WATER QUALITY IN LAKE GREENWOOD:

A STATUS REPORT AND NEXT STEPS

Lake Greenwood in the morning sun.
Photo courtesy Ben Keys

Watershed Leaders Forum 2
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The Appalachian and Upper Savannah Councils of Governments and Upstate Forever

As part of the
Saluda-Reedy Watershed Consortium

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A STATUS REPORT AND NEXT STEPS

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Prepared by the Appalachian and Upper Savannah Councils of Governments,
in cooperation with Upstate Forever and the Saluda-Reedy Watershed Consortium.

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INTRODUCTION

The summer of 1999 will not be remembered fondly by many Lake Greenwood residents. It was during this time of drought that low water levels and an unprecedented growth of algae combined to keep people and boats off the lake. Docks that were fortunate enough to have water around them appeared to be floating in a sea of matted green grass.

The 1999 algae bloom on Lake Greenwood covered much of the Reedy arm of the lake with a thick mat of algal growth.

Almost immediately, questions surfaced about the quality of the water in the lake. Elected officials were asked for money to help address the problem. Water quality experts gave their assessments and offered some temporary solutions. In the end, the coming of winter killed the algae. The effects of the bloom lingered on, though, as residents searched for answers to the cause of the growth and worried about the potential for its return.

While the algae bloom may be most recognizable issue concerning water quality in Lake Greenwood, it certainly does not define the lake. On the one hand, the lake faces some real threats to its long-term health. But at the same time, Lake Greenwood has provided safe drinking water and recreational opportunities to nearby residents for over sixty years. The challenge that the Lakelands community faces is to respond constructively based on sound science, investing in solutions that will address the root causes of the lake's problems rather than just their symptoms.

In the heart of the fast-growing Upstate of South Carolina, Lake Greenwood has become a prime example of the impacts of growth on water resources. This report will give a brief history of Lake Greenwood, identify some of the key players in its management, and provide an overview of water quality studies completed to date and a preview of those that are currently underway.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

HISTORY AND MANAGEMENT OF LAKE GREENWOOD

Lake Greenwood is a key resource for the Lakelands region. Since its construction, it has served as both a focal point for the community and an engine for its growth. The lake was completed only 65 years ago – within living memory of the region's oldest residents – but it is difficult to imagine the Lakelands without it. The vitality of the region is inexorably tied to the health of the lake.

Overview and History

The Saluda River is the largest river in Greenwood County. Its headwaters lie in northern Greenville and Pickens counties along the state line, and the river ends in the City of Columbia where it merges with the Broad River to form the Congaree. The watershed is one of five major basins that drain South Carolina, and the Saluda basin runs through some of the most populous areas of the state.

Greenwood County planned a project to dam the Saluda River as a resource for drinking water and electricity in 1933. An application was made at that time to the Public Works Administration in Washington, DC to construct a dam at Buzzard's Roost, near Chappells, SC. Opposition from private power companies delayed the construction of this and other similar projects across the country until a U.S. Supreme Court decision in 1938 declared the projects constitutional. This decision opened the way for a number of federally funded hydroelectric projects, including the Tennessee Valley Authority (TVA).

Construction of the dam at Buzzard's Roost occurred between 1938 and 1940. The powerhouse at the dam was equipped with three turbines, each driving a five megawatt AC generator to provide power to the Greenwood area. Water was impounded to a surface elevation of 440 feet above sea level, which was later revised to 439 feet above sea level for efficient operations and reserve storage capacity.

The lake has a surface area of approximately 11,400 acres. The maximum depth is 68.9 feet, with an average depth of 23 feet. The lake's watershed comprises 1,165 square miles. Both the Saluda River and Lake Greenwood serve as municipal water sources for the City of Greenwood and the Towns of Ninety Six and Ware Shoals.

The dam was operated by the Greenwood County Electrification Commission until that commission was dissolved and the operations folded into the general County administration. In 1966, Greenwood County passed a referendum to sell the transmission lines and the steam generating plant, and to lease the power generating plant to Duke Power Company. The lease on the hydroelectric plant continues through 2006, at which time control reverts to the County. The lake itself remains the property of Greenwood County.

General Condition

In 1971, Black and Veatch Engineers compiled a report entitled "Long Range Water and Wastewater Plan for the Greater Greenwood Area." This report discusses water quality at the time as follows: "The lake water has a history of being difficult to treat, and it is of relatively poor quality in several respects. Chemical, physical, and biological characteristics of the water are at times objectionable."

