

South Carolina Water Resources Research Institute

Annual Technical Report

FY 2003

Introduction

The SCWRC is coming off another exciting and fruitful year. The highlight of 2003 has been the formation of the Saluda Reedy Watershed Consortium, of which the SCWRC is a founding member. The consortium was successful in securing funding from a private foundation as well as Fujifilm Corporation to initiate work on the watershed through an initial project titled: The Saluda-Reedy Watershed Consortium: Taking Action for Water Quality Improvement and Watershed Management.

The Reedy River is a primary tributary in the Saluda River watershed that flows from the foothills of the Blue Ridge escarpment into Lake Greenwood and then into Lake Murray joining the Broad River in Columbia. The Reedy has shaped and been impacted by the industrialization, especially the old textile industry, and urbanization of that corridor, most notably the section from Greenville to the confluence with the Saluda River and into Lake Greenwood.

As South Carolina continues its rapid urbanization, the Reedy is providing a unique opportunity to assess impacts from urbanization, growth and changing land use patterns. The recent fuel spill from the Colonial Pipeline and the subsequent settlement along with interests from governmental organizations, universities and private organizations regarding sensible growth policies is providing the impetus to use the Reedy River as a real world laboratory to study growth and sustainable environments.

The following entities are members of the consortium: Upstate Forever Clemson Environmental Institute, Clemson University Jim Self Center on the Future, Clemson University Pinnacle Consulting Group, Inc. South Carolina Water Resources Center, Clemson University South Carolina Department of Natural Resources Friends of Reedy River, Inc. Conestee Foundation Upper Savannah Land Trust Spectro Tech, Inc. Lander University Furman University

Research Program

Projects currently underway: Real-time Water Quality Monitoring for Education and Stakeholder Feedback in the Saluda-Reedy Watershed Funding Agency: USGS/SC Water Resources Center PI: Dr. Christopher Post-Clemson University

Toxicological Effects of Environmental Pollutants in Lake Conestee Funding Agency: USGS/SC Water Resources Center PI: Dr. Peter van den Hurk Clemson University

Projects funded from sources other than USGS:

Maintaining Natural Capital in Rapidly Developing Watersheds Funding Agency: National Science Foundation Partners: Oklahoma State University, University of Arkansas, Washington State University

Monitoring Coastal Wetland Change and Modeling Ecosystems in SC Funding Agency: NASA/EPSCOR
Program Partners: University of South Carolina, College of Charleston

"The Saluda and Reedy River Watershed Land Use and Water Quality Assessment" Funding Agency:
Proposal submitted to V.Kann Rasmussen Foundation Partners: Multidisciplinary effort at Clemson
University, Lander University and Furman University

GIS-based Database Management and Spatial Modeling for Coastal Ecosystems Funding Agency: S.C.
Sea Grant LU-CES Program/NOAA Partners: University of South Carolina, NOAA NOS Southeast
Fisheries Center

Forest Fuel Load Classification using Hyperspectral Image Analysis Funding Agency: U.S. Forest Service
Partners: SpectroTech, Inc.

The NY State Wetland Monitoring System: A Remote Sensing Assessment Funding Agency: U.S.
Environmental Protection Agency Partners: SUNY-Albany

Assessment of Urban Forest Cover and Structure in the Greenville-Spartanburg Metropolitan Area:
Implications and Opportunities for Local Policy Changes Funding Agency: U.S. Forest Service Partners:
Pinnacle Consulting Group

Real-time Water Quality Monitoring for Education and Stakeholder Feedback in the Saluda-Reedy Watershed

Basic Information

Title:	Real-time Water Quality Monitoring for Education and Stakeholder Feedback in the Saluda-Reedy Watershed
Project Number:	2003SC7B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	Third
Research Category:	Not Applicable
Focus Category:	Water Quality, Management and Planning, Education
Descriptors:	Watershed Management, Water Quality, Real-Time Management
Principal Investigators:	Christopher Post, Stephen Klaine

Publication

1. Post, C.J, M. Goddard, S. Klaine, J. Smink, R. Otter, and J. Hayes, 2003, Real-Time Water Quality Monitoring of Nonpoint Source Pollution in the Saluda-Reedy Watershed, South Carolina in USVI Water Quality Conference, December 4.
2. Post, C.J., M. Goddard, and S. Klaine, 2003, Real-time Water Quality Monitoring in the Saluda-Reedy Watershed. South Carolina Environmental Symposium, Oct. 15-17, Myrtle Beach, SC.

