkin-Pee Dee River Basin, which included the Project waters, began during the late 1940s and early 1950s. Two water quality issues within the basin since these early studies have been sedimentation and nutrient loading (e.g., North Carolina State Stream Sanitation Committee 1953; U.S. Department of Agriculture 1980; Korfmacher 1996; NCDWQ 2002a).

During 1953, the state of North Carolina published a pollution survey report of the Yadkin-Pee Dee River Basin (North Carolina State Stream Sanitation Committee 1953). Surface waters of Lake Tillery were classified as A-II or water supply with approved completed treatment. The water quality was described as “natural” or of non-polluted watershed conditions based on turbidity, color, solids, nutrients, biological oxygen demand, coliform bacteria, sulfates, chloride, and several heavy metals. Blewett Falls Lake, and the riverine portion of the Pee Dee River below the Tillery Development, was classified as “C” and best suited for fishing. The waters were considered slightly “polluted” based on the same measured water quality variables. Most of the tributaries in the watershed were classified as “natural” or undisturbed. However, several main tributaries were classified as “grossly polluted” (e.g., Clarke Creek, Irish Buffalo Creek, and Rocky River) or “slightly polluted” (e.g., Coodle Creek, Dutch Buffalo Creek, and the Little River) during this study. The Pee Dee River below the Blewett Development to the South Carolina state line was classified as A-II or water supply.

The North Carolina Department of Conservation and Development conducted an assessment of the water resources in the Yadkin-Pee Dee River Basin in 1955. Water quality was determined to be of good quality although there were localized areas of industrial and municipal pollution (North Carolina Division of Water Resources, Inlets, and Coastal Waterways 1955). Heavy sediment loading in the basin during periods of high runoff from precipitation events was noted in the report.

The U.S. Environmental Protection Agency (USEPA) conducted an assessment of both lakes' trophic status (i.e., each lake's biological productivity) and nutrient loadings during 1973 as part of the National Eutrophication Survey (USEPA 1975a, 1975b). During that study, both lakes were characterized as "eutrophic" or over-enriched by nutrients. Lake Tillery and Blewett Falls Lake ranked eleventh and thirteenth, respectively, in overall trophic condition of 16 North Carolina lakes sampled in 1973 based on six water quality parameters (total phosphorus, dissolved orthophosphorus, inorganic nitrogen, Secchi disk transparency, chlorophyll *a*, and dissolved oxygen concentrations). The study also concluded that primary productivity in Blewett Falls Lake might have been light-limited based on the low chlorophyll *a* concentrations, high nutrient concentrations, high turbidity, and short hydraulic retention time. Nutrient loading in both reservoirs, cited in the study, included both point (wastewater treatment plants) and non-point sources along the main stem of the Yadkin-Pee Dee River as well as associated tributaries.

Weiss and Kuenzler (1976) conducted another trophic assessment of both reservoirs during 1976 and determined that the reservoirs should be classified as mesotrophic or of moderate biological productivity. This classification was based on the investigator's water quality classification system of North Carolina reservoirs and used only summer water quality data.

The North Carolina Division of Water Quality (formerly known as the Division of Environmental Management) has also monitored both reservoirs and the free-flowing reaches of the river below each development since 1981 as part of its statewide lake assessment and basinwide water quality management programs (NCDEM 1983, 1989, 1992a, 1992b; NCDWQ 1998).

Deviations from the state water quality standards in Lake Tillery, cited in these studies, included percent oxygen saturation during 1983 and a few instances of lead and copper concentrations during 1983, 1984, and 1989. These studies determined that major sources of pollution (mainly nutrient loading and sedimentation) were from mining, construction, wastewater treatment, and agricultural land practices. Overall, these studies found Lake Tillery to be mesotrophic and fully supporting its designated water quality uses.

Blewett Falls Lake was classified as eutrophic during a 1982 study and ranked 53 out of 59 water bodies considered the most nutrient-enriched throughout the state (NCDEM 1983). Only five other reservoirs had nutrient concentrations greater than Blewett Falls Lake at that time. The Rocky River was cited as a tributary of elevated nutrient enrichment and suspended solids. In assessments conducted from 1981 to 1986, Blewett Falls Lake was predominantly classified as eutrophic with nutrient concentrations and chlorophyll *a* concentrations exceeding the state water quality standards at that time. The lake fully supported its designated uses during this period although the potential for water quality problems continued to exist. A subsequent assessment during 1984 also found the reservoir to be eutrophic but fully supporting its uses. During 1992 and 1994, Blewett Falls Lake was classified as threatened in water quality support use (NCDEM 1992b, 1994). Threatened lakes are those typically experiencing eutrophication that could become problematic in future years.

Progress Energy also conducted periodic water quality surveys of Lake Tillery and Blewett Falls Lake during 1986, 1992, and 1993 (CP&L 1987, 1993, and 1995). These surveys indicated that the river-reservoir system fully supported the designated uses for the water bodies and further concluded that the system's water quality had not appreciably changed over a 20-year period based on data comparisons from other historical surveys. Water quality concerns — elevated nutrient and sediment loading — cited by state and federal resource agencies during the early 1970s to the 1980s were still relevant in the early 1990s. Instances of water quality standards not being met in either lake were due to known sources of pollution upstream of each lake. These surveys also documented brief seasonal (summer) depressions of dissolved oxygen (DO) in the headwaters of Lake Tillery just below Falls Hydroelectric Plant and in the immediate tailwaters downstream of the Tillery Hydroelectric Plant. The river below the Blewett Development was relatively well-oxygenated owing to the well-mixed water column of the lake.

