

LAKE & RESERVOIR ASSESSMENTS ROANOKE RIVER BASIN



Lake Isaac Walton

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TABLE OF CONTENTS

TABLES.....	3
GLOSSARY	4
OVERVIEW.....	6
ASSESSMENT METHODOLOGY	6
ASSESSMENT BY 8-DIGIT HUC	
HUC 03010102	
John H. Kerr Reservoir	8
HUC 03010103	
Hanging Rock Lake	9
Kernersville Reservoir	10
Belews Lake.....	11
HUC 03050104	
Farmer Lake	12
Hyc0 Lake.....	14
Lake Roxboro.....	15
Mayo Reservoir.....	16
Lake Isaac Walton	17
HUC 03050106	
Roanoke Rapids Lake	18
HUC 03010106	
Lake Gaston.....	20
REFERENCES.....	21

Appendix A. Roanoke River Basin Lakes Use Support Matrix

Appendix B. Roanoke River Basin Lakes Use Support Data

Tables

Table 1. Results of Kernersville Reservoir Algal Growth Potential Test – August 26, 2009.....	12
Table 2. Results of Roanoke Rapids Reservoir Algal Growth Potential Test – August 26, 2009.	19

GLOSSARY

Algae	Small aquatic plants that occur as single cells, colonies, or filaments. May also be referred to as phytoplankton, although phytoplankton are a subset of algae.
Algal biovolume	The volume of all living algae in a unit area at a given point in time. To determine biovolume, individual cells in a known amount of sample are counted. Cells are measured to obtain their cell volume, which is used in calculating biovolume
Algal density	The density of algae based on the number of units (single cells, filaments and/or colonies) present in a milliliter of water. The severity of an algae bloom many be determined by the algal density as follows: Mild bloom = 20,000 to 30,000 units/ml Severe bloom = 30,000 to 100,000 units/ml Extreme bloom = Greater than 100,000 units/ml
Algal Growth Potential Test (AGPT)	A test to determine the nutrient that is the most limiting to the growth of algae body of water. The sample water is split such that one sub-sample is given additional nitrogen, another is given phosphorus, a third may be given a combination of nitrogen and phosphorus, and one sub-sample is not treated and acts as the control. A specific species of algae is added to each sub-sample and is allowed to grow for a given period of time. The dry weights of algae in each sub-sample and the control are then measured to determine the rate of productivity in each treatment. The treatment (nitrogen or phosphorus) with the greatest algal productivity is said to be the limiting nutrient of the sample source. If the control sample has an algal dry weight greater than 5 mg/L, the source water is considered to be unlimited for either nitrogen or phosphorus.
Centric diatom	Diatoms photosynthetic algae that have a siliceous skeleton (frustule) and are found in almost every aquatic environment including fresh and marine waters, soils, in fact almost anywhere moist. Centric diatoms are circular in shape and are often found in the water column.
Chlorophyll a	Chlorophyll a is an algal pigment that is used as an approximate measure of algal biomass. The concentration of chlorophyll-a is used in the calculation of the NCTSI, and the value listed is a lake-wide average from all sampling locations.
Clinograde	In productive lakes where oxygen levels drop to zero in the lower waters near the bottom, the graphed changes in oxygen from the surface to the lake bottom produces a curve known as clinograde curve.
Cocoid	Round or spherical shaped cell
Conductivity	This is a measure of the ability of water to conduct an electrical current. This measure increases as water becomes more mineralized. The concentrations listed are the range of values observed in surface readings from the sampling locations.
Dissolved oxygen	The range of surface concentrations found at the sampling locations.
Dissolved oxygen saturation	The capacity of water to absorb oxygen gas. Often expressed as a percentage, the amount of oxygen that can dissolved into water will change depending on a number of parameters, the most important being temperature. Dissolved oxygen saturation is inversely proportion to temperature, that is, as temperature increases, water's capacity for oxygen will decrease, and vice versa.
Eutrophic	Describes a lake with high plant productivity and low water transparency.

Eutrophication	The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a lake.
Limiting nutrient	The plant nutrient present in lowest concentration relative to need limits growth such that addition of the limiting nutrient will stimulate additional growth. In north temperate lakes, phosphorus (P) is commonly the limiting nutrient for algal growth
Manganese	A naturally occurring metal commonly found in soils and organic matter. As a trace nutrient, manganese is essential to all forms of biological life. Manganese in lakes is released from bottom sediments and enters the water column when the oxygen concentration in the water near the lake bottom is extremely low or absent. Manganese in lake water may cause taste and odor problems in drinking water and require additional treatment of the raw water at water treatment facilities to alleviate this problem.
Mesotrophic	Describes a lake with moderate plant productivity and water transparency
NCTSI	North Carolina Trophic State Index was specifically developed for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (NRCD 1982). It takes the nutrients present along with chlorophyll a and Secchi depth to calculate a lake's biological productivity.
Oligotrophic	Describes a lake with low plant productivity and high water transparency.
pH	The range of surface pH readings found at the sampling locations. This value is used to express the relative acidity or alkalinity of water
Photic zone	The portion of the water column in which there is sufficient light for algal growth. DWQ considers 2 times the Secchi depth as depicting the photic zone.
Secchi depth	This is a measure of water transparency expressed in meters. This parameter is used in the calculation of the NCTSI value for the lake. The depth listed is an average value from all sampling locations in the lake.
Temperature	The range of surface temperatures found at the sampling locations.
Total Kjeldahl nitrogen	The sum of organic nitrogen and ammonia in a water body. High measurements of TKN typically results from sewage and manure discharges in water bodies.
Total organic Nitrogen (TON)	Total Organic Nitrogen (TON) can represent a major reservoir of nitrogen in aquatic systems during summer months. Similar to phosphorus, this concentration can be related to lake productivity and is used in the calculation of the NCTSI. The concentration listed is a lake-wide average from all sampling stations and is calculated by subtracting Ammonia concentrations from TKN concentrations.
Total phosphorus (TP)	Total phosphorus (TP) includes all forms of phosphorus that occur in water. This nutrient is essential for the growth of aquatic plants and is often the nutrient that limits the growth of phytoplankton. It is used to calculate the NCTSI. The concentration listed is a lake-wide average from all sampling stations.
Trophic state	This is a relative description of the biological productivity of a lake based on the calculated NCTSI value. Trophic states may range from extremely productive (Hypereutrophic) to very low productivity (Oligotrophic)
Turbidity	A measure of the ability of light to pass through a volume of water. Turbidity may be influenced by suspended sediment and/or algae in the water.
Watershed	A drainage area in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Overview