Real-time Water Quality Monitoring for Education and Stakeholder Feedback in the Saluda-Reedy Watershed

Statement of critical regional or State water problem:

Water quality in a watershed is ultimately dependent on the policy decisions made within the watershed that shape the landscape. These decisions are often made in the absence of scientific information concerning the critical resources. It is insufficient to monitor water quality and publish papers. If we are to facilitate behavioral and policy changes that result in better water quality we must present stakeholders and policymakers with accurate, timely information upon which to base their daily decisions.

The Saluda-Reedy Watershed above Lake Greenwood is the natural catchment for 1,165 square miles of the Blue Ridge foothills and upper Piedmont of northwestern South Carolina. During the past century, but especially over the last twenty-five years, the Reedy River has been seriously impacted by urban development. This development continues to move down the Reedy River corridor and is now making its way to the Saluda River. Greenwood County and especially Lake Greenwood are experiencing the adverse effects of these rapid changes.

Greenwood, South Carolina is experiencing strong manufacturing expansion, has an emerging biotech industry and will probably become the fastest growing county without a major interstate highway. Greenville's continued growth will depend on the ability to handle its waste, while Greenwood's future depends on a reliable source of drinking water and access to an equitable share of the assimilative capacity of the Saluda and Reedy Rivers. What was once an abundant resource has become the umbilical link of these two growing counties; and the capacity of that resource is finite.

We believe that the delivery of timely information to the policy makers within Greenville will take a large step toward aiding in the development of more environmentally-sound land use policy within the Saluda-Reedy watershed. Through the use of satellite equipment located at water quality sampling stations on the Reedy River above and below Greenville (supported by the American Distance Education Consortium), and development of algorithms to rapidly process data into information and post it to a web site (the focus of this proposal), we will present stakeholders and policy makers with scientifically-sound, accurate information in a timely fashion upon which to base their decisions.

Statement of results or benefits

Results of proposed research will facilitate the processing of water quality data downloaded from satellites. These data will come from water quality sampling sites located above and below the city of Greenville. Results of the sampling and analysis will present policy makers with real time information on the water quality of the Reedy River and, most importantly, how this water quality changes as the river flows through Greenville. We will work directly with policy makers to insure that they can readily interpret information on the web page. We anticipate that we will repeat this effort with

county and city councils in Laurens and Greenwood counties that lie downstream from Greenville. Through related, concurrent projects we are forming working relationships with policy makers in Greenville, Laurens and Greenwood counties. These projects include Changing Land Use and the Environment (supported by the USDA-NRCS), The Saluda-Reedy Watershed Consortium: Taking Action for Water Quality Improvement and Watershed Management (supported by the V. Kann Rasmussen Foundation), and Satellite Linkages for Real Time Stakeholder Feedback in Watersheds (supported by the American Distance Education Consortium). It is this last project that is supplying the equipment and satellite time necessary for this project.

In addition to supplying information to policy makers in the watershed, we believe that real time water quality information will be of use in the classroom. We will encourage, and help where possible, teachers to develop curricula and exercises that utilize this data to demonstrate and teach concepts to students. Examples of these concepts include water quality (e.g. What is dissolved oxygen and why is it important in our rivers and lakes?), watershed processes (e.g. How does land use affect water quality in the watershed?) and data analyses (e.g. What is trend analysis and how can it be useful?).

Finally, through promotion of the web site to the public, we anticipate that citizens will become better educated concerning water resources in the Reedy River and ask informed questions to their elected officials concerning policy decisions that impact water quality.