The NCDWQ has conducted the most contemporary assessments of water quality in the Yadkin-Pee Dee River Basin (NCDWQ 1998, 2000, 2002a). Basinwide water quality issues were increased nutrient enrichment, increased urbanization, instream sedimentation from nonpoint sources, and instream impacts from permitted municipal and industrial discharges. Turbidity was noted as regularly exceeding water quality standard (50 NTU) throughout the basin, and copper concentrations were also elevated and above the North Carolina action level of 7 µg/L at most monitoring locations.

Trophic status of either Lake Tillery or Blewett Falls Lake has not changed appreciably since 1981. Each reservoir continues to fully support its designated uses (NCDWQ 2002a). The NCDWQ cited the short hydraulic residence times of both reservoirs (Blewett Falls Lake - 7 days and Lake Tillery - 15 days) as a factor influencing primary production, which reduced the residence time for nutrient uptake by phytoplankton. Seasonal depressions of DO concentrations (August 1999) were noted in the headwaters of Lake Tillery and the immediate tailwaters downstream (at North Carolina Highway 731 Bridge) of the Tillery Hydroelectric Plant. The portion of the Pee Dee River below Lake Tillery was considered partially supporting its designated uses due to low DO concentrations from the hypolimnetic discharge from the Tillery Hydroelectric Plant (NCDWQ 1998, 2002a). In Blewett Falls Lake, the NCDWQ monitoring found elevated pH, DO, and percent oxygen saturation. Secchi disk transparency was less than one meter, and nutrient concentrations ranged from moderate to elevated.

Long-term monitoring by the NCDWQ since 1980 has shown DO concentrations below the state water quality standard of 5.0 mg/L at least 10 percent of the 13-year period at the following locations: (1) Pee Dee River at North Carolina Highway 731 below the Tillery Development; (2) Brown Creek, a tributary associated with the Pee Dee National Wildlife Refuge; (3) Pee Dee River at North Carolina Highway 109; (4) Pee Dee River at U.S. Highway 74 below the Blewett Development; and (5) Marks Creek, a tributary downstream of the Blewett Development.

During 1999 through 2000, the NCDWQ analyzed fish tissue samples from the Pee Dee River below the Blewett Development for mercury and other trace metals (NCDWQ 2002a). All results indicated non-detectable levels based on laboratory reporting limits and below applicable state and federal human health and fish consumption criteria.

The first comprehensive water resources management plans for the Yadkin-Pee Dee River were completed during the early 1980s (North Carolina Office of Governor, South Carolina Office of Governor, and U.S. Water Resources Council 1981). Subsequent basinwide assessments have been conducted by the NCDWQ with the most recent assessments occurring in 1998 and 2002 (NCDWQ 1998, 2002a).

South Carolina initiated watershed planning and assessment of the Pee Dee River beginning in 1975. The most recent assessments of the river in South Carolina were published in 1997 and again in 2001 (SCDHEC 1997, 2001).

The portion of the Pee Dee River watershed from the state line to Florence County, including physiographic areas in the Sand Hills and Upper and Lower Coastal Plains, was determined to be fully supporting its designated use during 1997 (SCDHEC 1997). Trends noted at the three mainstem monitoring locations included: (1) a significant decreasing pH trend, (2) a significant increasing trend in turbidity, and (3) occasional elevated concentrations of zinc, lead, nickel chromium, PCBs, DDTs, and diazinon in either water or sediments. Notable improvements included decreases in biochemical oxygen demand and total phosphorus and nitrogen concentrations.

The lower segment of the Pee Dee River in Dillon, Marion, and Florence Counties was fully supporting recreational uses during the 1997 assessment. Aquatic life uses were threatened due to occasional elevated concentrations of chromium and copper in excess of aquatic life standards. There was also a decreasing temporal trend in DO concentrations. This segment was identified as impaired in the 1996 303(d) secondary list due to elevated concentrations of copper from unknown sources.

In the 2001 assessment, the SCDHEC noted the river was fully supporting its designated use at the two monitoring sites in the upper portion of the river from Cheraw to Society Hill. Recreational uses were fully supported, but aquatic life uses were not supported at the third site located near Darlington due to elevated copper concentrations. A significant decreasing temporal trend in DO concentrations was also noted at this station. In the lower portion of the river, the river was fully supporting recreational use, but not aquatic life use, due to continued occurrences of elevated copper concentrations.

4.3.2 Surface Water Quality Classifications and Identified Impairments

Surface water quality classifications are designations applied to surface water bodies, to define the uses to be protected within the identified water body. These classifications have an associated set of water quality standards necessary to protect the uses (NCDWQ 2002b; SCDHEC 2001).

Lake Tillery, Blewett Falls Lake, and the Pee Dee River reach between the two hydroelectric developments have been classified by the NCDWQ as drinking water supplies (WS-IV and WS-V) and suitable for primary (Class B) and secondary recreation uses (Class C) including fishing, wildlife, fish, aquatic life propagation and survival, and agriculture. Both lakes were classified as fully supporting the classified uses during a 1998 - 1999 lake assessment conducted by the NCDWQ (NCDWQ 2000). The Pee Dee River reach below the Blewett Falls Development to the North Carolina-South Carolina state line is classified as Class C or suitable for secondary recreational uses.

In South Carolina, the Pee Dee River (also known as the Great Pee Dee River) from the state line to Florence County has been classified as "FW" or freshwaters, which are suitable for primary and secondary contact recreation, and as a source for drinking water (SCDHEC 2001). This designation also includes waters that are suitable for fishing and the survival and propagation of a balanced indigenous aquatic community.