The Roanoke River basin extends from its source in the Blue Ridge Mountains of Virginia to the Albemarle Sound in North Carolina, encompassing mountainous, piedmont, and coastal topography as it flows generally east- southeastward. This North Carolina constitute 3,503 square miles of drainage area and approximately 2,389 miles of streams and rivers. Fifteen counties and 42 municipalities are also included in the basin. The ecoregions associated with this river basin include the Sauratown Mountains; the Triassic Basins, Southern Outer Piedmont, Northern Inner Piedmont, Carolina Slate Belt, Northern Outer Piedmont; the Rolling Coastal Plain, Southeastern Floodplains and Low Terraces, the Mid-Atlantic Flatwoods and Mid-Atlantic Floodplains and Low Terraces (Griffith *et al* 2002). Though the spread of urban and suburban development has occurred in the Roanoke River basin as elsewhere in the state, the greatest portion of land cover in the basin has remained forest and, to a lesser extent, agriculture-based. Also characteristic of activities throughout the state, nonpoint source runoff and numerous small point source dischargers associated with development and agricultural activities have great potential to affect water quality in the basin (NCDENR, April 2005).

Eleven lakes were sampled in this river basin by DWQ staff in 2009. Three of these lakes, Farmer Lake, Lake Roxboro and Kernersville Lake, were also sampled in 2007. Kernersville Lake was greater than the chlorophyll *a* water quality standard on two sampling trips, but only nine samples of chlorophyll *a* were collected in 2009 and the lake was not impaired for this parameter based on the required protocol for impairment (i.e., data collected from no less than ten samples during the five-year sampling period). Farmer Lake and Lake Roxboro were sampled in 2007 in addition to 2009 for a total of 15 sampling trips. Farmer Lake was determined to be Supporting while Lake Roxboro was determined to be Impaired for chlorophyll *a*.

Lake Gaston and Roanoke Rapids Lake have been placed on the 303(d) List of impaired surface water for nuisance levels of aquatic weeds. A statewide fish consumption advisory for largemouth bass due to mercury contamination was issued by the NC Department of Health and Human Services, Division of Public Health. This advisory includes lakes in Roanoke River Basin which might support largemouth bass (<http://www.epi.state.nc.us/epi/fish/current.html>).

Following the description of the assessment methodology used for the Roanoke River Basin, there are individual summaries for each of the lakes and a two-paged matrix that distills the information used to make the lakes use support assessments.

Assessment Methodology

For this report, data from January 1, 2005 through September 30, 2009 were reviewed. All of the lakes in this report were sampled only during the summer of 2009 in May through September and of these lakes, three were also sampled in 2007 (see above). Data were assessed for excursions of the state's water quality standards for chlorophyll *a*, pH, dissolved oxygen, water temperature, and turbidity as they apply to lake's use classification (i.e., general surface water or Class C, Class B, Water Supply (WS), etc.). Other parameters discussed in this report include Secchi depth and percent dissolved oxygen saturation. Secchi depth provides a measure of water clarity and is used in calculating the trophic or nutrient enriched status of a lake. Percent dissolved oxygen saturation gives information on the amount of dissolved oxygen in the water column and may be increased by photosynthesis or depressed by oxygen-consuming decomposition.

A water quality standard is exceeded (denoted by CE in matrix) if data values do not meet the state's water quality standard for more than 10% of the samples where the sample size consists of 10 or more observations for the basinwide assessment period. Ideally, ten observations are needed to provide sufficient data for a reasonable interpretation of water quality conditions within the lake or reservoir. Fewer observations increase the possibility of misinterpreting random unusual conditions as

representative of ongoing water quality trends, but are still useful for identifying possible water quality issues and targeting particular lakes for more intensive study and support assessment. If the water quality standard is exceeded, either in less than 10% of the data collected during the assessment period or if the sample observation size is less than 10 for the basinwide assessment period, then the water quality standard for that parameter is designated exceeded (E in the matrix).

Additional data considered as part of the use support assessment include historic DWQ water quality data, documented algal blooms and/or fish kills, problematic aquatic macrophytes, or listing on the EPA's 303(d) List of Impaired Waters.