Nature, scope and objectives of the research, timeline

The focus of this proposal is both to develop algorithms to display the real-time water quality data and video images on the world-wide-web and to devise ways of making this information relevant and accessible to stakeholders. Interactive maps will be employed to help visitors understand the link between watersheds and water quality and also to visualize the water quality of the Reedy River as it changes over time and space. Additional field samples for other sample sites will be statistically compared to determine if it is possible to accurately estimate other parameters (phosphorus, nitrogen and fecal coliform) from the measured water quality data. Real-time graphics and images representing the water quality and quantity of the Reedy River will be on a dedicated webpage and will also be available to be shared through state, county and city agency and other stakeholder websites.

This project is organized into six major objectives in order to maximize the transfer of the technology to the stakeholders:

1. Develop algorithms to validate and translate sensor water quality information (dissolved oxygen, pH, turbidity, and conductivity) and video images from a satellite downlink to a dedicated webpage.
2. Create a website that displays this information in the form of real-time charts and video images with detailed explanations of how this information relates to the current water quality of the Reedy River.

that stakeholders could understand the link between weather conditions, river level and water quality. Interactive charts will examine historical trends in water quality between the two sample locations and to help understand the importance of storm events. A professional graphic designer will be employed to develop and structure the website developed by to assure quality and usability. In depth explanation of terms and the relative importance of the water quality parameters would be included for stakeholder accessibility.

A subset of the real-time charts will be made available for use on stakeholder websites to increase the impact of this project. Through custom programming it will be possible to allow stakeholder groups to add the charts representing the current water quality of the river to their websites through a simple linking process. In every case the charts will link back to the main project website for in-depth explanation.

Interactive Map Component

An interactive map website will be developed using customization of ArcIMS 4.0 web-GIS software. The software is available at Clemson through a site-license and a specialized GIS web-server is available to host the project. The goal of this site will be to allow stakeholders to explore watersheds that determine the water quality at the two sampling locations. In addition, through the inclusion of other sample data, the water quality condition of the river will be graphically illustrated. Spatial data layers including land use, population density, roads and other identifying features will be the basis for the map website.

Estimating Additional Water Quality Parameters

Additional water quality parameters that will not be measured with the satellite-linked sensors, such as phosphorus, nitrogen and fecal coliform could likely be estimated on a real-time basis using linear regression (Christensen et al., 2002). This technique uses linear regression to compare other sample data with the real-time parameters in order to provide real-time estimates of water quality indicators that it is not yet possible to measure on an instantaneous basis. The estimated values for phosphorus, nitrogen and fecal coliform would only be included on the website if the regression equations have a strong predictive ability and would include an explanation of how the estimates were derived.

Christensen, V.G., Rasmussen, P.P. and Ziegler, A.C., 2002. Real-time water quality monitoring and regression analysis to estimate nutrient and bacteria concentrations in Kansas streams. *Water Science and Technology*, 45(9): 205-211.

System Evaluation

Impact and success of this project will be measured in four ways: 1) detailed web logs will be kept and analyzed to access the number of unique visitors to the main website and also to each stakeholder website that uses the provided real-time water quality data, 2) the number of stakeholder groups that choose to utilize the real-time information, 3) the feedback provided and questions asked through a user-feedback section of the website, and 4) direct feedback from stakeholders.

Related research:

The Changing land Use and the Environment project, supported by USDA-NRCS, focuses on developing cause and effect relationships between land use and water quality in the Saluada-Reedy watershed. As such, this project has established 12 automated water sampling sites within the watershed. These sites automatically sample water from the river during a storm event. Samples are collected manually and taken back to the laboratory for analyses. The Satellite Linkages for Real Time Stakeholder Feedback in Watersheds project, supported by the American Distance Education Consortium, focuses on the equipment and satellite linkages necessary to fully automate two of these sites (one above and one below the City of Greenville on the Reedy River). This automation goes beyond the water sampling to the use of in-stream probes that continuously monitor dissolved oxygen, pH, turbidity, and conductivity. The data are continuously up-linked to a satellite and down-linked to Clemson University. It is these data that, in this project, we propose to develop the ability to automatically process and upload information onto a web site.

