



## WATER RESOURCES RESEARCH GRANT PROPOSAL

**Title:** Initiating Effective Algae Reduction on Lake Greenwood, South Carolina

**Focus Categories:** WQL, NU, LIP

**Keywords:** Watershed Management, Water Quality, Water Pollution Policy, Lake Eutrophication

**Duration:** 4/00 to 4/01

**Federal:** \$25,000

**Non-Federal:** \$50,000

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**Congressional District:** 3<sup>rd</sup>

**Need for and Benefits of the Research**

During the summer of 1999, users of Lake Greenwood, a water body located in the Saluda River Basin in South Carolina, endured aesthetic, recreational, and commercial water-use losses due to high levels of algae in segments of the lake. According to the South Carolina Department of Health and Environmental Control (SCDHEC), algal blooms on Lake Greenwood have been generally increasing in magnitude over the past decade even though nutrient levels in the lake and its upstream tributaries have been shown to be in significant decline over this period. The 1999 bloom has been described by SCDHEC as the most severe to date.

The situation has raised questions with Lake Greenwood water users about the scientific observations currently being used to explain the recurrence of this phenomenon. And the incidences and their characteristic uncertainties have provoked further public debate about the available and effective remedies. No objective, comprehensive review of the scientific information available to assess the causes of the “Lake Greenwood algae problem” has been conducted to date. Hence, no analyses of the public policy alternatives available to effectively address the problem have ever been completed and communicated to the lake users.

Thus, there is current need for a thorough *ex parte* review of the scientific information available to make estimations on the causes of algal blooms on Lake Greenwood. There is also need for simultaneous assimilation of water user information to objectively assess

impairments to water uses on the lake. With this information, clear public policy goals can be developed and policy alternatives can then be analyzed and communicated in terms of the relative effectiveness of each in meeting the immediate and long-term objectives of the Lake Greenwood water users.

### **Nature, Scope, and Objectives of the Research**

Lake Greenwood covers approximately 11,500 acres in three counties and is a popular site for recreational boating, fishing and swimming. The lake is no less popular for development, as numerous home sites circle the lakefront. Furthermore, it serves as the source of drinking water for much of Greenwood County's 85,000 residents.

The summer of 1999 found nearly 1000 acres of the lake covered with a thick and malodorous population of filamentous algae. The algal bloom occurred near the stretch of the lake where the Reedy River flows into it. This sudden bloom of algae was attributed to the high levels of phosphorus and nitrogen measured in the water. In particular, this variety of algae is thought to flourish in water with high levels of nitrogen compounds common in treated sewerage.

Along the lower stretch of the Reedy River, as it leaves the City of Greenville headed toward Laurens County and Lake Greenwood, two sewerage treatment plants of the Western Carolina Regional Sewer Authority discharge treated effluent into its waters. As Greenville City and County have grown, more and more of this treated effluent has been discharged into the river. But, there are other sources suspected as contributing to the overall level of nutrient enrichment in the lake; including septic tanks that drain to streams, animal wastes and fertilizers that runoff from urban areas and agricultural lands, and automobiles and industrial facilities that emit water-bound pollutants into the atmosphere.

There does seem to be *some* public consensus on the Lake Greenwood algae problem: The excessive algal growth on Lake Greenwood is attributable to heavy nutrient loading to the upper lake segment and its upstream tributaries, primarily from anthropogenic sources of nitrogen and phosphorous. The Lake Greenwood algae problem, then, can be *objectively* characterized as the periodic occurrence of an increment of algal biomass in the lake in excess of the natural level, which is directly related to the nitrogen and phosphorous that are in excess of their natural levels under certain atmospheric conditions known to be conducive to algal blooms.

But, "the problem" in the Lake Greenwood case, a case that is in no way exceptional, has never actually been identified in this manner. This is, in part, due to the fact that there is no such complete and perfect information about the source, transport, and fate of nitrogen and phosphorous and the variety of organic and inorganic compounds in which they are present in the Saluda River Basin. It is also due to the fact that there is no perfect information about the cause-and-effect relationship between the presence of these compounds and the species of algae that are prevalent in Lake Greenwood during algal

blooms. But, the “algae problem” is not characterized and estimated first, strictly in terms of objective science, in large part due to public policy constraints.