Lakes receive an overall rating of Supporting or Impaired when 10 or more samples per water quality criteria are collected for evaluation within the basinwide assessment period. Otherwise, the lake is considered as Not Rated. The exception is for a lake listed on the 303(d) List of Impaired Waters or where additional data indicates water quality problems not captured during sampling. These lakes are listed as Impaired along with the reason for the impairment.

For a more complete discussion of lake ecology and assessment, please go to <http://www.esb.enr.state.nc.us/>. The 1990 North Carolina Lake Assessment Report (downloadable from this website) contains a detailed chapter on ecological concepts that clarifies how the parameters discussed in this review relate to water quality and reservoir health.

HUC 03010102



John H. Kerr Reservoir

The John H. Kerr Reservoir (also called Kerr Lake) is a multipurpose impoundment constructed and operated by the US Army Corps of Engineers to provide flood control, recreation and hydroelectric power. The reservoir crosses the North Carolina-Virginia state line with the majority of the lake located in Virginia. Kerr Reservoir is the first of three chain lake impoundments on the Roanoke River in North Carolina. The reservoir has a mean hydraulic retention time of 124 days. Major tributaries to Kerr Lake include the Roanoke River, Hyco River, and the Dan River. Sampling of the lake is confined to the Nutbush Creek Arm because it is the only portion of the lake that lies within North Carolina. John H. Kerr Reservoir is classified B (or suitable for swimming).

Kerr Lake was sampled monthly from May through September in 2009. Surface dissolved oxygen was greatest in May and ranged from 8.3 mg/L to 8.8 mg/L. The lowest surface dissolved oxygen value was observed in August (7.2 mg/L). Surface pH values ranged from 8.4 s.u to 7.8 s.u. Secchi depths ranged from 0.9 to 2.6 meters, indicating that the clarity of the water was good. No violations of the state water quality standards for dissolved oxygen, water temperature or pH were observed for Kerr Lake in 2009. Total phosphorus concentrations in 2009 were low as were total Kjeldahl nitrogen and ammonia concentrations. Nitrite plus nitrate ranged from elevated in May to low in June through September. Total organic nitrogen values were moderate in 2009. Chlorophyll *a* values ranged from low to moderate (Appendix B) and no violations of the state water quality standard of 40 µg/L for chlorophyll *a* were observed. Based on the calculated NCTSI scores, Kerr Lake was determined to have low biological productivity (oligotrophic) in June and moderate productivity (mesotrophic) in May, July, August and September. In previous sampling years going back to 1981 when DWQ started to monitor this lake, the trophic state has been either mesotrophic or very productive (eutrophic). May 2009 was the first time the trophic state was determined to be oligotrophic.

The Nutbush Creek arm of Kerr Lake was placed on the 303(d) List of Impaired Surface Waters in 1998 for impaired biological integrity (related to the aquatic invertebrate community and population in the creek).

HUC 03010103



Hanging Rock Lake

Hanging Rock Lake is a 12 acre impoundment located within Hanging Rock State Park. The original earthen and concrete dam was built at this location in 1938 as a Civilian Conservation Corps project. The 445-acre watershed is primarily forested. Hanging Rock Lake has a classification of B (suitable for swimming).

This small lake was monitored monthly from May through September by DWQ staff from the Winston-Salem Regional Office. Surface dissolved oxygen ranged from 8.6 mg/L to 7.0 mg/L and surface water temperatures ranged from 19.5C in May to 28.0C in August. Secchi depths range from 3.0 to 3.5 meters, indicating that the clarity of the water was very good. This is also supported by the low turbidity levels which ranged from 1.7 to 2.0 NTU and the low suspended solids concentrations, which were below the DWQ Water Quality detection levels.

Nutrient concentrations in Hanging Rock Lake in 2009 were low. Total phosphorus, ammonia and nitrite plus nitrate values were below laboratory detection levels while total Kjeldahl nitrogen concentrations were low. In response to the low nutrient levels in this lake, chlorophyll *a*, and indicator of algal productivity, was also very low (range = 3.4 to 7.2 µg/L).

Based on the calculated NCTSI scores for 2009, Hanging Rock Lake was determined to have very low biological productivity (oligotrophic). This lake has been found to be consistently oligotrophic since it was first monitored by DWQ in 1985.



Kernersville Reservoir

Kernersville Reservoir, built in 1952, is a back-up water supply for the Town of Kernersville. The lake is an impoundment of Belews Creek. Since 1984, Kernersville has been buying their potable water from the City of Winston-Salem. The reservoir will continue to be maintained as an emergency water supply. Upstream land use in its 3.3 mi² drainage area has become industrialized. This small reservoir is classified as WS-IV and B.

Kernersville Reservoir was sampled five times in 2007 and five times in 2009 by DWQ staff. In 2007, Secchi depths were less than one meter, indicating that the clarity of the water was poor. Surface dissolved oxygen from May through July ranged from 7.9 to 6.5 mg/L, then dropped to 4.9 mg/L in August and 4.6 mg/L in September. Total phosphorus concentrations were moderate and total Kjeldahl nitrogen ranged from moderate to elevated. Both ammonia and nitrite plus nitrate were below the DWQ Water Quality Laboratory detection levels. Chlorophyll *a* values ranged from moderate to elevated. On September 13, 2007, the chlorophyll *a* value was 53 µg/L, which was greater than the state water quality standard of 40 µg/L. An algal analysis of a water sample collected on September 13, 2007 indicated the presence of an algal bloom dominated by the filamentous blue-green alga *Cylindrospermopsis sp.* and the euglenoid *Trachelomonas sp.* Both algae are associated with nutrient-rich water and are known to produce taste and odor problems in drinking water.