Training potential

Two graduate students will be trained on this project (one supported by federal funds and one supported by non-federal funds). These students will insure that the automated equipment functions correctly in the field as well as develop the algorithms necessary to process the data and transmit the information. As such these students will gain significant training and experience in field and laboratory work as well as computer programming and mathematical algorithm development. We anticipate that these students will also be involved with policy maker education. This will provide a social science experience to their training. Hence, these students will have an appreciation for both the natural and social sciences and how they interrelate to facilitate environmentally sound management of natural resources.

Additional training opportunities will be provided for other students and faculty who are participating in related concurrent projects. This will reinforce the team concept of our research efforts. We also anticipate that training opportunities will be made available to educators to help them develop curricula and exercises that utilize information generated in this project.

- attenuation in a subsurface flow riparian wetland. *J. Environ. Qual.* 30:1732-1737.
- Karen, DJ, PE Ross, and SJ Klaine. 2001. Xenobiotic impacts on the skeletal system of teleosts. *Rev Environ Contam Toxicol.* 172:1-19.
- Wilson, P.C., S.J. Klaine, and T. Whitwell. 2001. Simazine toxicity to- and Uptake by *Myriophyllum aquaticum*. *J. Aquat. Plant Manage.* Volume 39
- Wilson, P.C., S.J. Klaine, and T. Whitwell. 2001. Metalaxyl toxicity, uptake, and distribution in several ornamental plant species. *J. Environ. Qual.* 30:411-417.
- Naddy, R.B. and S.J. Klaine. 2001. Effect of Pulse Frequency and Interval on the Toxicity of Chlorpyrifos to *Daphnia magna*. *Chemosphere* 45:497-506.
- Bielmyer, G.K., R. A. Bell. 2002. Effects of ligand-bound silver on *Ceriodaphnia dubia*. *Environ. Toxicol. Chem.* 21(10): 2204-2208.
- Taylor, M., S. J. Klaine, F.P. Carvalho, D. Barcelo, J. Everetts. 2002. *Pesticide Residues in Coastal Tropical Ecosystems*. Taylor and Francis Publishing, London.
- Klaine, S. J. and F. L. Mayer. 2002. *Watershed-Based Ecological Risk Assessment for Coastal Tropical Ecosystems*. in Taylor, M., S. J. Klaine, F.P. Carvalho, D. Barcelo, J. Everetts. 2002. *Pesticide Residues in Coastal Tropical Ecosystems*. Taylor and Francis Publishing, London.
- Klaine, S.J., M. A. Lewis, S. L. Knuteson. 2002. Phytotoxicity. in D. J. Hoffman, B. A. Rattner, G. A. Burton, Jr. (eds.). 1995. *Handbook of Ecotoxicology*. 2nd ed. Lewis Publishers, Boca Raton, Florida.
- S. L. Knuteson, T. Whitwell, and S. J. Klaine. 2002. Influence of Plant Age and Size on Simazine Toxicity and Uptake *J Environ Qual* 2002 31: 2096-2103
-

Copper Develop. Assoc. USDA/NRCS	Influence of environmental parameters on cooper in roof runoff Changing Land Use & Environment	8/15/02 – 12/31/02 1/01/03 – 1/01/04	\$15,000 \$550,000
--	--	---	-----------------------

Graduate Education:

1987 - present
 25 Master of Science graduates
 16 Doctor of Philosophy graduates

20. Matching funds commitment letter:

Please see attached.