Sources of Water Quality Impairment

Impaired water quality refers to water bodies that do not meet state designated water quality use classifications, such as water supply, fishing, or propagation of aquatic life (NCDWQ 2002c). Best professional judgment is applied by the responsible state water quality agency, along with numeric and narrative standards criteria and anti-degradation requirements defined in 40 CFR 131 when evaluating the ability of a water body to serve its uses. Impaired water bodies are identified by state water quality agencies through a listing process of Section 303(d) of the Clean Water Act.

The Pee Dee River from Tillery Dam to the mouth of Turkey Top Creek, including Blewett Falls Lake (24.5 river km or 15.2 river miles), was listed as impaired and partially supporting its designated use due to low DO concentrations during the summer months (NCDWQ 2002c). In addition, the segment of the Pee Dee River from Turkey Top Creek to Savannah Creek was also listed as impaired due to pH fluctuations from agricultural sources. Turkey Top Creek is located approximately 5 km (3 miles) below the North Carolina Highway 109 Bridge while Savannah Creek is located in the headwaters area of Blewett Falls Lake. Below the Blewett Falls Development, the North Carolina segment of the Pee Dee River was listed as support threatened due to low DO concentrations during the summer months.

Three locations in the lower Pee Dee River in South Carolina have been listed as impaired under Section 303(d) of the Clean Water Act (SCDHEC 2002a, 2002b). Recreational use was listed as impaired due to elevated fecal coliform counts at the monitoring station located near Society Hill at U.S. Highway 15/401. Elevated copper concentrations at South Carolina Highway 34 resulted in impairment of aquatic life use at that river location. Aquatic life use was also listed as impaired due to low DO concentrations in the lower Coastal Plain reach of the river at U.S. Highway 701 near Yauhannah, South Carolina, approximately 276 km (171 miles) downstream of the Blewett Development.

The lower Pee Dee River in South Carolina was also listed as impaired for fish consumption due to elevated mercury concentrations in fish. A fish consumption advisory is in effect for bowfin and largemouth bass for the entire South Carolina portion of the river (SCDHEC 2002b).

4.3.3 Progress Energy Water Quality Surveys at the Project

Progress Energy has conducted recent surveys from 1998 to 2001 of water quality conditions in the vicinity of the Project. Sampling methodology for the surveys as well as sample location maps are provided in Appendix D. Figures and tables prepared from the results of these surveys are located in Appendix E. Progress Energy is proposing to establish an RWG with stakeholders and stakeholders in the spring of 2003 to review these data. The RWGs will discuss, and as appropriate, identify areas where additional surveys may be required by Progress Energy to address specific Project operation impacts provided there is some reasonable evidence of a Project impact.

Hydrological Conditions During Water Quality and Other Environmental Surveys

Precipitation levels and subsequent river flows varied greatly during this period in the two river reaches below each hydroelectric development (Figures E-1 and E-2). An El Niño pattern occurred during 1998 resulting in above normal precipitation levels and river flow (discharge peaks ranging from 43,100 to 81,300 cfs) in the river reach below the Blewett Development during first six months of the year. However, river flows declined below the average long-term flow conditions from 1999 through 2001 as a result of below normal precipitation and drought conditions experienced during the majority of months for that period (Cooney et al. 1999, 2000, 2001; Ragland et al. 1999, 2000, 2001, 2002) (Figure E-1). Occasional peak river flows observed from 1999 to 2001 were the result of above average precipitation events such as tropical storm systems (e.g., Hurricane Floyd in September 1999) or other weather systems. Flows below the Blewett Development, ranged from 187 cfs (baseflow conditions) to 12,462 cfs during water quality studies associated with that facility during 1999 and 2001 (Figure E-3).

In the river reach below the Tillery Development, peak discharges were the greatest from January through May 2000 and again during March and April 2001 with the highest flows ranging from approximately 28,000 to 29,000 cfs (Figure E-2). However, discharge was generally less than 5,000 cfs in that river reach for the majority of the study period during 2000-2001 (Figures E-2 and E-3). Mean total flows from the Tillery Development during 2000 and 2001 ranged from 52 (baseflow conditions) to 9,350 cfs (Figure E-3).

In summary, precipitation levels and streamflow in the Yadkin-Pee Dee River Basin were generally characterized as below normal conditions during the majority of the period of water quality surveys, particularly from 1999 to 2001. From a water quality perspective, it would be expected that nutrient and sediment inputs in both reservoirs would be less, on the average, than during normal or above average precipitation and streamflow years. However, periodic high flow events during this period would influence environmental variables, depending upon the magnitude and time of the year. Thus, these meteorological and hydrological conditions should be considered when evaluating and discussing the environmental data.

Lake levels were relatively stable at both lakes on the sampling dates of water quality studies from 1999 to 2001 (Figures E-4 and E-5). Lake Tillery usually deviated 0.3 m (one foot) or less during the period of study. In Blewett Falls Lake, lake fluctuation was greater and averaged approximately 0.6 m (two feet) owing to the smaller reservoir volume *vs*. river inflow and the hydraulic capacity of the Blewett Hydroelectric Plant. There was a noticeable decline in both lake levels (1.8-3.0 m or 6-10 ft) during September through November of 2001, which resulted from a FERC required inspection and testing of the tainter gates at the Tillery Development. Blewett Falls Lake was also lowered during this testing to receive water released during the draw down of Lake Tillery. Both lakes returned to normal operating levels by the end of November.

Water Quality Results

The water quality raw data (i.e., temperature, DO, specific conductance, pH, and Secchi disk transparency depth) collected at both reservoirs and the receiving Pee Dee River tailwaters of each hydroelectric development are presented in Appendix E.1. The water chemistry data are presented in Appendix E.2 and includes alkalinity, hardness, turbidity, solids constituents, nutrient concentrations, total organic carbon, biological oxygen demand (BOD), chemical oxygen demand (COD), and selected metal concentrations.