In 2009, Secchi depths were less than one meter (range = 0.6 to 0.8 meters). Surface dissolved oxygen ranged from 6.8 to 6.7 mg/L. Nutrient concentrations in 2009 were similar to those observed in 2007. Total phosphorus values were moderate and total Kjeldahl nitrogen was elevated. Ammonia and nitrite plus nitrate were generally below detection levels. Chlorophyll *a* ranged from 25 µg/L to 42 µg/L.

An Algal Growth Potential Test (AGPT) was performed in August 2009. A composite water sample from within the photic zone was collected at the sampling site and shipped to the EPA Region IV Laboratory in Athens, GA for analysis. The results of the test are shown below in Table 1. The lake water from the site was determined to be nitrogen limited (i.e., algal productivity was limited by the concentration of nitrogen present in the water).

Table 1. Results of Algal Growth Potential Test – August 26, 2009.

AGPT- MSC, mg/L (Dry Weight)

Station	Control	C+N	C+P	Limiting Nutrient
ROA0092A	1.38	3.62	1.43	N

AGPT - Algal Growth Potential Test

MSC - Maximum Standing Crop

C+N - Control + 1.0 mg/L Nitrate-N

C+P - Control + 0.05 mg/L Phosphate-P

FW - Freshwater AGPT using *Selenastrum* as test alga

Based on the calculated NCTSI scores, Kernersville Reservoir was determined to have elevated biological productivity (eutrophic) in 2007 and 2009. This reservoir has been found to be eutrophic since it was first monitored by DWQ in 1985, with the exception of 1994 when it was found to have moderate productivity (mesotrophic). Of nine chlorophyll *a* samples collected from 2007 through 2009, two samples were greater than the state water quality standard of 40 µg/L.



Belews Lake

Belews Lake is located on Belews Creek, a tributary of the Dan River. This lake is situated in the Northern Piedmont of North Carolina. Construction of the dam was completed in 1973. The lake was built by Duke Power Company to provide a source of condenser cooling water for the Belews Creek Steam Station. The maximum depth of Belews Lake is approximately 144 feet (44 meters). The 69.6 mi² hilly watershed is mostly forested and agricultural with some urban areas. Retention time is approximately 4.1 years. Belews Lake is classified WS-IV and C.

DWQ staff sampled Belews Lake five times from May through September 2009. Secchi depths ranged from 3.0 to 5.5 meters, which is indicative of very good water clarity for a piedmont lake. Surface dissolved oxygen in 2009 ranged from 6.2 to 8.2 mg/L and pH values ranged from 7.3 to 7.7 s.u. Elevated water temperatures were detected at some sampling locations in 2009 and are likely the result of thermal discharge from the coal-fired power plant.

Total phosphorus and ammonia concentrations were consistently less than the Division of Water Quality Laboratory detection levels. Total Kjeldahl nitrogen concentrations were low and nitrite plus nitrate values were below laboratory detection levels from June through September. In May, the concentrations of nitrite plus nitrate were moderate. Chlorophyll a values were low and were similar to values previously observed in this lake since 1981 when it was first monitored by DWQ. Based on the calculated NCTSI scores, Belews Lake was determined to have very low biological productivity (oligotrophic) in 2009 and has been consistently oligotrophic since 1981.

As required by the NPDES permit (NC00233306) for Belews Creek Steam Station ash basin effluent, Duke Energy is required to monitor upstream and downstream of the ash basin discharge. In 2007, the Dan River water quality was determined to be similar to that observed in previous monitoring years. Both sulfate and magnesium concentrations were found to be greater downstream than upstream of the ash basin discharge, however these differences were of very low magnitude (<1.0 mg/L). As in previous sampling years, concentrations of arsenic, cadmium and selenium were consistently below laboratory detection limits and North Carolina state water quality standards (Duke Energy, December 2008).

During the latter seven months of 2007, drought conditions in the region substantially reduced the surface elevation of Belews Lake. Declines in the lake level threatened the availability of cooling water for and operation of the Belews Creek Steam Station. In January 2008, regulatory approval was granted for winter 2008 pumping of Dan River water to provide aid for Belews Lake water levels. Pumping from the Dan River started on January 22, 2008 and ended on March 31, 2008. Subsequent spring tributary flows increased the lake level and brought the lake to full pond level by April 9, 2008. Duke Energy monitored the water quality of Belews Lake monthly during the pumping operation and in 2008, released a report on the results of that monitoring. The 2008 report stated that, as shown during the 2002-2003 pumping operation, water quality impacts were: 1) limited primarily to the immediate vicinity of the pump outlets in the lake; 2) of transient duration (i.e., days as opposed to weeks); and 3) insignificant when compared to effects of 1998-2002 drought or seasonal storm runoff related events (Duke Energy, July 2008).