21. Negotiated indirect cost rate agreement:

N/A

Toxicological Effects of Environmental Pollutants in Lake Contee

Basic Information

Title:	Toxicological Effects of Environmental Pollutants in Lake Contee
Project Number:	2003SC8B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	Third and Fourth
Research Category:	None
Focus Category:	Water Quality, Toxic Substances, Surface Water
Descriptors:	None
Principal Investigators:	Peter van den Hurk, Stephen Klaine, David Hargett

Publication

Toxicological Effects of Environmental Pollutants in Lake Conestee

Statement of critical regional or State water problem:

Water quantity and quality are impacted in the Reedy River basin (65 sq. mi. above Lake Conestee) due to impacts from diverse and highly urbanized land uses within the watershed. Much of the contaminants historically deposited into the river from land activities have accumulated in the sediments of Lake Conestee. These contaminated sediments may impact flora and fauna in the immediate area or, if remobilized, potentially impact downstream ecosystems. Hence, it is critical to characterize the risk associated with these sediment-bound contaminants. In addition, these sedimented contaminants may pose a threat to humans who utilize the Reedy River for subsistence fishing. Lake Conestee has ironically provided an important mechanism within the watershed to trap and sequester large masses of contaminants within the Reedy basin. The volume of sediments that have accumulated in the formerly 145-acre lake is estimated at 2.3 million cubic yards. Based on the results of two rounds of Targeted Brownfields Assessment activities, conducted under EPA CLP (Superfund) protocol, the sediments contain literally millions of pounds of heavy metals (notably Cr, Pb, Zn, and Cu), and millions of pounds of polyaromatic hydrocarbons (notably benzo-a-pyrene, anthracene, phenanthrene, fluoranthene, pyrene, and others). As a “stilling basin” just downstream of urban Greenville, and the city’s primary wastewater treatment plant, Lake Conestee has provided the perfect environment for the accumulation of sediments and with them, the kinds of contaminants that have a strong affinity to be bound to those sediments via physical and chemical mechanisms. These include the metals, PAHs, pesticides, and PCBs so prolifically produced and used by our society through much of the 20th century. Thus, Lake Conestee has prevented the further transport downstream of these thousands of tons of contaminated sediments. This is highly significant in that the Reedy is a major tributary to Lake Greenwood, the potable water supply for the City and County of Greenwood. This accumulation of contaminants, on the other hand, creates special management challenges to the future management of Lake Conestee, and raises significant questions about the ecological consequences of such masses and mixes of contaminants.

Statement of results or benefits

Very little is known about effects of the toxicants in Lake Conestee on living organisms in the area. Collecting animals from the area and investigating how different biochemical parameters in the animals are affected by the toxicants will give an insight into the health of these organisms, and in a broader sense, the health of the ecosystem of the lake and its wetland communities, and the downstream watershed. Knowledge of the health of aquatic organisms in the lake will help in assessing the potential health risks for humans who eat fish from the lake and use the lake for other recreational purposes. Measuring biological effects in resident animals provides information in addition to the chemical concentrations in water and sediment. Chemical analyses alone often do not provide enough information to predict site-specific bioavailability of the chemicals of concern. And even measuring uptake and accumulation of contaminants in living animals does not

allow prediction of health effects, because important groups of contaminants (like PAHs) are rapidly transformed and/or excreted. Measurement of biochemical and physiological parameters gives direct information on the bioavailability of measured chemicals, the health effects of these chemicals, and it gives information on the presence of toxic compounds that are not routinely measured in chemical surveys.

Efforts are underway to develop remediation plans and to design new public use and management plans for the lake area. Results from this study will be beneficial in developing remediation plans, and after remediation and restructuring, a new sampling program can be developed to compare after-remediation with pre-remediation situations. This will give information on the effectiveness of the remediation and the improvement of the environmental health of the lake.

Nature, scope and objectives of the research, timeline

The proposed study will focus on measuring biochemical health indicators in a resident fish species. Little is known about the fish populations in Lake Conestee, but largemouth bass is expected to be a good study species because of its wide-spread in the Reedy River watershed. This allows for comparison of animals from contaminated sites with subjects from clean sites in the same watershed.

Fish species have been used extensively for monitoring environmental impacts in aquatic environments. Fish species have the potential for accumulating potential toxicants, and their life cycle usually spans a longer period than invertebrates, which allows for a longer period of contact with potential toxicants. Also, fish, like smallmouth bass, are of direct importance to human health because of their value as game fish and use for human consumption.