In compliance with §303(d) of the federal Clean Water Act, SCDHEC has identified segments of Lake Greenwood as “impaired,” or “not fully supporting” designated uses and aquatic life. Water pollution problems in Lake Greenwood are thus characterized, from the onset, partly by subjective judgements about “appropriate uses” and “natural conditions” and done so with an eye to the predetermined, administratively preferred statutory remedies. Thus, the Lake Greenwood algae problem has never been characterized scientifically strictly in terms of the recurring surplus of algal biomass.

This is not to say that there is no scientific information available to characterize the Lake Greenwood algae problem. The species of algae present at blooms on the lake have been identified. The levels of Chlorophyll A, the proxy for the concentration of algae in the lake, are regularly monitored and reported. Information on the levels of total phosphorous, total Kjeldahl nitrogen, ammonia-nitrogen, ammonium-nitrogen, nitrate-nitrogen, and nitrite-nitrogen are available in time series. There are time-series measurements of the biochemical oxygen demand and the dissolved oxygen in segments of the lake. There is information available on the history of turbidity in the lake. All of these parameters are indicative of excess algal growth.

But, these measurements are not the primary impetus for Lake Greenwood's current “impaired” designation. In terms of regulatory priorities, Lake Greenwood is “impaired” for swimming due to high levels of bacteria and “does not fully support” aquatic life due to excursion in pH. No scientific assessment of the Lake Greenwood algae problem has thus ever been required for reporting; and no comprehensive, objective assessment of the problem has ever been completed and conveyed to the concerned public. The information that has been made available by SCDHEC is a characterization of the lake as being in a highly “eutrophic” condition.

Specifically, information from which to draw conclusions about the extent to which both nitrogen and phosphorous respectively contribute to the algae problem on the lake has yet to be assimilated, summarized and assessed. Information on the sources of nitrogen and phosphorous loading to the lake and its upstream tributaries has not been reported in any comprehensive way. No effort has been made to summarize known information from water and air pollutant transport models about nitrogen and phosphorous in and around the Saluda River Basin. So, in general terms, the scientific information on the source, transport, and fate of the pollutants that are the stimulus for these algal blooms has not been assimilated in an effort to even begin developing and testing theories on the nature and source of the Lake Greenwood algae problem.

At a minimum, the following can be summarized in a single report:

1. The quantitative estimates of the transfer and fate of the nitrogen and phosphorous that comes from NPDES

permitted discharge pipes on the lake and upstream of the lake

2. The course estimates of the transfer and fate of nitrogen and phosphorous that runs off of land and into the lake and upstream of the lake

3. The course estimates of the transfer and fate of nitrogen and phosphorous that is deposited from the atmosphere into the lake and upstream of the lake

4. The general relationship between the presence of the prevalent species of algae during blooms and coinciding nitrogen and phosphorous compound concentrations and atmospheric conditions

With an objectively estimated cause-and-effect relationship between both nitrogen and phosphorous and the incidence of algal blooms, impaired water uses can then be objectively and systematically examined. First, information about water users on the lake can be compiled and assessed to provide estimates of the nature and degree of the specific aesthetic, recreational, and commercial uses of the lake in the absence of high levels of algae. Then, water use impairment can be related to the presence of excess algae, the actual sources of which are the nitrogen and phosphorous compounds that have been discharged from wastewater treatment facilities, carried to streams via land runoff, and emitted from smokestacks and tailpipes.

Thus, at a minimum, the following can be summarized and included in the report described above:

5. The available information suggestive of the relative degrees to which Lake Greenwood water *uses* are valued by Lake Greenwood water *users*

6. The course estimates of the relationships between the respective use impairments due to excessive algal growth and the respective contributors of the excessive algal growth.

The anthropogenic sources of the excess nutrients must be examined in this manner -- in the context of their relative contributions to the algae problem on Lake Greenwood -- before the relative *effectiveness* of alternative courses of action to remedy the Lake Greenwood algae problem can be objectively evaluated, reported to the concerned public, and then debated and ultimately pursued.