HUC 03010104



Farmer Lake

Farmer Lake, a water supply reservoir for the City of Yanceyville, was built in 1983. The reservoir is an impoundment of an unnamed tributary of Country Line Creek in Caswell County. Farmer Lake is also used extensively for fishing with a boat ramp located near the dam. The land uses within the watershed include agriculture and forests. Farmer Lake is classified WS-II HQW CA (CA = watershed critical area)

DWQ staff sampled this lake once a month from May through September in 2007 and ten times in 2009 (twice a month from May through September). Secchi depths were less than one meter with the exceptions of measurements taken near the dam, which were approximately a meter. Secchi depths of less than a meter are usually indicative of poor water clarity. This lake was thermally stratified during the summers of 2007 and 2009 with a thermocline present at a depth between three to four meters from the surface near the dam. From the point of the thermocline to the lake bottom, dissolved oxygen concentrations were hypoxic (4.0 mg/L or less). By late June, Farmer Lake exhibited very strong thermal stratification with dissolved oxygen concentrations at four to five meters from the surface ranging from 0.7 mg/L to 0.2 mg/L.

Total phosphorus concentrations ranged from moderate to elevated and total Kjeldahl nitrogen was elevated in 2007 and 2009. Ammonia and nitrite plus nitrate concentrations were low. Chlorophyll a values ranged from moderate to elevated. At the most upstream lake sampling site (ROA027G), chlorophyll a values were greater than the state water quality standard of 40 µg/L on seven sampling dates between 2007 and 2009 (Appendix B). This equaled a 47% exceedance of the chlorophyll a standard for this one sampling site. Turbidity at site ROA027G also exceeded the state water quality standard of 25 NTU five times or 33% of the sampling trips in 2007 and 2009.

In 2007, four photic zone phytoplankton samples from two stations were analyzed – three samples from the upper end of the lake (ROA027G) collected in June, August and September and one sample from near the dam (ROA027L) collected in July. Chlorophyll a values on the days these phytoplankton samples were collected were greater than the state water quality standard of 40 µg/L. The blue-green alga, *Cylindrospermopsis sp.* was dominant at the upstream sampling site on and *Planktolyngbia sp.* was dominant at the sampling site near the dam. Blue-green algae blooms commonly occur in the Piedmont during the late summer months in lakes and ponds and are associated with waters with elevated nutrient concentrations.

In 2009, analysis of phytoplankton samples collected from Farmer Lake determined the presence of blooms, which began in June and continued throughout September. These blooms were determined to be at severe levels beginning in June (the unit density was between 30,000 and 100,000 units/ml) and dominated by filamentous blue-green algae – primarily *Cylindrospermopsis sp.*, which comprised up to 80% of the total density. Euglenoids were also present and frequently dominated the assemblages in terms of biovolume. Blue-green algae are common indicators of nutrient enrichment. Blooms may cause unsightly water discoloration, surface films and mats, along with taste and odor problems in drinking water if advanced treatment is not employed. Euglenoids are found in waters rich in organic matter and may cause water discolorations that range from red or brown to green. Dense numbers of euglenoids may cause surface films that are often described as looking like spilled paint.

Farmer Lake was determined to have elevated biological productivity (eutrophic) in 2007 and 2009 based on the calculated NC Trophic State Index Scores. Due to the documented presence of algal blooms and elevated chlorophyll a values in the upper end of this lake, continued monitoring is advised. Sampling site ROA027G exceeded the state water quality standards for chlorophyll a and turbidity for more than 10% of the 15 sampling events for that site.

Subbasin 030205



Hyco Lake

Hyco Lake is located on the Hyco River approximately three miles south of the North Carolina-Virginia State line in Person and Caswell Counties. This reservoir was constructed in 1965 to provide cooling water for the Carolina Power & Light Company (currently Progress Energy) Roxboro Steam Plant. Hyco Lake has maximum depth of 49 feet (15 meters) and a mean hydraulic retention time of 180 days. The drainage area for Hyco Lake is characterized by rolling hills and land use along the 159 mile (256 kilometer) shoreline is primarily residential, forested, and agricultural. Hyco Lake is classified WS-V B.

Secchi depths in 2009 ranged from 1.1 to 2.5 meters, indicating good water clarity. Surface physical parameters (dissolved oxygen, pH and water temperature) were similar to measurements observed in previous sampling years. Surface conductivity, however, was much higher in 2009 than in previous sampling years and ranged from 189 to 281 umhos/cm. Total solids were also greater in 2009 (range = 160 to 260 mg/L) while total suspended solids and turbidity values were similar to those observed in previous years.

Nutrient concentrations in Hyco Lake generally ranged from low to moderate and chlorophyll *a* values ranged from 2.6 to 22 µg/L. The highest chlorophyll *a* value (22 µg/L) was observed on June 22 in the South Hyco Creek arm of the reservoir, downstream of the NC Hwy 57 Bridge. This was the greatest chlorophyll *a* concentration recorded since DWQ monitoring first began monitoring Hyco Reservoir in 1983. Based on the calculated NCTSI scores, Hyco Lake was determined to moderate biological productivity in 2009.

In 2008, Progress Energy notified the Raleigh Regional Office (RRO) of DWQ that the FGD wastewater settling basin was seeping and at risk of failure. To reduce this risk, Progress Energy dewatered the settling basin into the adjacent ash pond to reduce the hydraulic head in the settling basin. On February 27, 2008, Progress Energy notified RRO staff that an 8 to 12 foot wide berm failure had occurred on the flush pond berm, allowing water from the pond to discharge into the adjacent Ash Pond. According to Progress Energy, at the time of the berm failure, the flush pond only contained start up water and not backwash water from the FGD Bioreactor. The RRO requested Progress Energy to conduct additional sampling of both lake surface water and adjacent ground water in an effort to determine changes or effects of the waste streams as a result of the treatment unit failure, bypass and changes in the treatment capacities of the settling basin. This sampling effort was conducted eight times in March and April. Data from this monitoring effort revealed elevated levels of thallium, selenium, copper, beryllium, silver, mercury and antimony in the effluent stream from outfall 003 in Hyco Lake and from a non-potable well located within 500 feet of the FGD Settling Pond and the FGD Flush Pond.