Animals will be collected at two time periods during the year to give more insight into seasonal changes. It is proposed to collect in late spring and late fall. The analysis of the biomarkers is anticipated to be completed within a year from the first sampling period.

Methods, procedures, facilities

Largemouth bass will be collected in Lake Conestee with stationary nets. A reference site in the Reedy River watershed will be sampled in the upstream area, above the mayor pollutant input sites in the Greenville area. Also, a location downstream of the Lake Conestee dam will be sampled to investigate the effect of downstream dispersion of contaminants.

The animals will be collected from the nets, and tissue samples (blood, bile, liver, spleen) will be harvested from fresh fish, and immediately frozen in liquid nitrogen for later analysis.

The laboratories at the Clemson Institute for Environmental Toxicology are equipped for a wide variety toxicological research. Extensive chemical analytical facilities are complemented by specific equipment for molecular, biochemical, enzymological, immunological, cellular and whole-animal experiments.

The following set of biomarkers will be measured in the collected tissues:

Bile fluorescence: This measurement will give the first indication if animals have been exposed to polycyclic aromatic hydrocarbons (PAHs). PAHs are known for their toxicity, and some of them are potent carcinogens. There are clear causal links between PAH exposure and formation of tumors and other diseases in fish. When these compounds enter the organism, they are changed (biotransformed) into less toxic compounds that are easier to excrete for the organisms. These changed compounds are mostly removed by the liver and excreted in the bile. Because these compounds are highly fluorescent, analysis of bile samples by fluorescence spectrophotometry will give an overall indication of exposure of the animals to PAHs.

Biotransformation enzymes. Some of the enzymes which are responsible for the biotransformation of PAHs, but also for PCBs, dioxins and other organochlorine compounds, are easily measured. Either the total amount of these enzymes, or the enzymatic activity are measured. Because these enzymes can dramatically increase their activity after exposure of the organism to the toxicants mentioned above, they are excellent biomarkers for exposure. The enzymes that will be measured are cytochrome-P450 isoforms, glucuronosyltransferase and glutathionetransferase. Well-established, standardized protocols will be used to measure these enzymes.

Metallothioneins. Because considerable exposure to heavy metals is expected in Lake Conestee, the induction of metallothioneins (MT) will be measured. These proteins are especially designed to bind and detoxify metals that enter an organism, thus protecting liver and kidneys from damage induced by metals. Elevated concentrations of these proteins indicate that the organism has been exposed to metals. MT is measured with specific antibodies in an immunoassay, or by measuring the metal content of MT that is purified from the collected fish.

Anti-oxidative enzymes. When organisms are exposed to organic pollutants or to heavy metals, the protective pathways described above may not be enough to detoxify the pollutants. As a result, reactive oxygen species may be produced in reactions of the pollutants with cellular compounds. Too much reactive oxygen can have serious effects on biological membranes, and can lead to damage of the DNA. Several protective enzymes are present in the cells, which protect the cells from damage by reactive oxygen. One of these protective enzymes is superoxide dismutase (SOD). Increased expression of this enzyme can be measured, and is a general biomarker that indicates exposure to harmful compounds.

DNA damage. Even though protective mechanisms are present, DNA damage can occur in animals exposed to pollutants. If DNA damage is increased in animals from polluted areas, this may lead to severe effects like tumor formation. A well-established method to measure DNA damage is the TUNEL assay. This assay measures the breakage of DNA strands, which occurs after reactive oxygen species have reacted with DNA, or when breakdown products of PAHs bind to DNA. Even though most cells have DNA repair systems, these systems can be impaired by pollutant exposure, leading to permanent DNA damage and cell death or tumor formation.

Endocrine disruptors. Some environmental pollutants have been shown to mimic growth and sex hormones in wildlife species. Especially pulp mill effluents, but also other sources of organic pollutants (domestic waste water) are known sources for these endocrine disruptors. One potential effect in fish of estrogen-like compounds is the formation of egg-yolk proteins in male animals. Increased vitellogenin concentration, a specific yolk protein precursor, in male fish is a good biomarker for exposure to environmental estrogens. Vitellogenin is easily measured in blood samples with specific antibodies.