"Difficulties resulting from chemical characteristics of the lake supply include objectionable quantities of iron and manganese and low alkalinity," the report continued. " Every effort should be made to enhance the water quality in the Lake. Both water supply and recreational uses would benefit from the improved quality."

At the time the Black and Veatch report was written, the major sources of impact to water quality in the lake were upstream industries and municipal sewer systems. These point sources pumped millions of pounds of contaminants of all kinds into the Saluda and Reedy Rivers, some of which ultimately ended up in Lake Greenwood. The legacy of the century of discharges that preceded the passage of the Clean Water Act in 1970 is still felt in the lake, and will be for decades to come.

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Today, the primary threat to water quality in Lake Greenwood – and throughout the watershed – is untreated stormwater discharges from developed areas and from construction sites, both upstream and around the lake itself. Stormwater carries contaminants of all kinds into the rivers and streams that feed the lake, from heavy metals to nutrients to bacteria. The statements made in 1971 about the lake's water quality still hold true today – all that has changed is the primary source of the impacts.

Sedimentation has filled in substantial portions of Lake Greenwood that were once open water.

Management Objectives

Greenwood County is the local political body responsible for managing Lake Greenwood. From issuing permits to zoning, the County has taken an active role in improving the quality of life in the area and in providing safe drinking water for residents. The Greenwood City/County Comprehensive Plan (available online at www.ci.greenwood.sc.us/Planning_ComprehensivePlan.aspx) identifies the following objectives related to water quality:

1. Provide a nonpoint source education program
2. Reduce agricultural pollution through conservation practices requiring controls of cropland erosion and surface water runoff
3. Set back croplands from water resources to provide a buffer area
4. Plan farm layouts to minimize alteration of the natural drainage pattern and prevent water pollution
5. Continue alternative watering techniques for livestock operations to decrease fecal coliform bacteria
6. Recommend SC Forestry Best Management Practices, through the SC Forestry Commission, to minimize nonpoint source pollution
7. Require buffer strips of natural vegetation along water bodies and tributary watercourses
8. Locate heavy industry where water discharges present the least ecological threat
9. Maintain the quality, volume, and rate of flow of watershed drainage systems
10. Review all residential development and construction applications for compliance with ecosystem protection requirements
11. Establish control measures in residential developments to prevent degradation of the quality, volume, and rate of flow of the natural drainage system of the watershed
12. Establish additional requirements and a special review process for waterfront and flood plain residential development and construction proposals
13. Increase impervious surface ratios in order to utilize permeable surfaces where feasible
14. Provide city/county best management practices and development incentives through a comprehensive development regulation for the development community

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15. Prevent groundwater contamination through assistance from DHEC and other state agencies and programs
16. Establish comprehensive sewer service to properties around Lake Greenwood and the City of Greenwood to minimize septic tank pollution in high to moderate density residential areas

Greenwood County and the municipalities of Greenwood, Ware Shoals and Ninety Six have officially adopted these objectives as part of their Comprehensive Plan. These objectives are similar to natural resources objectives adopted by local governments in Laurens and Newberry Counties.

While Greenwood County is the legal owner of the lake, the Greenwood Commissioners of Public Works (CPW) is responsible for treatment and distribution of the water. This water system is the fifth largest in South Carolina, and CPW estimates that the water supply is adequate to accommodate the growth projected over the next two to three decades. The treatment plant was placed into service in 1961 and presently has a capacity of 30 million gallons per day. The water system has storage capacity of 10.8 million gallons consisting of 7 million gallons of ground storage and 3.8 million gallons of elevated storage. CPW serves an area of approximately 180 square miles in Greenwood County and has over 19,000 customers.

CPW releases an Annual Drinking Water Quality Report for its customers. This report is available online at www.greenwoodcpw.com, or by calling (864) 953-2411. The latest report shows that there were no system violations and that the drinking water meets or exceeds all federal and state requirements.

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RESEARCH FINDINGS TO DATE

Lake Greenwood and the Reedy and Saluda rivers have been the subject of many scientific research projects over the past few years. This part of the report offers short summaries of some of these projects. This does not constitute an attempt to list each and every research project, but rather to give an overview and provide links and contacts for a selected set of projects that, taken together, represent the breadth of research conducted on Lake Greenwood. Additional listings are welcome, and readers with information about research projects not listed here are encouraged to contact Jennifer Rennicks, the Saluda-Reedy Watershed Consortium project coordinator, at jrennicks@upstateforever.org.

All of these projects represent works in progress. As such, all findings are tentative, and the conclusions of one project may not be entirely consistent with those of another project. For additional information about the current status of each project, please contact the researcher listed for that project.