At the request of the Raleigh Regional Office, staff from DWQ's Intensive Survey Unit collected water and sediment samples on July 21, 2008 from various lake sites near the FGD wastewater treatment system along with two additional sites located upstream and downstream of the facility. Results of this sampling indicated that elevated metals detected by Progress Energy in the spring were now at very low levels or below DWQ laboratory detection levels. Thallium was present in the sediment samples along with vanadium and selenium, however, water samples collected near the bottom of the reservoir at the three sediment sampling sites exhibited concentrations of these metals below the DWQ laboratory's detection levels. Physical measurements taken at each sampling site were similar to those observed in the past with the exception of conductivity values, which were the greatest recorded by DWQ staff since 1983 when this reservoir was first monitored.

Progress Energy monitors the limnology and fisheries in Hyco Lake. The primary objective of this program is to provide an assessment of the effect of the operation of the Roxboro Steam Electric Plant on the water and aquatic life in Hyco Lake. The most recent monitoring effort was conducted in 2008. No significant changes in the physical parameters and nutrient concentrations of the lake were observed. In 2008, increases in the annual mean concentrations of hardness, some ions and in specific conductance were observed in the vicinity of the power plant discharge. These increases were attributed to operations of the new FGD system. Although slight increases in arsenic and selenium were observed near the power plant outfall, these values were not greater than the applicable state water quality standards (Progress Energy, August 2009)



Lake Roxboro

Lake Roxboro is located in Caswell and Person Counties near the Town of Roxboro and covers 195 acres (79 hectares). The lake, which is an impoundment of South Hyco Creek, was filled in 1978 and is owned by the Town of Roxboro. Land uses in the watershed include agriculture, forest, and residential areas. Lake Roxboro is classified WS-II B HQW (High Quality Water).

DWQ staff sampled this lake once a month from May through September in 2007 and twice a month from May through September in 2009. Secchi depths in May, 2007 ranged from 1.2 to 1.5 meters. These were the greatest Secchi depths observed at this lake for the two years. Generally, Secchi depths near the dam were close to one meter, while measurements at the mid and upper lake sampling sites were less than a meter. Secchi depths less than a meter are indicators of poor water clarity. Thermal stratification of this lake was present by May with the thermocline occurring at a depth of approximately three to four meters from the surface. Dissolved oxygen concentrations at the thermocline were

frequently hypoxic (less than 4.0 mg/L) near the dam (ROA030DE). Below four meters, the concentration of dissolved oxygen ranged from 0.3 to 0.1 mg/L (depth to bottom approximately 10 meters).

Total phosphorus concentrations in 2007 and 2009 ranged from moderate to elevated, with the greatest concentrations of this nutrient occurring at the most upstream lake sampling site (ROA030DA). Total Kjeldahl nitrogen concentrations were elevated at all three lake sampling sites. Ammonia and nitrite plus nitrate ranged from less than DWQ Water Quality laboratory detection limits to moderate. Chlorophyll *a* values ranged from moderate to elevated. Concentrations greater than the state water quality chlorophyll *a* standard of 40 µg/L occurred six times between 2007 and 2009 and always at sampling site ROA030DA. Lakewide mean chlorophyll *a* values were greater than the state water quality standard in two out of 15 sampling trips (13%).

Water samples were collected on each of the five sampling trips for analysis of algae in the lake's photic zone. Based on an analysis of samples collected at ROA030DA at the uppermost end of Lake Roxboro, severe algal blooms were recorded in May, July, August and September 2009. A small diatom (*Achnanthisidium sp.*) dominated the algal bloom in May. By July, blue-green algae dominated the phytoplankton assemblage and these blooms continued through September. *Cylindrospermopsis sp.* was the dominant species present in these blooms. Euglenoids were also present in samples collected in June through August. Both blue-green algae and euglenoids are associated with nutrient-rich waters. Blue-green algae may discolor surface waters along with forming flecks, films and/or mats. Euglenoids may produce dramatic surface films ranging in color from red to brown and green. These films are often described as looking like spilled paint on the surface of the lake.

Lake Roxboro was determined to have elevated biological productivity (eutrophic) in 2007 and 2009 based on the calculated NCTSI scores, and is also Impaired for elevated levels of chlorophyll *a*.



Mayo Reservoir

Mayo Reservoir is located on Mayo Creek in Person County just south of the Virginia border and covers 2,800 acres (1,133 hectares). Owned by Progress Energy, the reservoir was completed in 1983 to provide cooling water for the Mayo Electric Generating Plant. Mayo Reservoir has an average retention time of 36 months. The drainage area is characterized by rolling hills with forests and agriculture.

Secchi depth ranged from 1.5 to 4.0 meters, indicating good water clarity. Surface physical parameters (dissolved oxygen, pH and water temperature) in 2009 were similar to those values observed in this reservoir since it was first monitored by DWQ in 1983. Conductivity values, however, were greater in 2009 (range = 111 to 166 $\mu\text{mhos/cm}$). Total solids were also greater in 2009 than in previous years (range = 80 to 130 mg/L) while values for turbidity and total solids remained the same.