Acetylcholinesterase inhibition. Most insecticides have a specific neurological effect: they interfere with the function of neurotransmitters. Animals that are exposed to pesticides may show inhibition of their acetylcholinesterases, which is measured by a standardized assay. When the natural function of this enzyme is impaired by pesticides, neurological effects can be expected which can lead to altered behavior of fish species. This altered behavior (erratic swimming, reduced feeding capacity) may lead to reduced fitness and eventually to early death.

Related research:

This research complements research that will focus on the Reedy River watershed and the impacts that human activities have on ecosystem health. This research, supported by a grant from the V. Kahn Rasmussen foundation, will facilitate chemical, ecological and toxicological studies to better characterize the risk associated with contaminants buried in the sediments of Lake Conestee. The biochemical research proposed in this grant will complement these studies and provide all the information necessary to perform an ecological risk assessment on Lake Conestee. Results of the risk assessment can be used

to make scientifically-sound decisions regarding future management of this ecosystem as well as the rest of the Reedy River.

Training potential

It is anticipated that with the help of funding for this project, one graduate student working towards a Masters or a PhD degree in Environmental Toxicology can be supported for a one year period. Presently, we are applying for support through the governors school summer research program to support a high school student intern.

Investigator's qualifications

Principal investigator: Peter van den Hurk, Ph.D. Assistant Professor, Department of Environmental Toxicology, Clemson University

Information Transfer Program

From the project, Real-time Water Quality Monitoring for Education and Stakeholder Feedback in the Saluda-Reedy Watershed, three students have been involved with this project. one computer science master's student was trained in data acquisition, transfer and display from remote watershed sensors to a real-time website. A doctoral student developed GIS data for the Saluda-Reedy Watershed, including a stream and watershed layer that was incorporated into the web-based GIS website. Also, a Masters student, from the Department of Forestry and Natural Resources, helped to develop algorithms to estimate river health from in-situ sensors.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	0	0	0	0
Masters	3	0	0	0	3
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	5	0	0	0	5

Notable Awards and Achievements

One poster presentation from the project "Toxicological Effects of Environmental Pollutants in Lake Contee" was presented:

Otter, Ryan. March 2004. "Watershed-scale Application of Biomarkers to Assess Ecosystem Health." Carolina Chapter of the Society for Environmental Toxicology and Chemistry, Atlanta, GA.

Publications from Prior Projects

- 1996SC101B ("Assessment of the Effect of Biturbation on Advective Contaminant Exchange at the SedimentStream Interface") - Water Resources Research Institute Reports - Work, Paul A., Paul Moore, John McEnery, and D.D. Reible. 1999. "Assessment of the Effect of Bioturbation on Advective Contaminant Exchange at the SedimentStream Interface." South Carolina Water Resources Center, Clemson University, Clemson, SC, 180 pages.
- 1996SC101B ("Assessment of the Effect of Biturbation on Advective Contaminant Exchange at the SedimentStream Interface") - Dissertations - Moore, Paul Roland. 1999. "Bioturbation and Pore Water Exchange in a Laboratory Flume." MS Dissertation, Civil Engineering, Clemson University, Clemson, SC, 165 pages.
- 1996SC101B ("Assessment of the Effect of Biturbation on Advective Contaminant Exchange at the SedimentStream Interface") - Dissertations - McEnery, John Anthony. 2000. "Interstitial Pore Water Flux Through Streambeds of Varying Composition." Ph.D. Dissertation, Civil Engineering, Clemson University, Clemson, SC, 172 pages.
- 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Water Resources Research Institute Reports - Backman, Kenneth F., and Sheila J. Backman. 2000. "Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region." South Carolina Water Resources Center, Clemson University, Clemson, SC, 35 pages.
- 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the

- Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Backman, Sheila J., and Kenneth F. Backman. 2001. "Perceptions of Water Quality in the Five Lake Savannah Watershed Region." In College of Health, Education and Human Development Faculty Research Forum, Clemson University, Clemson, SC, p. 3.
6. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Davis, Jason, and Kenneth F. Backman. 2001. "Boaters and Marina Operators' Perceptions of Water Quality in the Five Lake Savannah Watershed Region." In Southeastern Recreation Research Conference, Asheville, NC, February 21-23.
 7. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Walker, Joseph, and Kenneth F. Backman. 2001. "Exploring the Effect of Trip Distance on Boaters' Perception of Water Quality." In Southeastern Recreation Research Conference, Asheville, NC, February 21-23.
 8. 2000SC44B ("Initiating Effective Algae Reduction on Lake Greenwood, South Carolina") - Conference Proceedings - Blacklocke, Sean. 1999. "Regulating Animal Agriculture in America: Who Benefits?" In 80th Annual Conference of the American Farm Bureau Federation, Albuquerque, NM.
 9. 2000SC44B ("Initiating Effective Algae Reduction on Lake Greenwood, South Carolina") - Conference Proceedings - Blacklocke, Sean. 1999. "An Inquiry into the Rationale for Prioritizing South Carolina's Animal Feeding Operations for Water Pollution Regulation" In 1st Annual South Carolina Water and Environmental Symposium, University of South Carolina, Columbia, SC.
 10. 2000SC3B ("Reestablishment of an Estuarine Marsh and Waterway after Causeway Removal") - Water Resources Research Institute Reports - Curran, Mary Carla, Randall Cross, and Earl J. Hayter. 2001. "Reestablishment of an Estuarine Marsh and Waterway after Causeway Removal." South Carolina Water Resources Center, Clemson University, Clemson, South Carolina, 11 pages.
 11. 2001SC3781B ("Reservoir Shoreline Erosion and Sediment Deposition with Cohesive Sediments") - Water Resources Research Institute Reports - Eric, Sebnem and Paul A. Work. 2002. "Prediction of Shoreline Erosion and Sedimentation in Hartwell Lake, SC/GA, Georgia Tech Regional Engineering Program Civil and Environmental Engineering, Report No. GTREPCEE/2002-1, South Carolina Water Resources Center, Clemson University, Clemson, South Carolina, 97 pages.
 12. 2001SC3761B ("Using Spatial Techniques to Assess the Contribution of Animal Agriculture on Watershed Impairment for the Saluda River Watershed in South Carolina") - Water Resources Research Institute Reports - Lu, Kang S., and Jeffery S. Allen. 2001. "Animal Agriculture and Watershed Impairment in South Carolina." South Carolina Water Resources Center, Clemson University, Clemson, SC, 69 pages.
 13. 2002SC4B ("Renovating Water for Conservation and Reuse: Developing Design Parameters for Constructed Wetlands for Domestic Wastewater Treatment and Mitigation") - Water Resources Research Institute Reports - Rodgers, Jr., John H., Kristina V. Garber, Jeffery S. Gallagher, Camille L. Stagg. 2002. "Renovating Water for Conservation and Reuse: Developing Design Parameters for Constructed Wetlands to Domestic Wastewater Treatment and Mitigation, South Carolina Water Resources Center, Clemson University, Clemson, South Carolina, 28 pages.
 14. 2002SC1B ("Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina") - Conference Proceedings - Lu, Kang S., and Jeffery S. Allen. 2003. "Animal Agriculture and Watershed Impairment in South Carolina: A GIS based spatial assessment." In Ninth International Symposium on Animal, Agriculture and Food Processing Waste (ISAAFPW 2003), Durham, NC.

15. 2002SC1B ("Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina") - Other Publications - Allen, Jeffery S., and Kang S. Lu. 2002. "Animal Agriculture and Watershed Impairment in South Carolina." Report submitted to PSA Agrisystems Productivity and Profitability Competitive Grants Program.
16. 2002SC1B ("Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina") - Other Publications - Allen, Jeffery S., and Kang S. Lu. 2002. Modeling and Predicting Future Urban Growth in the Charleston, South Carolina Area. Special issue of Conservation Ecology, {online} URL: <http://www.consecol.org/vol8/iss2/art2>.