PROJECT: ***Water Quality Data Mining and Trends Analysis***

GOAL: ***To assess long-term trends in water quality and flows in the Saluda-Reedy watershed***

FULL REPORT: **www.saludareedy.org/research/indepth_reports/data_mining.pdf**

CONTACT: ***Dr. Dave Hargett, North Wind Consulting***
dhargett@northwind-inc.com

This report provides the most comprehensive assessment conducted to date of long-term trends in water quality in the Saluda-Reedy basin. Major insights gained from the data-mining process include:

- **Long-term recovery from historical pollutant loading:** Most of the areas within the SRW demonstrate marked improvement for most water quality parameters over the last 30 years.
- **Impact of the Clean Water Act (CWA) of 1972:** Many of the improvements in water quality can be traced back to the effective implementation of the CWA of 1972.
- **Continued & chronic impact to urban / industrial stream reaches:** The urban portions of the watershed are, without question, the most severely impacted historically, and they continue to suffer the influences of urban stormwater runoff.
- **Recent impacts to reaches downstream of development:** Areas that continue to be subject to changes in land use quickly demonstrate degradation of water quality.
- **Upward trends in BOD & TN loading in suburban reaches:** Some urbanizing areas demonstrate clear increasing trends in concentrations of oxygen-demanding substances and total nitrogen.
- **Distinctions in "long-term" vs. "recent" impacts:** The older data is distinctive from the newer data, reflecting shifts in land use and environmental practices, as well as changes and improvements in monitoring methodology and technology.

The report offers in-depth explanation of these and other findings, with data and graphs that illustrate trends in a wide range of parameters. Additional data-mining activities are underway, beginning with partitioning of the data into "wet", "normal", and "dry" periods so as to examine the effects of climate and streamflow on water quality. In addition, the data suggest strong links between water quality trends and land use, and ongoing research will seek to better define these relationships.

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PROJECT: **Characterization of Hydrologic Input into Lake Greenwood**

GOAL: **To quantify the total load of nutrients and other key contaminants entering Lake Greenwood from the Saluda and the Reedy**

FULL REPORT: www.saludareedy.org/research/indepth_reports/hydrologic_input.pdf

CONTACT: **Dr. Steve Klaine, Clemson University**
slkaine@clemson.edu

This report documents the total load of key contaminants entering Lake Greenwood from the two major basins in the watershed, the Reedy and the Saluda River. It combines primary data collected during storm events at sampling stations on the Reedy and the Saluda where each empties into Lake Greenwood with base (non-storm) flow sample data collected by SC DHEC. Samples were collected during over 25 storm events from December 2003 through June 2005.

Research results showed that Saluda River Basin contributed eight to ten times more suspended solids to Lake Greenwood during 2004 than did the Reedy. However, the load of nitrogen and phosphorus was approximately equal in the two rivers, suggesting that the Reedy's load of contaminants comes more from point sources (sewage treatment plants and other specific discharges) whereas the Saluda's comes mostly from non-point sources (that is, stormwater runoff). These data will be incorporated into the ongoing water quality modeling efforts described in the next project summary below, with the goal of developing a computer model of the interactions among the key variables that shape water quality watershed wide.

PROJECT: **Nutrient-Algae-Oxygen Interactions in Lake Greenwood**

GOAL: **To develop a dynamic computer model of the interactions among key factors affecting water quality in the lake**

FULL REPORT: www.saludareedy.org/research/indepth_reports/model_calibration.pdf

CONTACT: **Dr. Hank McKellar, SC Department of Natural Resources**
mckellarh@dnr.sc.gov

This report documents the results from a year of intensive water sampling that focused on interactions among nutrients, algae, and oxygen depletion in the lake. Throughout 2004, water was collected at various depths at 12 sampling sites along the length of the lake and analyzed for temperature, dissolved oxygen, phosphorus, and algal growth.

Project conclusions are still preliminary; however, findings to date include the following:

- High phosphorus levels are seen mainly in the upper end of the lake, especially in the Reedy arm
- Patterns of algal growth vary with seasonal changes in light levels and water temperature, with accumulation of algae peaking in the late fall
- As the water heats up, the zone of oxygen depleted water increases, reducing the quality of fish habitat
- By early summer, there is very little water that was sufficiently cool and sufficiently oxygen rich for high quality fish habitat, a condition that persists into early fall

Once the model is fully developed and calibrated, it can be used to assess the likely impacts of various scenarios on water quality in the lake. What will be the effect on algae blooms in the Saluda arm of Lake Greenwood, for instance, if additional major wastewater treatment plants are built on the Saluda River? How will high-quality fish habitat be affected if the phosphorus load from the Reedy goes up? These and other questions will be addressed by the model beginning late in 2006.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