Total phosphorus, nitrite plus nitrate and ammonia concentrations were very low in 2009 while total Kjeldahl nitrogen ranged from low to moderate. Chlorophyll *a* values were also low in 2009 (range = 3.1 to 14 $\mu\text{g/L}$). Based on the calculated NCTSI scores, Mayo Reservoir was determined to exhibit very low biological productivity in May, August and September, and moderate productivity (mesotrophic) in June and July

Progress Energy monitored the water, sediments and fisheries of this reservoir in 2008 as required by the National Pollutant Discharge Elimination System (NPDES) Permit No. 003837. Nutrient concentrations in 2008 were relatively low and similar among all of the sampling stations with the exceptions of phosphorus and total organic nitrogen. The concentrations for these nutrients were found to be higher in the upper reservoir. Chlorophyll *a* concentrations were less than the state water quality standard of 40 $\mu\text{g/L}$ at all of the lake sampling sites. Trace elements measured along a transect extending from the location of the power plant ashpond discharge to the opposite lake shore were low or below laboratory detection levels. The greatest levels of trace elements were observed near the ashpond discharge. (Progress Energy, April 2009).



Lake Isaac Walton

Lake Isaac Walton (also called Roxboro Lake) is located in Person County near the Town of Roxboro and is the primary water supply for the town. The lake was built in the 1930's. Satterfield and Storys Creek are the main tributaries. Maximum depth is about 23 feet (seven meters) and retention time is approximately 30 days. The watershed is comprised of agricultural land, pastures, and residential areas. Lake Isaac Walton is classified WS-II HQW CA.

This lake was sampled monthly from May through September in 2009. Secchi depths at the sampling site near the dam and near the middle of the lake ranged from 2.1 meters to 1.2 meters, indicating good water clarity. The third sampling site located in a upstream cove had Secchi depths that ranged from 0.8 meters to 0.5 meters. These low readings indicated that the clarity of the water at this sampling site was greatly reduced as compared with the rest of the lake. In September, the Secchi depths at all three lake

sampling sites were less than one meter. Field notes indicate that the level of Lake Isaac Walton had dropped by three feet in September.

The highest surface dissolved oxygen reading was observed at the upstream sampling site in June (9.6 mg/L) and the lowest dissolved oxygen reading was observed at this site in September (5.0 mg/L). In 2009, pH values at the lake surface were within state water quality standards.

Total phosphorus concentrations were low near the dam and the middle of the lake, but elevated at the sampling site in the cove. Total Kjeldahl nitrogen was elevated while nitrite plus nitrate and ammonia concentrations were generally low. Chlorophyll *a* values ranged from low to elevated, with the highest chlorophyll *a* value observed near the dam in August (35 µg/L). In August, a green film was observed along the shoreline near the upper end of the lake. Analysis of a water sample taken at this bloom determined that the alga *Euglena sp.* was responsible for this bloom.

Based on the calculated NCTSI scores for 2009, Lake Isaac Walton was determined to be very biologically productive (eutrophic). This lake has been eutrophic since it was first monitored by DWQ in 1988.

HUC 03050106



Roanoke Rapids Lake

Roanoke Rapids Lake, located on the Roanoke River immediately downstream from Lake Gaston, is owned by the Virginia Electric and Power Company and used for hydropower generation as well as public recreation and as a water supply. Maximum depth is 89 feet (27 meters), mean depth is 16 feet (five meters), and volume is $96 \times 10^6 \text{m}^3$. The Roanoke River is the major tributary to the reservoir and drains nearly all of its 8,294 mi^2 (21,482 km^2) watershed. Releases from Lake Gaston located directly upstream account for almost all of the inflow into Roanoke Rapids Lake. This reservoir is classified Ws-IV B CA.

Roanoke Rapids Lake was sampled monthly from May through September 2009. Secchi depths ranged from 2.6 to 1.2 meters, indicating that the clarity of the lake water was good. In May, the lake was well oxygenated down to the bottom and not thermal stratification was observed. By July, hypoxic conditions (dissolved oxygen <4.0 mg/L) were present near the dam (sampling site ROA039E) at a depth of 8.0 meters from the surface (depth to bottom = 11.3 meters). Total phosphorus, ammonia and total Kjeldahl nitrogen values were low in 2009. Nitrite plus nitrate values were elevated in May through July, then dropped to levels below the Water Quality Laboratory detection limits in August and September.

In August, the surface dissolved oxygen value at the most upstream sampling site (ROA039C) was 11.2 mg/L and the pH value was 9.7 s.u. The combination of elevated dissolved oxygen and pH are suggestive of elevated photosynthetic activity. The chlorophyll *a* concentration at ROA039C in August was 13 µg/L, which was the highest chlorophyll *a* value observed for Roanoke Rapids Lake during the 2009. An analysis of a phytoplankton sample collected at this site on August 26 indicated that an algae bloom was present based upon biovolume which was greater than 10,000 mm³/m³ (13,000 mm³/m³) and that the assemblage was dominated by the diatom, *Aulacoseira* sp. This diatom forms chains that may consist of hundreds of cells. For comparison, a water sample collected at the mid-lake sampling site (ROA039D) had an algal biovolume less than 1,000 mm³/m³ and a cell density greater than that observed at ROA039C. *Aulacoseira* sp. was not present in the mid-lake water sample. The upstream lake sampling site in Roanoke Rapids Lake also has a significant amount of submerged aquatic plants and the combination of photosynthetic activity from the plants and the phytoplankton may account for the elevated dissolved oxygen and pH values.

