ANNUAL PROGRAM

CURRENT RESEARCH JULY 1, 2005, TO JUNE 30, 2006

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The Water Resources Research Institute is a unit of The University of North Carolina system headquartered in Jordan Hall on the North Carolina State University campus.

It is one of 54 state water institutes authorized by the Water Resources Research Act of 1964 to administer and promote federal/state partnerships in research and information transfer on water-related issues.

The mission of WRRI is threefold: to identify the state's ever-changing research needs, to motivate and support research by qualified scientists, and to provide for technology transfer.

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New research

NCSU researchers aim to improve the accuracy of PLAT in predicting phosphorus loss from organic soils of the lower NC Coastal Plain

The phosphorus loss assessment tool (PLAT) was developed to predict phosphorus losses from agricultural land to surface and groundwater in order to identify sites that need intensive management to reduce phosphorus losses. The PLAT software was based on best available science and uses many site and management factors to calculate phosphorus loss potential. One of the factors is soil group—organic, sands, loams and clays; with organic soils predicted to release greater amounts of soluble phosphorus than the other groups. Risk for phosphorus loss is assigned to soil groups based on the Mehlich 3 phosphorus extraction soil test. However recent evidence suggests if organic soils contain significant amounts of aluminum, they may bind phosphorus more strongly than predicted by PLAT.

There is little information on the aluminum content of the organic soils of the lower NC Coastal Plain, but these soils can vary greatly in their mineral content, and it is very likely that the phosphorus release characteristics will also vary. For phosphorus losses from organic soils to be accurately predicted by PLAT, differences among these soils in aluminum content and the relationship to phosphorus solubility must be characterized. In this project, the investigators will assess the aluminum content of organic soils common to the lower NC Coastal Plain, evaluate the effect of the aluminum content on phosphorus release, and establish the relationship between Mehlich 3 extractable phosphorus and soluble phosphorus in these soils. They will sample different types of organic soils—from deep organic to shallow organic over a mineral layer—with a range of phosphorus content. They will then perform different types of extractions to quantify aluminum content and identify the forms of phosphorus and their potential availability and mobility.

To understand better the variability in phosphorus release among organic soils, the investigators will also perform in-depth fractionation of phosphorus forms. The results of this study might lead to groupings on which to base PLAT algorithms for different soil series within the organic soils.

To address the effect on soluble phosphorus release of irregular phosphorus loadings that frequently occur with intensive agriculture, the investigators will perform incubation experiments using organic soils and fertilizer and manure. The results of these experiments are expected to be useful for designing nutrient management plans for organic soils.

Results of the studies will be incorporated into the PLAT software.

Validating the Phosphorus Loss Assessment Tool for the Organic Soils of North Carolina (70212)
Rory Maguire and Deanna Osmond, Department of Soil Science, NC State University
June 15, 2004, to June 14, 2005
Funded by WRRI

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Members of the Board of Directors of the Water Resources Research Institute are appointed by the President of The University of North Carolina system. The Board establishes Institute policy, and the Chairman of the Board makes appointments to the Technical Committee.

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WRRI ADVISORY COMMITTEE

The Advisory Committee of the Water Resources Research Institute is composed of representatives from state and federal programs, local government, industry, environmental organizations, private consultants, water and wastewater treatment plants, the university research community and others. The committee advises the Institute on the need for water-related research in North Carolina, the region, and the nation.

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The Technical Committee of the Water Resources Research Institute is composed of university faculty representing many disciplines. Each year a committee is appointed to review research proposals and provide expert advice on the technical merits and usefulness of the proposals.

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2004 - 2005 INSTITUTE RESEARCH PRIORITIES

At its meeting in May 2003, the WRRI Advisory Committee selected the following topics as priority water-related research needs in North Carolina for the 2004-2005 fiscal year:

Existing and emerging contaminants
Determine the sub-lethal and reproductive effects on natural community composition and human health of low-levels of pharmaceuticals, endocrine disruptors, and other chemicals. Fate and transport investigations are needed of on-site wastewater treatment plants and orphan landfills.

Water supply/drought issues
Examine future water supplies and drought management as related to development (imperviousness), economic implications, and water conservation/efficiency.

Erosion and sediment control/stormwater
Identify cost-effective erosion and sediment control strategies and technologies; develop stromwater best management practices and management strategies to protect downstream water quantity and quality.

Nutrients and water quality
Determine appropriate nutrient criteria for free-flowing streams in NC. Illuminate the effects of nutrients and trace constituents in groundwater discharge on nutrient cycling and estuarine ecology. Determine fate and transport of NOx and SOx in western NC.