PROJECT: **River Basins Research Initiative (RBRI)**

GOAL: **To develop a systematic understanding of human impacts – particularly that of urban land use – on rivers in the piedmont region of South Carolina**

FULL REPORT: http://ees.furman.edu/research/rbri/rbri.html
General information only; contact researcher below for more information

CONTACT: **Dr. Brannon Andersen, Furman University**
brannon.andersen@furman.edu

The River Basins Research Initiative is a long-term study of the entire Lower Broad River Basin funded by grants from NSF, EPA, NASA, South Carolina Department of Health and Environmental Control, Associated Colleges of the South, the Rockefeller Brothers Foundation, the Saluda-Reedy Watershed Consortium, and Furman University. The long-term goal of this research program is the systematic characterization of both rural and urban watersheds to develop an understanding of the extent of human impact on river systems, particularly from urbanization, in the piedmont of South Carolina. The Greenville-Spartanburg metropolitan area, one of the fastest growing metropolitan areas in the country, is located in the headwaters of the study area.

Findings to date include the following:

- The single largest anthropogenic impact on the chemical composition of rivers in the region is the discharge of treated effluent from wastewater treatment plants (WWTPs). During drought conditions, as much as 70% of the river flow can be effluent.
- The highest population densities, and therefore the largest WWTPs, are in the headwaters of rivers where the river discharge is the smallest.
- There is considerable variation in the composition of effluent, including a twenty-fold variation in the nitrate concentration.
- WWTP effluent discharges into the Reedy at roughly five times the volume of effluent discharge into the Saluda, but the Reedy River only has roughly one-fifth of the flow of the Saluda River. Initial results indicate that the Reedy has a WWTP effluent "signature" from below the Mauldin Road WWTP all the way to Lake Greenwood.
- Discharge of effluent into the Saluda River does not have any impact on the chemical composition of the river because the river discharge is large compared to the discharge of any one of the eight WWTPs.

In conclusion, while the flux (mass per unit time) of nutrients, particularly nitrogen, reaching Lake Greenwood via the Saluda River is greater than that of the Reedy River, the nutrient density (mass per unit volume, or concentration) is much greater on the Reedy that the Saluda. Dissolved phosphorous, in particular, has a much higher concentration in the Reedy that in the Saluda. This may explain why eutrophication is more prevalent in the Reedy embayment of Lake Greenwood that the Saluda embayment.

PROJECT: **Sedimentation in the Upper Reaches of Lake Greenwood**

GOAL: **To determine how much water storage capacity in the Reedy and Saluda arms of the lake has been lost to sedimentation**

FULL REPORT: www.saludareedy.org/research/indepth_reports/sedimentation.pdf

CONTACT: **Dr. Dave Hargett, North Wind Consulting**
dhargett@northwind-inc.com

This report summarizes a study of sedimentation that documents how much sediment has been deposited in the upper seven percent of the lake since its construction. Sedimentation is defined as the build up of solid material, usually in the bed of a lake, river, or stream. The Saluda-Reedy Watershed Consortium sponsored this project with technical assistance by Pinnacle Consulting Group and the USDA – Natural Resources Conservation Service.

Surveys of the area were done by boat and by using existing aerial maps. Findings include:

- Over 307 acres of open water has been lost through conversion to vegetated bottomlands (mostly floodplain forest)
- Over 2 billion gallons of water storage volume has been displaced by sediment

The report concludes with an overview of the impacts of sedimentation on the ecological, recreation, and economic value of the lake. It notes that sedimentation causes the lake to become shallower, altering habitat and causing warmer water temperatures. This can lead to more frequent and serious algal blooms, can restrict lake access from homeowner's properties, and may cause loss of property value. The report also states that, even in areas not fully filled in, shallower water can restrict boat access, leading to decreased recreational opportunities for lake residents.

PROJECT: **Lake Greenwood Sanitary Survey**

GOAL: **To gather baseline data regarding the number, condition, and potential impacts of onsite wastewater systems ("septic systems") around Lake Greenwood**

FULL REPORT: www.saludareedy.org/research/indepth_reports/sanitary.pdf

CONTACT: **Dr. Dave Hargett, North Wind Consulting**
dhargett@northwind-inc.com

This report documents methodology and progress to date on a survey of sanitary wastewater facilities surrounding Lake Greenwood. This is a phased project begun in 2004 and expected to continue through 2006. The purpose of the project is to assess the impact of onsite wastewater systems on the lake by building a body of information that will support improved management of these systems.