## Methods, Procedures, and Facilities

No additional facilities will be required to complete the project. No original field or laboratory observations will be necessary to generate this preliminary comprehensive assessment of the Lake Greenwood algae problem.

Each of the elements (1-6) described above can be collected, organized, and summarized in a manner that will provide a best-available state of the knowledge report on the Lake Greenwood algae problem. These six report elements and the primary sources that provide the information necessary to generate them are listed.

1. The quantitative estimates of the transfer and fate of the nitrogen and phosphorous that comes from NPDES permitted discharge pipes on the lake and upstream of the lake

q SCDHEC, Water Quality Model(s) applied to watersheds 03050109-080, 03050109-100, and 03050109-120; as required for establishing total maximum daily loads on water quality limited streams by 40 CFR Part 130.

2. The course estimates of the transfer and fate of nitrogen and phosphorous that runs off of land and into the lake and upstream of the lake

q SCDHEC, *Watershed Water Quality Assessment: Saluda River Basin*, Technical Report No. 005-98, December 1998.

q U.S. Environmental Protection Agency, *Better Assessment Science Integrating Point and Nonpoint Sources: Basins Version 2.0*, EPA-823-R-98-006, June 1998.

q U.S. Department of Commerce - Census Bureau, 1990 U.S. Census, as modified through December 1999.

q U.S. Department of Commerce - Census Bureau, 1992 U.S. Census of Agriculture, as modified through December 1999.

q U.S. Department of Agriculture, 1997 National Resources Inventory, December 1999.

q Pucket, Larry J., *Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States*, USGS National Water Quality Assessment Program, WRI94-4001, 1994.

3. The course estimates of the transfer and fate of nitrogen and phosphorous that is deposited from the atmosphere into the lake and upstream of the lake

q SCDHEC, Air Dispersion Model(s) for the 'Upstate' and 'Midlands' regions of South Carolina, as required for demonstrating compliance with South Carolina Air Pollution Control Regulations 62.5 and Title V of the federal Clean Air Act.

q U.S. Department of Agriculture, 1997 National Resources Inventory, December 1999.

q Maluk, T.L., Reuber, E.J., and Hughes, W.B., *Nutrients in waters of the Santee River Basin and coastal drainages, North and South Carolina, 1973-93*: U.S. Geological Survey Water-Resources Investigations Report 97-4172, 1997.

q Pucket, Larry J., *Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States*, USGS National Water Quality Assessment Program, WRI94-4001, 1994.

4. The general relationship between the presence of the prevalent species of algae during blooms and coinciding nitrogen and phosphorous compound concentrations and atmospheric conditions

q American Public Health Association, et al., *Standard Methods for the Examination of Water and Wastewater*, 20<sup>th</sup> Edition, 1999.

q DHEC complaint response database search for “watersheds 03050109-080, 03050109-100, and 03050109-120” and “January 1996 to December 1999.”

5. The available information suggestive of the relative degrees to which Lake Greenwood water *uses* are valued by Lake Greenwood water *users*

q Allen V. Kneese, "Measuring the Benefits of Clean Air and Water," Resources for the Future, Washington, DC, 1984.

q U.S. Environmental Protection Agency, *Liquid Assets: A Summertime Perspective on the Importance of Clean Water to the Nation's Economy*, 1996.

q U.S. Department of the Interior - Fish and Wildlife Service, *1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*, 1998.

q SCDHEC, *Watershed Water Quality Assessment: Saluda River Basin*, Technical Report No. 005-98, December 1998.

6. The course estimates of the relationships between the respective use impairments due to excessive algal growth and the respective contributors of the excessive algal growth.

q U.S. Environmental Protection Agency, national water quality storage and retrieval system (STORET), as modified through December 1999.

q U.S. Environmental Protection Agency, *National Water Quality Inventory: 1996 Report to Congress*, 1998.