Agronomic issues
Assess the potential for nutrient loss to ground and surface waters from fields receiving manure/biosolids, the amount of nutrients needed for realistic crop yield, and existing soil conditions. Assess the effectiveness of pasture BMPs for control of nutrients, bacteria, and sediment.

Water/wastewater financing and funding
Analyze opportunities for and obstacles to establishing a permanent funding source for water and wastewater infrastructure. Evaluate basic assumptions on revenue that affect municipalities' ability to keep pace with increasing maintenance and operating needs.

Economic and regulatory issues
Quantify the value of ecosystem services to demonstrate benefits of regulatory programs. Determine if wetland and stream functions can be adequately restored on a watershed scale if regulations provide for tradeoffs among type and functions.

Basin management
Determine ways to assign economic value to local water quality benefits provided by local ecosystems to encourage land use management. Determine appropriate management measures for water quality and habitat improvement as hydropower facilities in NC are relicensed.

Infrastructure issues
Assess risk versus the costs of providing security as opposed to response preparedness for various types of infrastructure (water and wastewater utilities; dams).

On-site wastewater management
Determine methods to renovate failed septic systems and drainfields and the viability of using advanced treatment to provide high quality effluent to drainfields.

Monitoring and data analysis
Determine relation between water quality data and growth of concentrated animal feeding operations through sound statistical analysis (longitudinal). Investigate and assess the regulatory implications of the continuing improvement in contaminant detection capabilities.

New research

NCSU team will monitor restoration projects for evaluation of success

When development impacts to streams, wetlands and riparian buffers in North Carolina are allowed under State or Corps of Engineers permits, these losses must be offset by creation, enhancement, restoration or preservation of like resources—a requirement called compensatory mitigation. In 1996 the NC General Assembly created the NC Wetlands Restoration Program (NCWRP)* to oversee compensatory mitigation throughout North Carolina and created a fund to receive mitigation payments and support mitigation projects. Several million dollars in restoration projects are now underway across the state.

Nationwide, efforts to create and restore wetlands and related resources have met with mixed success. Carefully designed, long-term monitoring of representative projects is needed to assess the success of restoration efforts in North Carolina and to recommend actions to improve success.

In this project, a team of faculty, technicians, and students associated with the NCSU Department of Biological and Agricultural Engineering will conduct a comprehensive monitoring program for 11 stream, wetland and buffer restoration projects designated by NCWRP. Under the direction of Dr. Greg Jennings, the team will assess physical and vegetation conditions at stream restoration sites. They will take annual photographs, quantify channel dimension, pattern and profile; quantify channel bed particle distribution; assess survivability of plant communities and invasive species; assess structures

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New research

UNC-Wilmington investigators will look for linkage between phosphorus and fecal microbes in aquatic sediments

New research

NCSU investigators will evaluate performance and cost effectiveness of individual measures and systems of measures to control sediment on construction sites

Erosion and sediment control systems currently used on construction sites have been shown to be relatively ineffective in retaining sediment on site during rain storms. Discharges from sites far exceed turbidity standards, and damage to adjacent water bodies is common. As attention in the Clean Water Act's TMDL (total maximum daily load) program turns to sediment, more effective approaches for controlling sediment from construction sites will be required.

The principal investigator on this project has devoted several years to studying the effectiveness of erosion and sediment control measures both at the NCSU Sediment and Erosion Control Research and Education Facility and on construction sites. His work has demonstrated that marginal improvement in effectiveness of traditional structural controls is possible with increased basin size, implementation of advanced technologies such as basin skimmers and baffles, and use of flocculants such as polyacrylamide. Results of his earlier work suggest that a system of such advanced controls supplemented by practices that infiltrate rainfall on-site—such as rapid revegetation and retention of vegetated/forested buffers—may be able to control sediment to avoid off-site damage and to reduce turbidity to meet water quality standards.

In this project, the investigator will use data from his earlier research to model and compare the effectiveness of various combinations of measures and practices. The investigator will use GeoWEPP, an adaptation of USDA's Water Erosion Prediction Program to GIS, and SIMWE models to simulate preconstruction water and sediment flow and their change during and after construction for three actual constructions sites in Piedmont and one site in the mountains. Both models use digital elevation, land cover, soil and rainfall data stored in GIS to simulate the runoff and sediment transport, and they support incorporation of several types of conservation and sediment control measures. For each site, investigators will model (1) pre-construction, (2) construction using standard practices, (3) construction using improved basin outlets and additional ditch check dams, (4&5) construction using ground cover (grass seed with either straw or mulch) plus standard practices, and (6&7) construction using extra buffers (either wooded or grassed) with dispersed flow, plus standard practices. For each scenario, the spatial pattern and magnitude of erosion, deposition, and sediment delivery to the site outlet will be determined. The investigators will evaluate the impact of the integrated systems beyond the construction sites and identify components of the systems that are highly effective and those that are not necessary or provide little protection.