Lake Tillery Water Quality

During the surveys conducted in 2000 by Progress Energy, Lake Tillery was characterized as a mesotrophic reservoir with moderate nutrient and solids concentrations, high water clarity, and weakly buffered with low anion and cation concentrations (i.e., chloride, sulfate, sodium, calcium, and magnesium concentrations) (Appendix E.2; Tables E-1 and E-2). Surface water cation and anion concentrations were ranked respectively as follows: sodium > calcium > magnesium and bicarbonate (alkalinity) > chloride > sulfate. Chlorophyll *a* concentrations, an indirect indicator of algal productivity, were usually in the low to moderate range with no values greater than the North Carolina water quality standard of 40 mg/L. Chlorophyll *a* concentrations ranged from less than 1 mg/L at Station K2 during December to 32 mg/L at Station F2 during March. The short retention time of the reservoir, coupled with the "filtering effect" of the four upstream reservoirs (i.e., High Rock Lake, Tuckertown Reservoir, Narrows Reservoir, and Falls Lake), influenced the nutrient and solids concentrations, turbidity values, and the trophic status of the lake.

Lake Tillery exhibited defined seasonal patterns of temperature and DO stratification during 2000 (Appendix E.1; Figures E-6 and E-7). The lake was isothermal with a well-mixed water column during the fall (September through December) and winter months (January and February). Thermal and DO stratification existed, primarily during the summer months, with well-defined epilimnion, metalimnion (thermocline), and hypolimnion strata. A brief period of thermal and DO stratification was evident in March of 2000; but the lake destratified by April, which was most likely related to increased reservoir inflow and outflow. Stratification patterns returned during May and persisted until September. During August, a period of strong thermal stratification, the temperature gradient in the reservoir (Stations B2, D2, F2, and H2) ranged from 5.7 to 7.4 $^{\circ}$C from the surface to bottom waters.

A strong clinograde oxygen curve was observed in the summer stratification period with oxygen depletion to less than 5 mg/L occurring below 5-7 meters in the middle and lower lake areas (Stations B2, D2, and F2) (Figure E-7). In the upper reservoir at Stations H2 and K2, the entire reservoir water column remained oxygenated during the summer stratification period due to the shallower depth and the influence of inflows from the Uwharrie River and the Falls Hydroelectric Plant. Station K2 was freely circulating throughout the entire year due to its location just below the Falls Hydroelectric Plant tailwaters. Thermal stratification was disrupted in the reservoir by early September with displacement of anoxic bottom waters throughout the water column, particularly in the deeper, lower reservoir areas at Stations B2 and D2 (Appendix E.1 and Figures E-6 and E-7).

DO concentrations remained above the North Carolina water quality standard of 5.0 mg/L in the surface waters of Lake Tillery during 2000 (Table E-1). No seasonal summertime depression of surface DO concentrations below 5.0 mg/L was evident in the upper reservoir areas (Stations H2 or K2) as noted in other environmental investigations conducted in the 1980s and 1990s (CP&L

1993; NCDWQ 1998, 2002a). However, there was a distinct longitudinal gradient in surface temperature and DO concentrations during the summer months from the upper to lower reservoir (Appendix E.1; Table E-1; and Figures E-6 and E-7). This gradient indicated the Falls Hydroelectric Plant, and to some extent the Uwharrie River, influenced the surface temperature and DO concentrations in the upper reservoir (i.e., cooler temperatures in the upper reservoir but with lower oxygen concentrations).

Biological (BOD) and chemical oxygen demand (COD) were generally low in surface and bottom waters with values usually less than laboratory reporting limits of 2 and 20 mg/L, respectively (Tables E-1 and E-2). No spatial differences were evident in surface or bottom waters of the upper, middle, or lower reservoir areas during 2000. Slightly elevated values of COD were observed in March, July, or October depending upon reservoir location. The greater COD values in October may have been related to reservoir destratification of Lake Tillery and the upstream reservoirs associated with normal fall turnover of reservoir water columns (Appendix E.2).

There were longitudinal surface gradients in turbidity, solids, and nutrient concentrations within the reservoir although these spatial patterns were not always statistically significant (Table E-1). These constituents were generally greater in the upper reservoir areas as compared to lower reservoir areas. Nitrate+nitrite-N and total phosphorus concentrations exhibited a significant decreasing gradient from the headwaters area (Station K2) to the lower reservoir area (Station B2) (Table E-1). The ions calcium and sodium also exhibited a similar statistically significant spatial pattern; however, these differences were not considered of a magnitude to be of biological or water quality significance.

Although longitudinal gradients were observed in surface waters in several water quality and chemistry variables, there were no statistically significant spatial patterns observed in bottom waters of the upper, middle, and lower reservoir areas (Table E-2).

Occasional pulses of nutrients, aluminum, solids, and turbidity, and lowered Secchi disk transparencies into the reservoir were related to large precipitation events in the river basin, which resulted in increased inputs of nutrient and sediment from the watershed (e.g., February 2000; see Appendix E.2 and Figures E-2 and E-3).

Surface *vs*. bottom differences (paired t-tests) in concentrations of water chemistry variables were not consistently observed throughout the reservoir (Table E-3). There were statistically significantly greater concentrations of total solids, nitrate+nitrite-N, total phosphorus, and aluminum concentrations in the bottom waters at the deeper, lower reservoir area (Station B2) (Table E-3). Total nitrogen was also greater in bottom waters as compared to surface waters but this difference was not statistically different. Nutrient constituents were expected to be greater in bottom waters due to anoxic conditions and associated biochemical processes associated with seasonal stratification in deeper reservoir areas. In the middle reservoir, total dissolved solids, nitrate+nitrite-N, hardness, and the anions — calcium and magnesium were significantly greater in bottom *vs*. surface waters. As mentioned previously, the upper reservoir area, Station K2, was shallow and well mixed due to its location just below the Falls Hydroelectric Plant. Few vertical differences in water chemistry variables would be expected in this area.