### **Related Research**

Currently, the most comprehensive sources of information available to Lake Greenwood water users regarding their algae problem are:

SCDHEC, *Watershed Water Quality Assessment: Saluda River Basin*, Technical Report No. 005-98, December 1998.

SCDHEC, *South Carolina Watershed Assessment and FY 1999-2000 Watershed Restoration Priorities*, September 1998.

In these reports, available STORET data on sampling concentrations of total phosphorous, nitrate-nitrogen, and ammonia-nitrogen are not provided or summarized. In the Saluda River Basin Plan that preceded the current one, nitrogen was listed as the "limiting" nutrient in the Reedy River Arm of Lake Greenwood. The current report characterizes the stream segment as having "high phosphorous concentrations," and nitrogen concentrations in the stream segment are not mentioned in the same context. Notably, both total phosphorous and total nitrogen concentrations are reported to be in "significant decreasing trends." (p.50)

A series of studies have been done in the USGS "SANT" study area to identify the water and air point and nonpoint sources of nutrient pollution in the Saluda Watershed. For an example, see:

Maluk, T.L., Reuber, E.J., and Hughes, W.B., *Nutrients in waters of the Santee River Basin and coastal drainages, North and South Carolina, 1973-93*: U.S. Geological Survey Water-Resources Investigations Report 97-4172, 1997.

The USGS, NOAA, EPA, and a number of other cooperating federal, state, and local agencies and universities have teamed up to form the National Atmospheric Deposition Program. Some of the recent summarized work from this collaborative effort describing atmospheric deposition of nitrogen was released in December 1999 as part of the latest National Resources Inventory. See:

U.S. Department of Agriculture, 1997 National Resources Inventory, December 1999.

Under 40 CFR Part 130.7, states must "assemble and evaluate all existing and readily-available water quality data and information" when identifying waters as "impaired." It is widely recognized that much of the scientific work available to make assessments of water-use impairments and effective remedies has historically been ignored or suppressed due to the inflexibility of current federal and state water pollution policies. In August of 1999, in response to this widespread public acknowledgement, the U.S. Environmental Protection Agency proposed new rules for states to follow in identifying and addressing "impaired" water bodies. See:

U.S. Federal Register / Vol. 64, No. 162 / Monday, August 23, 1999 / Proposed Rules.

If these proposed rules are promulgated as regulation, much of the information gathered in this proposed report and its dissemination to the water users on Lake Greenwood will technically be required of states such as South Carolina with delegated authority to enforce the federal Clean Water Act.

No effort, to date, has been made or is otherwise planned to objectively and independently assess nitrogen pollution, phosphorous pollution, excessive algal growth, actual water uses, and algae-impaired water uses on Lake Greenwood, South Carolina; and then comprehensively estimate from the information cause-and-effect relationships between pollutants and impaired uses. Such an effort to objectively *characterize* the Lake Greenwood algae problem is fundamental to any effective subsequent effort to *address* the problem.

### **Information Transfer Plan**

Both governmental agencies and non governmental organizations have expressed considerable interest in a report that provides details on the origin, transport and fate of pollutants in Lake Greenwood, particularly the cause of the increasing algal blooms during the summer months. The Greenwood City/County Planning Department and Friends of Lake Greenwood and Its Rivers are seeking assistance in gathering information and conducting public forums to create awareness and educate resource users and residents about water quality issues involving Lake Greenwood. Thus, initial efforts in working with these parties -- and potentially others -- would involve meetings to: identify issues and exchange ideas; establish public goals and objectives for water users; inventory natural, cultural and human activities that affect water quality; present report findings and conclusions (as information becomes available); and, develop effective strategies to achieve previously established goals and objectives.

Additionally, a technical report should be prepared and made available to all interested parties, including academic, scientific, regulatory and legislative groups. This report would hopefully serve as a model for similar efforts needed across the State, throughout the region, and around the nation. The report would address the six areas identified earlier and document the process and outcome of efforts by various groups seeking both information and consultation in developing action strategies.

Additionally, a minimum of two articles should be developed to submit to appropriate academic or professional journals. This activity will allow the dissemination of the results to a wider audience and expose the study to critical review.