As part of the modeling, the investigators will explore the potential of a new technology, Tangible User Interface, based on a flexible solid 3-dimensional model of the landscape for quickly determining and demonstrating the impact of different measures and systems on runoff water quality.

An integral part of the project is economic evaluation of the private costs and benefits of individual practices and systems. Data on construction and operating/maintenance costs of practices and systems will be collected and used for a partial budgeting analysis of the seven scenarios. Costs will be related to differences in sediment delivery to identify the most cost efficient measures that will meet standards and loading limitations under TMDLs. The results will be summarized as a ranking. Benefits to developers—defined as avoided costs attributable to sediment load reduction (such as stream restoration and storm drain cleanout)—will also be determined for each scenario.

The results of this project will allow improved decision making for both developers and regulators.

Assessment of Standard and Alternative Sediment and Turbidity Control Systems for Impacts on Water Quality (70211)
Richard A. McLaughlin, Department of Soil Science, and Grada A. A. Wossink, Department of Agricultural and Resource Economics, NC State University
June 1, 2004, to May 31, 2005
Funded by WRRI

NCSU team *continued from page 3*

installed for restoration purposes; and assess Bank Erosion Hazard Index and Near Bank Shear Stress along the reach. The team will assess vegetation and hydrologic conditions at wetland and buffer restoration sites. They will assess survivability of plant communities and invasive species and will install water level recorders and collect data three times annually. Each year they will summarize data and prepare reports. At the request of NCWRP, research level analyses will be performed.

*The NC Wetland Restoration Program has now been folded in to the NC Ecosystem Enhancement Program.

Monitoring of Stream, Wetland and Buffer Restoration Projects (50347)
Gregory D. Jennings, Water Resources Research Institute
October 1, 2003, to September 30, 2008
Funded by the Wetlands Restoration Program, NC Department of Environment and Natural Resources

New research

New techniques from NCSU Center for Earth Observation will allow better focus on erosion and sedimentation in watershed management

Accurately classifying, quantifying, and mapping land use/land cover (LU/LC) within a watershed at frequent intervals (2-5 years) is a critical component of planning for watershed management for water quality purposes. In this project, which builds on one completed in 2003, the investigators will further advance techniques for using satellite observations of the earth's surface to perform these tasks.

In the earlier study, the investigators used IKONOS 4-meter, multispectral satellite imagery to create a detailed LU/LC map of the stream riparian zones and adjacent environment of the Hominy Creek Watershed near Wilson, NC, in the Neuse River Basin. IKONOS proved effective for identifying difficult-to-assess land cover types in urban watersheds, particularly impervious surfaces. However, single-date IKONOS imagery was found to have limited usefulness for distinguishing between bare/disturbed soils and fallow agriculture and between grass/open space and active agriculture. These limitations restrict the ability to provide current LU/LC data for calculating erosion and sediment yield and weighted runoff curves and for mapping riparian zones and connectivity of impervious surfaces or potential pollutant sources to streams. The investigators concluded that to accurately classify these uses, multi-date imagery is needed. This fact, along with the obvious fact that the ability to detect changes in LU/LC is necessary to understand the impact of land use on water quality, led to a proposal to investigate the use of multi-date IKONOS imagery enhanced through a proprietary fusion technique for improved LU/LC classifications within an urban watershed.

IKONOS provides 4-meter resolution in four bands in the blue, green, red and near infrared portions of the electromagnetic spectrum as well as 1-meter black and white panchromatic data. Using an advanced data fusion technique developed at the NCSU Center for Earth Observation (for which a patent is pending), the investigators will use the panchromatic data to increase the resolution of the multispectral data. This technique makes it possible to preserve the spectral integrity of the fused data, making it more useful for image classification and modeling. For this study, the investigators will acquire one high-resolution, late summer (2004) IKONOS image to compare with the previously acquired 2002 early spring image. The comparison between active and inactive growing seasons should resolve the areas of classification confusion.

The investigators will also investigate the use of data from the new SPOT-5 satellite for LU/LC. SPOT-5 provides 10-meter multispectral and 5- and 2.5-meter panchromatic images. Unlike IKONOS—which provides images on a "by-request" basis only, SPOT-5 archives images of the entire Earth's surface on regularly repeated cycles. Therefore SPOT-5 may provide a cheaper alternative for acquiring repetitive high-resolution imagery.