Chlorophyll *a* concentrations were greater in the middle reservoir area (Station F2) as compared to the upper and lower reservoir areas (Stations B2 and K2) (Table E-1 and Figure E-8). This spatial pattern was most likely related to reservoir hydrodynamics (flow and circulation patterns) as influenced by power plant discharge or withdrawal depending upon the area. Chlorophyll *a* concentrations peaked throughout the reservoir during March with smaller peaks observed during May and October, depending upon reservoir location (Figure E-8). Elevated pH values (9.0) were also observed throughout the reservoir in March, which indicated an algal bloom occurred during this period (Appendix E.1; Table E-1). Total nitrogen to total phosphorus ratios ranged from 17:1 to 22:1 in the reservoir during 2000 which suggested phosphorus was the limiting factor in algal productivity (Table E-1).

The trace elements — aluminum, copper, and mercury — were generally low in the reservoir during 2000 (Tables E-1 and E-2). A pulse of aluminum levels was observed in February 2000 as a result of a large precipitation event and sediment inputs into the reservoir from the watershed. Aluminum is bound to clay soil particles, and there is usually a positive relationship between precipitation events, sediment loading, and aluminum levels in Piedmont reservoir systems (NCDWQ 2002a). Copper concentrations ranged from less than 1.0 to 4.5 µg/L, and no values were greater than the North Carolina action level of 7 µg/L.[5]

A long-term comparison of was made between 1992 and 2000 Progress Energy annual baseline data sets to determine if there were any significant changes in surface and bottom water quality over the past eight years (Table E-4). Only odd month data (i.e., January, March, May, July, September, and November) were evaluated for both years to provide for a valid data comparison. Bimonthly sampling was conducted in 1992 while monthly sampling was conducted in 2000.

Total dissolved solids, hardness, total organic carbon, and most anions and cations were significantly greater in both surface and bottom waters during 2000 than during 1992 (Table E-4). Specific conductance was significantly greater in surface waters during 2000. Conversely, most nutrient concentrations, aluminum, and copper were generally greater in 1992 than in 2000. Turbidity values were not statistically different between these years. Surface water temperatures, DO concentrations, chlorophyll *a*, and pH were also comparable between years.

Differences in water quality and chemistry variables most likely reflected varying amounts of precipitation, reservoir inflow, and reservoir outflow between the two years rather than any significant long-term changes in the overall water quality in Lake Tillery. There was more rainfall and inflow during 1992 (CP&L 1993; Ragland et al. 2001) than in 2000 (drought year with below average precipitation and inflow), which subsequently influenced anion and cation concentrations, solids constituents, hardness, aluminum concentrations, and specific conductance. Greater nutrient concentrations indicated additional inputs from the watershed during a wetter year (1992).

Blewett Falls Lake Water Quality

Blewett Falls Lake continued to be characterized as a nutrient-enriched, turbid, eutrophic reservoir with elevated solids and weakly buffered soft waters during 1999 and 2001 (Tables E-5 and E-6). Surface water cation and anion concentrations were ranked respectively as follows:

[5] The action level refers to a water borne concentration of an analyte that if exceeded may require further regulatory action by the responsible water quality agency (NCDENR 2002(b)).

sodium > calcium > magnesium and bicarbonate (alkalinity) > chloride > sulfate. This predominance pattern was consistent with ionic composition of Lake Tillery.

The eutrophic characterization was consistent with results from previous investigations since the early 1980s (CP&L 1995; NCDEM 1983, 1989, 1992a; NCDWQ 1998, 2002a). Nutrient and sediment inputs from the surrounding watershed, most notably from the Rocky River tributary of the Pee Dee River, resulted in distinct differences in the water quality characteristics and trophic status of Blewett Falls Lake when compared to Lake Tillery. For example, mean turbidity values were 1.3 to 3.3 times greater in Blewett Falls Lake than Lake Tillery. One turbidity value in the lower reservoir area of Blewett Falls Lake (52 NTU) exceeded the North Carolina water standard of 50 NTU during March 2001 (Appendix E.2 and Table E-6).

Large precipitation events and subsequent stream inflow influenced temporal patterns relative to nutrient and sediment inputs into Blewett Falls Lake (e.g., January and February 1999; see Appendix E.2 and Figure E-3). For example, total phosphorus mean concentrations were 1.8 to 5.0 times greater in Blewett Falls Lake than Lake Tillery (Tables E-1, E-5, and E-6). Mean turbidity values were approximately twice as great in Blewett Falls Lake than Lake Tillery, while the converse pattern applied to Secchi disk transparency.

Blewett Falls Lake exhibited weak to moderate thermal stratification patterns in the middle and lower reservoir areas during 1999 and 2001 (Appendix E.1; Figures E-9 and E-10). The upper reservoir (Station H2) was always well-mixed and uniform in temperature and DO throughout the year due to the shallow, semi-riverine nature of this headwaters area.

In the middle and lower reservoir areas, the water column was uniformly mixed and free-circulating during the majority of both years with stratification only evident during two or three months during the late spring (May) or summer (June and August). During 1999, thermal stratification existed in May and June; de-stratification occurred during July and only a weak thermocline existed in August (Figure E-9). Thermal stratification was weak to nonexistent during 2001 (Figure E-10). These results continued to indicate that Blewett Falls Lake was a well-mixed reservoir due to its shallow depth, small storage volume, short retention time

(7 days), and the generating capacity and operating mode of the hydroelectric plant (CP&L 1995).