Phase I of this work has been primarily a Geographic Information System (GIS) task, which attempts to capture the best available planning data from county and state records. Likewise, best available health department data will be captured with regard to individual septic systems. The product of this phase of work is a data warehouse that will support ongoing phases of sanitary survey, system assessment, and the development of a lakeshore management plan. To date, the project has gathered all available data layers, handled data quality and compatibility issues, and assembled data into a spatially referenced GIS database.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

PROJECT: **Land Cover Classification and Change Analysis**

GOAL: **To assess the rate and pattern of conversion from rural to developed land uses in the Saluda-Reedy watershed over the last two decades**

FULL REPORT: www.saludareedy.org/research/indepth_reports/land_cover.pdf

CONTACT: **Dr. Jeff Allen, Clemson University**
jeff@strom.clemson.edu

This report documents work completed to date on a large-scale effort to document the pattern of development across the Upstate since 1985. The results of the land use classification process will then be used as the basis for a predictive model that will generate year-by-year maps of future land use change. This model will predict future urban growth based on urban transition probabilities using an array of spatial data, as well as set urban growth scenarios using aspatial data.

The growth scenarios are based on two assumptions. First, it is assumed that the ratio of overall land use change to overall population growth over the last 15 years will remain the relatively stable for the next 30 years. After analyzing historic population data as well as urban land cover data, it was found that population of the Upstate region increased 16% between 1990 and 2000, while urban area increased 72%. Those numbers provide a growth ratio of nearly 5 to 1, meaning that as population increases by a certain percentage each year, the total urban area should grow at five times that rate.

Even this rate is probably conservative for two reasons. First, it is likely that overall population growth in the I-85 corridor may be greater than in the region as a whole. Second, a higher ratio of urban land use change over population growth has been observed in a number of locations. Other research has shown that many metropolitan areas – such as Detroit (13:1), St. Louis (7:1) and Baltimore (5:1) – have seen similar or higher ratios between 1960 and 1990, which is a longer term than the current study used.

The growth projection maps will be released by mid-2006, and will serve as the basis for a variety of analyses of the impacts of land use change on water quality.

PROJECT: **Atmospheric Nitrogen Input to Lake Greenwood**

GOAL: **To make a preliminary determination as to the significance of atmospheric deposition of nitrogen as a nutrient source for Lake Greenwood**

FULL REPORT: www.awma.org/journal/ShowAbstract.asp?Year=&PaperID=989
Abstract only; contact researcher below for more information

CONTACT: **Dr. Christos Christoforou, Clemson University**
csc@clemson.edu

This report documents concentrations of nitrogen in the air at two locations in the watershed. Measurements were taken on the Reedy River in downtown Greenville and on Lake Greenwood itself. Air quality was measured during four 24 hour periods in January 2001 and March 2001. Sampling over Lake Greenwood indicated that the area is in danger of exceeding the National Ambient Air Quality Standards (NAAQS) for atmospheric nitrogen. The need for more sampling over longer periods of time is required to understand the nature of atmospheric fine aerosol and its impact on the lake.

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PROJECT: **Changing Land Use and the Environment (CLUE)**

GOAL: **To characterize the local, on-site impacts and estimate the off-site impacts of land use change on water quality; and to develop strategies for mitigating these impacts**

FULL REPORT: **[No URL available]**
Contact researchers below for more information

CONTACT: **Dr. Steve Klaine, Clemson University**
sklaine@clemson.edu
Dr. John Hayes, Clemson University
jhayes@clemson.edu

The Changing Land Use and the Environment (CLUE) program is a multi-year project funded by the U.S. Department of Agriculture, the Saluda-Reedy Watershed Consortium, and other funding sources.

Project researchers have established comprehensive water quality sampling programs in two sub-basins in the Reedy River Watershed – one developed and another undergoing development – to characterize changes in storm water and receiving water quality and quantity as a function of land use. These data are used to evaluate the actual on-the-ground efficacy of best management practices (BMPs) as compared with reported values and model predictions. Findings to date include:

- The process of land use change does not adequately protect downstream ecosystems, even with the use of Best Management Practices (BMP) prescribed by regulations.
- The 20% of eroded soil allowed by law to migrate offsite during construction has a substantial impact downstream biota and habitat.
- Total suspended solids concentrations significantly reduce growth and reproduction of the water flea, *Daphnia magna*, even at concentrations below 100 mg/l. The water flea is an indicator species whose status is closely linked to water quality.
- Nutrients such as nitrogen and phosphorus begin to migrate from development sites even in the initial stages of development.