An Algal Growth Potential Test (AGPT) was performed on Roanoke Rapids Lake in August 2009. Composite water samples from within the photic zone were collected at each of the three lake sampling sites and shipped to the EPA Region IV Lab in Athens, GA for analysis. The results of the test are shown below in Table 2. The lake water at all of the sites were determined to be nitrogen limited (i.e., algal productivity was limited by the concentration of nitrogen present in the water).

Table 2. Results of Roanoke Rapids Reservoir Algal Growth Potential Test – August 26, 2009.

AGPT- MSC, mg/L (Dry Weight)

Station	Control	C+N	C+P	Limiting Nutrient
ROA039E	0.53	0.78	0.55	N
ROA039C	0.46	1.67	0.40	N
ROA039D	0.61	0.94	0.44	N

AGPT - Algal Growth Potential Test

MSC - Maximum Standing Crop

C+N - Control + 1.0 mg/L Nitrate-N

C+P - Control + 0.05 mg/L Phosphate-P

FW - Freshwater AGPT using *Selenastrum* as test alga

Based on the calculated NCTSI scores in 2009, Roanoke Rapids Lake was determined to be moderately productive (mesotrophic). Historically, this lake has varied between moderate to low biological productivity with the exceptions of 1981 and 1982 when the trophic state was determined to be mildly elevated (eutrophic).

Roanoke Rapids Lake was placed on the 303(d) List of Impaired Waters for an infestation of aquatic weeds. A TMDL plan for this lake was approved by the EPA in September 2006 (http://h2o.enr.state.nc.us/tmdl/documents/AquaticWeedTMDL_Final_EPA.pdf). Hydrilla (*Hydrilla*

verticillata), Eurasian milfoil (*Myriophyllum spicatum*) and Brazilian elodea (*Egeria densa*) are the dominant aquatic weeds. Control of these plants has been primarily through the application of herbicides in problem areas.

LAKE & RESERVOIR ASSESSMENTS

HUC 03010106



Lake Gaston

Lake Gaston is located on the North Carolina - Virginia border just downstream from the John H. Kerr Reservoir dam on the Roanoke River. The lake was built in 1962 by the Virginia Electric and Power Company for generating hydroelectric power. The maximum depth of the lake is 29 meters with a mean depth of six meters. The volume of the lake is $512 \times 10^6 \text{m}^3$. Drainage area for the lake is comprised of forested land with some agriculture, residential development and urbanized areas. Lake Gaston is classified WS-IV B.

DWQ staff monitored Lake Gaston monthly from May through September 2009. Surface dissolved oxygen concentrations ranged from 8.8 mg/L to 4.7 mg/L. Dissolved oxygen at the most upstream sampling site (ROA0382A) has historically been low due to hypolimnetic water releases from Kerr Reservoir. In 2009, the dissolved oxygen concentrations at this site were greater than the minimum state water quality standard of 4.0 mg/L for an instantaneous reading and ranged from 7.4 mg/L in May to 4.7 mg/L in June. Surface water temperatures ranged from 15.3 °C in May to 29.3 °C in July. Surface pH values ranged from 6.7 to 7.6 s.u. Secchi depths ranged from 1.0 to 2.7 meters, indicating that the clarity of the water was good.

Total phosphorus concentrations in 2009 were at or less than the DWQ Water Quality Laboratory detection levels. These values were similar to those observed in previous sampling years for Lake Gaston. Total Kjeldahl nitrogen concentrations were low and ammonia concentrations were less than laboratory detection levels with the exception of values observed in July and August at the most upstream lake sampling site ROA0382A, which were moderate to elevated. This may have due to the nutrient-rich bottom water released from Kerr Reservoir upstream. Nitrite plus nitrate values were elevated in May,

June and July and low in August with the exception of values at the upstream lake sampling site which remained elevated. Chlorophyll a values for Lake Gaston were low to moderate, which was similar to values previously observed in this lake.

Based on the calculated NCTSI scores for 2009, Lake Gaston was determined to have moderate biological productivity (mesotrophic). This lake has been determined to be mesotrophic since it was first monitored by DWQ in 1981 with the exception of 1994 when it was found to have very low biological productivity (oligotrophic).

Lake Gaston was placed on the 303(d) List of Impaired Waters in 1998 for nuisance levels of the invasive aquatic weed, *Hydrilla verticillata*. Efforts to control this plant have included the stocking of the lake with triploid Grass Carp and the application of herbicides. In 2009, the Lake Gaston Weed Control Council (www.lgwcc.org) treated approximately 1,500 acres of hydrilla by application of herbicides and restocked Grass Carp (approximately 6,500 fish) in the lake. In 2009, *Lyngbya woolei* was discovered in some of the coves of Lake Gaston. This filamentous alga that grows into thick mats at the bottom of slow moving bodies of freshwater. These mats may rise to the surface to maximize photosynthesis and continue growing. Lyngbya mats have a characteristic strong musty odor and, when handled, feel like clumps of wet wool or cotton. Healthy, growing mats are blue-black in color, but may turn yellow-green in intense light.

In November 2009, the North Carolina State Health Director issued a fish consumption advisory for walleye and largemouth bass in Lake Gaston due to high levels of mercury found in this fish.

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