Correspondingly, DO concentrations were uniform and indicative of a well-mixed water column except during periods of thermal stratification (Figures E-11 and E-12). A pronounced clinograde oxygen curve was observed in June and August 1999 with DO concentrations declining rapidly from 2 to 6 m, depending upon reservoir location. There was also DO depletion in September of 1999 even though the reservoir was only weakly stratified. The reservoir water column was well mixed and uniform in both temperature and DO by October.

DO stratification and reduction in the lower water column in the middle and lower reservoir areas were more persistent and pronounced during 2001 and occurred from May through September (Appendix E.1; Figure E-12). Additionally, DO stratification occurred during November, which was atypical for shallow warm water Piedmont North Carolina reservoir. This DO stratification was most likely related to the reservoir drawdown during September 2001 when there was a period of low reservoir inflow and little or no hydroelectric power generation (Figures E-2 to E-5). These conditions, along with the eutrophic nature of the reservoir, were most likely responsible for this DO pattern. Uniform DO concentrations appear again in December 2001 with the return to normal lake levels, resumption of power plant operations, and cooler fall temperatures.

There were no statistically significant longitudinal gradients in either water temperature or DO in Blewett Falls Lake during 1999 or 2001 (Tables E-5 and E-6). Furthermore, surface DO concentrations in Blewett Falls Lake were above the North Carolina water quality standard of 5.0 mg/L during 1999 and 2001. Dissolved oxygen concentrations ranged from 5.7 to 12.3 mg/L during 1999 and from 6.0 to 14.2 mg/L during 2001 (Tables E-5 and E-6).

Chlorophyll *a* concentrations in Blewett Falls Lake ranged from 1.8 to 41 mg/L during 1999 and from 2.7 to 39 mg/L during 2001 (Tables E-5 and E-6). A chlorophyll *a* value of 41 mg/L was observed in the middle reservoir (Station F2) in June 1999 during an algal bloom and slightly exceeded the North Carolina water quality standard of 40 mg/L.

All other chlorophyll *a* values were below the water quality standard during 1999 and 2001 although seasonal trends indicated algal bloom conditions present during the spring and summer, and early fall months of both years (Figures E-4 through E-8). During an algal bloom at Station F2 during June 2001, a surface pH value of 9.3 was measured and slightly exceeded the North Carolina water quality standard of 9.0 (NCDWQ 2002a; Appendix E.2). The DO concentration was above 100 percent saturation and also indicative of algal bloom conditions on this sampling date.

There was a longitudinal gradient in chlorophyll *a* concentrations with significantly greater concentrations in the lower and middle reservoir areas as compared to the upstream river (Station 12B) and reservoir headwaters (Station H2) areas during 1999 and 2001 (Tables E-5 and E-6; Figure E-8). This gradient was expected as the reservoir transitioned from a riverine to reservoir environment.

As previously observed during 1993 water quality surveys (CP&L 1995), very few longitudinal differences were observed in water chemistry characteristics during 1999 and 2001 within the reservoir or the upstream river station when compared to reservoir data (Tables E-5 and E-6). Total nitrogen and nitrate+nitrite-N were significantly greater at the upstream river area (Station 12B) when compared to the reservoir during 1999, but that spatial pattern was not observed in 2001. Total phosphorus exhibited a spatial gradient during both years; however, this relationship was not statistically significant. Total nitrogen to total phosphorus ratios ranged from 9:1 to 11:1 during 1999 and 2001 and indicated that phosphorus was not a limiting factor in algal productivity within the reservoir.

The BOD and COD mean values in Blewett Falls Lake were less than laboratory reporting limits of 2 and 20 mg/L, respectively, during 1999 and 2001 (Tables E-5 and E-6). However, more COD values were above the reporting limits during 2001; a year of lower inflow and outflow when compared to 1999 (Figure E-3). Twelve of the 36 BOD values were above the reporting limit during 2001 with the majority of these values observed in the middle and lower reservoir areas (Appendix E.2). The BOD values were the greatest during the summer months of 2001 while COD exhibited no defined seasonal pattern.

Trace metals — aluminum, copper, and mercury — were generally uniform and did not exhibit any significant longitudinal gradients in the reservoir during 1999 or 2001 (Appendix E.2; Tables E-5 and E-6). As observed in Lake Tillery, occasional pulses of aluminum were related to precipitation and subsequent river inflow events (e.g., upper reservoir area, Station H2, January 1999). All mercury concentrations were below the laboratory-reporting limit of 0.2 µg/L during both years. Mean copper concentrations were below the North Carolina action level of 7 µg/L in both years. However, 25 percent of the 1999 copper values were above the action level. Copper levels exceeding the action level have been observed in previous studies and the source of the copper was apparently from an unknown source(s) in the river basin (CP&L 1995; NCDWQ 1998, 2002a).

Pee Dee River Reach from the Tillery Development to Blewett Falls Lake

The water quality in this reach of the Pee Dee River was spatially and temporally influenced by operations of the Tillery Hydroelectric Plant and inputs from tributaries from the intervening watershed, most notably the Rocky River (Tables E-7 and E-8). The water quality in the river reach above the Rocky River confluence generally reflected characteristics of Lake Tillery due to the deep, hypolimnetic discharge of reservoir waters through the power plant. Nutrients, solids constituents, anions, and cations, hardness, alkalinity, and trace metals were similar between the immediate tailwaters area and Lake Tillery bottom waters based on a comparison of the 2000 data (Tables E-2 and E-7). The majority of BOD and COD values in the tailwaters area were less than respective reporting limits during 2000 and 2001 (Appendix E.2).