Another aspect of the project has been to identify installation and maintenance issues that affect BMP performance. Research to date has focused on factors that affect whether a builder will properly install and maintain silt fences during construction. Factors identified to date include:

- The developer still owns the lots
- The existing residents have a homeowners association
- Multiple-family dwellings exist in the subdivision

Results of this research are used to address questions posed by local regulators and decision-makers, developers, and planners concerning land use alternatives. Current technology transfer and outreach activities include educating municipal officials, designers, developers, building contractors and the public in storm water management and environmentally sound development practices.

PROJECT: ***Saluda River Basin Water Quality Assessment***

GOAL: **To provide a periodic broad-scale assessment of water quality in the Saluda basin as a whole**

FULL REPORT: http://www.scdhec.net/water/pubs/saluda.pdf

CONTACT: ***Andy Miller, SC Department of Health and Environmental Control***
millerca@dhec.sc.gov

This report is published by the South Carolina Department of Health and Environmental Control, and is updated periodically using DHEC's water quality monitoring data. The report covers the entire Saluda basin, from the headwaters at the North Carolina line to the confluence with the Broad River in downtown Columbia. The focus of the report is on the suite of parameters monitored by DHEC, including nutrients, fecal coliform, metals, and other contaminants of concern.

The report does not offer broad conclusions or findings; rather, it is a compendium of data that readers can draw upon to assess the status of any individual sub-watershed within the basin. The data contained in the report serves as the basis for DHEC's water quality work, and is the standard reference for determining the relative degree of impairment of a given water body.

PROJECT: ***Water Quality Analysis in Lake Greenwood***

GOAL: **To determine the levels of key pollutants in the lake and the role they play in promoting algae blooms**

FULL REPORT: **[No URL available]**
Contact researcher below for more information

CONTACT: ***Dr. Lynn Deanhardt, Lander University***
ldeanhar@lander.edu

In 2000, Lander University's environmental science faculty were awarded two grants to purchase equipment to analyze water quality in Lake Greenwood. The grants were from the V. Kann Rasmussen Foundation and Solutia. The money was used to purchase a Capillary Electrophoresis (CE) System. Students and faculty in the environmental science program used the CE System to test water quality at 11 different sites on the lake over a period of two years. The goal of the project was to identify pollutants entering and exiting the lake, with the goal of developing and understanding of the causes algal blooms on Lake Greenwood.

Research indicated that, during the warmest months of the year, total phosphorus levels in Lake Greenwood are often above 0.1 ppm (part per million), which is under certain conditions enough phosphorous to stimulate algae growth. The most common sources of phosphorus include fertilizers and detergents in wastewater discharges, as well as sediments in stormwater discharges. In addition, sampling determined that nitrogen levels in Lake Greenwood are nearly always above 0.5 ppm, which is also enough to stimulate algae growth under the right conditions. The project also concluded that extremely low levels of rainfall are definitely a contributing factor to the higher than normal levels of nutrients in Lake Greenwood.

Later Lander-led research in 2003 assessed the relative impacts of additional nutrient inputs to Lake Greenwood via a limiting nutrients assessment. The study found that nitrogen and phosphorous are co-limiting in the lake, meaning additions of either nutrient will stimulate additional algae growth.

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RESEARCH PROJECTS CURRENTLY UNDERWAY

The following is a listing of research projects sponsored by the Saluda-Reedy Watershed Consortium that are currently in progress. Results of these projects will be available by late 2006, and new project reports will be posted on the Consortium website at www.saludareedy.org/research/indepth.html. In addition, the online version of this report will be updated as new findings become available.

There are of course many other current research efforts sponsored by other organizations that focus on the Saluda-Reedy watershed. We welcome abstracts of such reports, and will incorporate them into future versions of this report. Please contact Jennifer Rennicks, the Saluda-Reedy Watershed Consortium project coordinator, at jrennicks@upstateforever.org for more information.

PROJECT: **Audit of Pavement-Related Ordinances**

COMPLETION: **June 30, 2006**

CONTACT: **Jason Van Driesche, Upstate Forever**
jasonvand@upstateforever.org

In-depth assessment of all Greenville County, Pickens County, and associated municipal ordinances that govern any aspect of the creation of new pavement, including street width and layout, parking lot size and layout, sidewalk and driveway specifications, cul de sac design, and so on; and development of recommendations for modification of such ordinances so as to minimize creation of new impervious cover while reducing the cost of development.