From the confluence of the Rocky River to Blewett Falls Lake, the water quality characteristics were influenced primarily by Rocky River inflow. The effect of this inflow on the Pee Dee River can be observed in the water quality data collected during 2000 and 2001 (Tables E-7 and E-8; Figures E-13 and E-14). During 2001, the majority of monitored variables — most solids and nutrient constituents, COD, anions and cations, hardness, total alkalinity, specific conductance, and trace elements — were significantly greater in the Rocky River compared to the two Pee Dee River stations. The 2000 data corroborated the Rocky River influence as a similar statistical pattern was observed in water quality variable between the immediate tailwaters (Station 1B) compared to the downstream mid-reach area (Station 12B). Turbidity values, concentrations of most solids and nutrient constituents, calcium, magnesium, aluminum, and copper were significantly greater at Station 12B compared to values at Station 1B (Table E-7). The spatial pattern of copper concentrations during both years indicated an unknown source of copper entering the reach from the Rocky River (Appendix E.2; Tables E-7 and E-8). The copper concentration was at the North Carolina action level of 7.0 µg/L during May 2001 in the Rocky River. The drought conditions during 2000 and 2001 most likely magnified the effects of point source discharges on water quality within the entire river basin, including the Rocky River watershed (NCDWQ 2002a).

These spatial differences indicated both point and nonpoint discharges in the Rocky River watershed were affecting a major portion of this river reach, as well as Blewett Falls Lake, and the immediate downstream reach of the Pee Dee River below the Blewett Development. Significant inputs of nutrients, sediments, and associated solids from the Rocky River occurred after high precipitation and stream flow events. In several instances, the turbidity at Station 12B was approximately two to three times greater than the North Carolina water quality standard (Appendix E.2; Figures E-13 and E-14).

The water temperature and DO regimes in this river reach were influenced to an extent by the hydroelectric plant discharge (Figures E-13 and E-14). Water temperatures were moderated in this reach by the power plant discharge and remained cooler than downstream surface water temperatures in Blewett Falls Lake and the reach of the Pee Dee River below the Blewett Development (Tables E-8, E-9, E-11, and E-12; Figures E-13 to E-17). No statistical differences were found in either mean temperatures or DO concentrations between the immediate tailwaters area and the middle portion of the reach at North Carolina Highway 109 Bridge (Station 12B) during 2000 and 2001 (Tables E-7 and E-8). There were also no statistical differences in mean temperatures of the two Pee Dee River stations when compared to the Rocky River station during 2001 (Table E-8).

Onset Stowaway® Tidbit® continuous temperature recording devices were used to evaluate the differences in the temperature regimes between this Pee Dee River reach and the reach below the Blewett Development (Figures E-15 and E-16). These devices were operating during January 2000 to April 2001 (Station 12B below Tillery Development and Station 1B below Blewett

Development) and January through August 2002 (Stations 1B and 12B below Tillery Development and Stations 1B, 2B, 3B, 4B, and 5B below the Blewett Development).

For the period of January 2000 to April 2001, the temperature regime in the Pee Dee River reach below the Tillery Development was significantly cooler than the immediate tailwaters below the Blewett Development (Figure E-15). The annual mean temperatures of the two reaches were 15.9 and 16.7 °C, respectively, with a mean difference of 1.3 °C (Figure E-15). Furthermore, the January through August 2002 data also showed significant differences ($P < 0.001$) with the mean temperature gradient as shown in Table 4-1.

TABLE 4-1
PEE DEE RIVER TEMPERATURE REGIME

Station	Location	(°C)[+]
1B	Pee Dee River, N.C. below Tillery — NC Highway 731	16.3[f]
12B	Pee Dee River, N.C. below Tillery — NC Highway 109	18.0[e]
1B1	Pee Dee River, NC. at Blewett Falls Hydroelectric Plant Discharge	18.5[d]
1B2	Pee Dee River, N.C. below Blewett — U.S. Highway 74	19.1[c]
2B	Pee Dee River, S.C. below Blewett — U.S. Highway 1	20.1[b]
3B	Pee Dee River, S.C. below Blewett — S.C. Highway 15/401	20.0[b]
4B	Pee Dee River, S.C. below Blewett — U.S. Highway 76	20.0[b]
5B	Pee Dee River, S.C. below Blewett at Staples Lake Landing	20.8[a]

[+]Different letter superscripts indicated statistically different mean values.

The lag time associated with warming of temperatures in the river reach below the Tillery Development during the spring and early summer months of 2002 appeared to be approximately 2 to 4 weeks compared to the river reach below the Blewett Development (Figure E-16).

DO concentrations in the river reach below Tillery were affected during the warmer summer months (June through September) by the power plant withdrawal of anoxic, stratified bottom waters from Lake Tillery (Tables E-8 and E-9; Figures E-13 and E-14). DO concentrations were below the North Carolina water quality standard (5.0 mg/L) on four occasions during the monitoring period of 1999 to 2001 — twice in the mid-reach area (Station 12B) during August 1999 (4.6 mg/L) and July 2001 (4.5 mg/L) and twice in the immediate tailwaters area (Station

1B) during June and September of 2000 (3.5 mg/L and 3.0 mg/L respective values) (Appendix E.1; Figures E-13 and E-14).