PROJECT: **Assessment of Performance of Stormwater Facilities**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Dave Hargett, North Wind Consulting**
dhargett@northwind-inc.com

Survey of stormwater detention facilities of varying ages and sizes in Greenville County to document condition and performance relative to design standards; and assessment of strengths and weaknesses of various design elements and of potential changes to enhance design, long-term performance, and maintenance.

PROJECT: **Assessment of Stormwater Regulatory Programs**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Dave Hargett, North Wind Consulting**
dhargett@northwind-inc.com

Assessment of strengths and weaknesses of the current stormwater regulatory system in Greenville County and its municipalities relative to national standards; the degree of implementation of Greenville County Stormwater Task Force recommendations; and opportunities for improving the stormwater management system.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

PROJECT: **History of and Factors Contributing to Flooding in the Upper Reedy Basin**

COMPLETION: **June 30, 2006**

CONTACT: **Jason Van Driesche, Upstate Forever**
jasonvand@upstateforever.org

Analysis of factors contributing to flooding in the Upper Reedy River Basin (defined as everything above Lake Conestee); of current and historic patterns and trends in flooding; of long-term changes in rainfall patterns; of the relationship of flooding trends to land use change and infrastructure patterns; and of socioeconomic impacts of and responses to floods.

PROJECT: **Analysis of Change in Impervious Cover**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Jeff Allen, Clemson University**
jeff@strom.clemson.edu

An analysis of historic and projected future changes in impervious cover watershed-wide using comparisons of USGS land-cover data, hyperspectral imagery data, and SRWC land-cover data; identification of sub-watersheds where development is likely to have a substantial impact on water quality over the next few decades; and assessment the relative severity of that impact based on the impervious cover that development is likely to generate.

PROJECT: **Assessment of Trends in Forest Cover Change**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Jeff Allen, Clemson University**
jeff@strom.clemson.edu

Analysis of historic and current forest cover in the Saluda-Reedy watershed; prediction of future change in forest cover given development patterns; and development of print and electronic materials for use in public outreach efforts.

PROJECT: **Identification of Priority Riparian Areas in the Reedy Basin**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Dave Hargett, North Wind Consulting**
dhargett@northwind-inc.com

Identification of riparian areas along the Reedy River that are the most vulnerable to loss and/or threatened by land use changes through a analysis of GIS data and development of screening criteria; and selection of a set of high-priority sites for conservation or restoration of riparian tree cover, with equal representation in urban, suburban, and rural areas.

PROJECT: **Audit of Erosion Prevention and Sediment Control Ordinances**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Dave Hargett, North Wind Consulting**
dhargett@northwind-inc.com

Audit of local ordinances and enforcement procedures in Greenville County, Anderson County, and the municipalities in each county that have independent erosion prevention programs, with a focus on identifying provisions or practices that create disincentives for compliance.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

PROJECT: ***Assessment of On-the-Ground Erosion Prevention Practices***

COMPLETION: ***June 30, 2006***

CONTACT: ***Dr. Dave Hargett, North Wind Consulting***
dhargett@northwind-inc.com

Technical review of on the ground erosion prevention practices in Greenville and Anderson Counties and in the City of Greenville, with the identifying trends in and causes of deficiencies in practices that result in unacceptable erosion prevention performance levels and may lead to water quality impacts.

PROJECT: ***Prediction and Modeling of Sources, Transport, and Fate of Sediment in the Saluda-Reedy Watershed***

COMPLETION: ***June 30, 2006***

CONTACT: ***Dr. Dave Hargett, North Wind Consulting***
dhargett@northwind-inc.com

Review of studies of Lake Greenwood and other regional reservoirs and of prevailing models for prediction of sedimentation; and development of a model of the sources, transport, and depositional dynamics of sediment delivered specifically to Lake Greenwood, with reference to established patterns in similar settings in the region and with the goal of establishing benchmarks of existing conditions against which future changes can be measured.

PROJECT: ***Evaluation of Sediment Management Options for Lake Greenwood***

COMPLETION: ***June 30, 2006***

CONTACT: ***Dr. Dave Hargett, North Wind Consulting***
dhargett@northwind-inc.com

Identification of sediment management options and development of a long term sediment management plan for Lake Greenwood, with a focus on technical practicability, environmental impacts, community acceptance, permitting requirements, water quality issues, costs, and funding considerations.

PROJECT: ***Identification of Factors Contributing to Poor Performance of On-Site Wastewater Systems and Assessment of Nature and Extent of Impacts***

COMPLETION: ***June 30, 2006***

CONTACT: ***Dr. Dave Hargett, North Wind Consulting***
dhargett@northwind-inc.com

Review of Lake Greenwood on-site wastewater performance issues, factors contributing to poor performance, and impacts of system failure to water quality; identification of antiquated and sub-standard systems based on compliance with current regulatory and performance standards; limited field assessment of impact of such systems on groundwater and surface water; and development of a report with recommendations for program improvements in the lakeshore area, highlighting areas warranting rehabilitation and management action.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

PROJECT: **Peak Flow Sampling and Analysis of Sediment Nutrient Release**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Steve Klaine, Clemson University**
sklaine@clemson.edu

Ongoing characterization of nutrient and hydrologic loadings into Lake Greenwood from the two stations at the bottom of the Reedy and Saluda basins; establishment of a third station below the Lake Greenwood dam to characterize nutrient and hydrologic export; and assessment of the role of lake bottom sediments in the lake's nutrient dynamics.

PROJECT: **Assessment of Point Source Discharges and Wet Weather Overflows**

COMPLETION: **June 30, 2006**

CONTACT: **Dr. Steve Klaine, Clemson University**
sklaine@clemson.edu

Compilation and assessment of all major NPDES permits in the Saluda-Reedy watershed, with a focus on treatment capacity, permitted discharges, permit violations, and wet weather bypasses; assessment of the chemical composition of effluents from wastewater treatment plants that discharge directly or indirectly to the Reedy and Saluda Rivers, and of downstream trends in nutrient concentrations between the Greenville area and Lake Greenwood; and development of a comprehensive assessment of point source discharges watershed wide.

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

CONCLUSIONS AND NEXT STEPS

If there is a positive side to the algae bloom of the summer of 1999, it is that water quality in Lake Greenwood and its watershed has become the focus of much study and discussion. This attention should come as no surprise, as disasters make for great research projects. What is unexpected, though, is the sharp focus and the careful coordination among the wide range of research efforts launched in the aftermath of the algae blooms. Even more unusual, the findings from these research projects are rapidly being translated into action to improve water quality. Lake Greenwood and its watershed have the potential to serve as a model for applied watershed research projects across the nation.

Research conducted to date has given us the beginnings of a solid foundation for action. Here is a summary of what we know at this point:

- Water quality in the Saluda-Reedy watershed – particularly in the urbanized upper reaches – has improved dramatically over the last few decades, largely because of the pollution control requirements in the Clean Water Act
- However, growth and development over the same period has introduced new threats to water quality in the form of erosion and stormwater runoff, which now outstrip wastewater discharges as the principal threats to water quality in the watershed
- As such, sediment is the number one threat to water quality in Lake Greenwood and in the watershed as a whole, due not only to its physical impacts on water quality and aquatic life but also to its ability to transport other contaminants for long distances
- The primary role of non-point source discharges notwithstanding, wastewater treatment plant discharges still have a significant impact on water quality, particularly in the Reedy where discharges constitute a large portion of base flow
- The geographic scale of development in the Greenville area is now large enough that the abovementioned non-point source impacts can be felt all the way down to Lake Greenwood, as the rural reaches of river between the metro area and the lake no longer serve as an complete buffer against upstream land use impacts
- Land use around Lake Greenwood itself is also a significant factor in shaping water quality in the lake, particularly as small, relatively informal cottages (as well as undeveloped land) are replaced by much larger, more formal year-round homes
- The legacy impacts of past discharges will continue to be felt for many years in the form of toxic chemicals buried in the sediments of the upper Reedy and in the form of phosphorous contained in the sediments in Lake Greenwood, and current management must take this legacy into account

By the end of 2006, a number of additional questions regarding water quality in the lake and its watershed will have been answered. These questions will include:

- What are the relative impacts of point source versus non-point source discharges on water quality in Lake Greenwood?
- How significant of a role do wet weather bypass pollutants play in water quality dynamics?
- How effective are stormwater basins as designed and maintained in this region at protecting water quality in the Saluda-Reedy watershed?
- How much increase in impervious cover and how much loss of forest cover can we expect over the next few decades, and what impact will this have on water quality in the absence of improved practices?

For additional information on water quality trends in Lake Greenwood as well as links to relevant organizations and web resources, please visit www.saludareedy.org/outreach/forums.html.

- How much more of Lake Greenwood will be silted in over the next few decades if upstream erosion control practices do not improve, and what will be the impact on lakeshore property values?
- What are the impacts of septic systems around Lake Greenwood on water quality in the lake, and what are the best strategies for mitigating those impacts?

We encourage anyone interested in the latest research on Lake Greenwood's future to visit our website regularly at www.saludareedy.org. For more information, contact the Saluda-Reedy Watershed Consortium project coordinator, Jennifer Rennicks, at jrennicks@upstateforever.org.

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