Pee Dee River Reach Below the Blewett Development

The water quality of the immediate downstream area of this river reach (Station 1B at U.S. Highway 74) closely resembled the water quality characteristics of Blewett Falls Lake due to the shallow depth of the power plant intake and the well-mixed lake water column (Tables E-9 and E-10). With increasing distance from the hydroelectric development (Stations 2B, 3B, 4B, and 5B), water quality characteristics were more influenced by physiographic topography changes, watershed inflow, natural inputs of organic matter, and point and nonpoint discharge sources. This reach transitioned from the Piedmont Fall Line zone into the Sandhills and Coastal Plain physiographic regions with changes in several physical features including channel gradient, substrate and soil properties, and land use patterns.

Waters of this reach were near neutral to slightly acidic in pH, moderately soft, and with low buffering capacity. Turbidity values and nutrient and solids concentrations were moderate to elevated in this reach and widely varied both spatially and temporally. Nutrients and solids generally increased with increasing distance from the hydroelectric development from the Piedmont to Coastal Plain regions as demonstrated by the statistical rankings of mean station values (Tables E-9 and E-10).

Water quality characteristics changed as the river transitioned from a Piedmont river (Stations 1B and 2B) to a Coastal Plain river in South Carolina (Stations 3B, 4B, and 5B). Total organic carbon concentrations were significantly greater in the lower reach due to organic matter inputs from blackwater tributaries and swamps. Sodium, chloride, and sulfate also become significantly more predominant in the lower river reach with a corresponding increase in specific conductance. Chlorophyll *a* concentrations were generally low except for elevated levels observed in the lower river reach (Station 5B) during the summer months of 1999 and 2001.

Total nitrogen values were elevated at Stations 3B and 4B during September 1999 with values of 4.9 and 5.8 mg/L, respectively, and most likely reflected inputs from a high stream flow event associated with the passage of Hurricane Floyd through the area (Appendix E.2; Figure E-1). Most other water quality variables, including total phosphorus, were also elevated at these two stations after this high flow event.

There was no significant difference in annual mean temperatures or DO concentrations at the five river reach stations during 1999 or 2001 (Tables E-9 and E-10; Figures E-17 and E-18). However, as discussed previously, significant differences were observed in the temperature regime of the river reach during January through August of 2002 based on continuous recorder data (Figure E-16) (see *Pee Dee River Reach from the Tillery Development to Blewett Falls Lake* section).

DO concentrations below the North Carolina water quality standard of 5.0 mg/L occurred at Station 1B, immediately below the Blewett Hydroelectric Plant, on two occasions during 1999 and 2001; a measurement of 4.4 mg/L on August 2, 1999, and a measurement of 4.8 mg/L on August 19, 2001 (Appendix E.1; Figures E-17 and E-18). Dissolved oxygen concentrations remained above the water quality standard at the other downstream stations during these periods. The exact distance and duration of these low DO events in the river reach below the Blewett Hydroelectric Plant was not determined during the 1999 or 2001 water quality studies. However, rapid re-aeration most likely took place in the set of shoals immediately below Station 1B. Although there were no statistical differences, increases in DO concentrations were observed at Station 2B, downstream of Station 1B, as waters were re-aerated through series of shoals in the Fall Line zone between the stations during both years.

Turbidity values varied widely within the river reach during 1999 and 2001 with no explicit spatial statistical differences (Figures E-17 and E-18). No values exceeded the North Carolina or South Carolina water quality standard of 50 NTU during either year (Tables E-9 and E-10). Spatial differences in turbidity values from the two reaches of the Pee Dee River below the Tillery and Blewett Developments indicated that Blewett Falls Lake was trapping sediment inputs from the intervening watershed.

Aluminum concentrations did not vary significantly throughout the river reach in 1999, but there was a significant spatial trend during 2001 with greater values at downstream river stations

(Tables E-9 and E-10). All mercury concentrations were below the laboratory detection limit. Copper concentrations exhibited no spatially significant pattern in 1999, but concentrations were significantly greater in the lower river areas during 2001 (Table E-10). Three of the twelve copper concentrations at Station 1B were above the North Carolina action level of 7 µg/L during 1999 (Appendix E.2). South Carolina uses copper concentrations of 2.9 and 3.8 µg/L, respectively, for calculation of chronic and acute aquatic life toxicity for discharge permit limitations (SCDHEC 1976). Copper concentrations exceeded the acute level in 16 samples from South Carolina waters during 1999 and five samples during 2001 (total sample size during each year equaled 48) (Appendix E.2). Elevated copper concentrations were cited as an impairment of aquatic life use in the river at South Carolina Highway 34 (SCDHEC 2002b).

4.4 Aquatic Resources

4.4.1 Fishery Resources

4.4.1.1 Fishery Management Activities

Fishery management studies conducted by the NCWRC on Lake Tillery and Blewett Falls Lake since the 1960s have primarily assessed the largemouth bass and crappie populations (Tatum 1960; Van Horn et al. 1981, 1986; Chapman 1983; Van Horn and Jones 1990). These studies were primarily designed to determine abundance, size, and age structure, young-of-year recruitment, and relative body condition of these sport fishes as related to harvest by anglers. Other fishery management activities have focused on the development of white bass fisheries within the reservoir-tailwater systems and a put-grow-and-take stocking program to develop striped bass fisheries within both reservoirs.

The NCWRC has stocked several species of sport fish in Lake Tillery and Blewett Falls Lake since the 1950s to enhance the reservoir sport fisheries and angler utilization (Tatum 1960; NCWRC 1966). Eight species have been stocked in Lake Tillery and included channel catfish, striped bass, white bass, bluegill, redear sunfish, largemouth bass, northern pike, and walleye. Of these species, only northern pike and walleye failed to develop viable populations. Smallmouth bass have been reportedly caught on occasion by anglers from Lake Tillery based on anecdotal