Both IKONOS and SPOT-5 data will be integrated with existing GIS layers and other ancillary sources to form a spatial information system that will be used to characterize buffer zones, map LU/LC, and conduct detailed LU/LC change analysis in the study area. The investigators will make recommendations for the use of the new techniques for other applications such as stream sedimentation studies, forest logging monitoring, and urbanization studies.

Integration of High Resolution Imagery in Cost-Effective Assessment of Land Use Practices Influencing Erosion and Sediment Yield (70207)
March 1, 2004, to February 28, 2005
Siamak Khorram and Stacy Nelson, Center for Earth Observation, NC State University
Funded by WRRI and the U.S. Geological Survey

UNC-G biologist will study whether riparian area restoration provides food for fish

The role of terrestrial subsidies in the form of leaf litter to stream ecosystems has long been appreciated and has served as a major premise in development of the River Continuum Concept, arguably the most important paradigm in the discipline of stream ecology. In recent years, there has been increasing recognition that many other forms of ecosystem subsidies are transferred between terrestrial riparian and adjacent stream ecosystems. For example, in certain ecosystems, migrating salmon provide a nitrogen subsidy to the riparian forest, while terrestrial grasshoppers get large portions of their diet from algae stranded along riverbanks during low flow.

In restored areas of North Buffalo Creek in Guilford County, NC, the investigator has observed increased fish densities in the face of limited macroinvertebrate restoration. These observations suggest that in urban NC Piedmont streams where macroinvertebrate fauna are severely impaired, restoration of riparian zones has potential to deliver food to support fish growth and thereby enhance fish production.

In this project the investigator will quantify the degree of recovery of the fish community and the trophic basis for fish production in restored urban streams. In restored and unrestored sections of North and South Buffalo Creek and in forested sections of both streams, the investigator will study fish abundance and richness, macroinvertebrate parameters, and fish diet. She will exploit the distinct ^{15}N sig-

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New research

NCSU investigators will evaluate potential for groundwater contamination from stockpiled poultry litter

North Carolina ranks first and fifth in the nation in turkey and broiler productions, respectively, with 45 million turkeys and 735 million broilers produced in 2003. Turkeys and broilers are predominantly raised on litter—a mixture of bedding material, manure, feathers, feed, and water, creating large amounts of litter each year. Many growers stockpile litter on bare soil over the winter and apply to corn in the spring, then stockpile over the summer and apply to winter wheat in the fall. In the North Carolina Coastal Plain, where there are coarse-textured soils with high water tables and large poultry operations, the practice of stockpiling litter on bare soils could be creating high risk of groundwater contamination by soluble poultry litter constituents.

Some constituents of poultry litter that could degrade groundwater are nitrate-nitrogen, ammoniacal-nitrogen, phosphorus, pathogens, and heavy metals such as copper, manganese and zinc. However, organic arsenic (As) compounds, such as roxarsone, are added to poultry feed to control intestinal parasites and disease and to promote growth. Since roxarsone is largely excreted, litter may contain up to 77 parts per million of dry litter weight. Microbes in litter and soil mineralize the less toxic, less mobile organic As compound into increasingly toxic and mobile As(V) and As(III) species. High temperature and high moisture content enhance degradation of organic As to more mobile species, so stockpiling litter without cover increases the risk of As leaching in an area where annual rainfall exceeds 50 inches. In addition, phosphate enhances As transport through the subsoil and increases dissolved As concentrations, and phosphate contamination is already a concern in poultry-producing regions of the NC Coastal Plain. Since many growers create uncovered litter stockpiles on bare soil at the same location year after year, the threat of As contamination of shallow groundwater is of particular concern in the NC Coastal Plain with its large poultry industry, sandy soils, and high rainfall depths. Since a large portion of the rural population in the NC Coastal Plain relies upon the shallow groundwater as the primary drinking water supply, As in drinking water could be a health concern.

While conditions are favorable for As contamination of groundwater from poultry litter in the NC Coastal Plain, no studies have been conducted to determine the extent to which contamination may be occurring. In this project, investigators will monitor As, nitrogen, and phosphorus transformations and concentrations within litter stockpiles as well as movement of litter constituents into soil. At NCSU's Horticultural Crops Research Station in Clinton, investigators will stockpile two batches of litter for consecutive five-month periods on a site that has not been previously contaminated with animal waste or metal-containing compounds. One batch of litter will be monitored under natural rainfall conditions, and one under simulated rainfall. Soil at the site will be sampled to three feet before stockpiling. Soon after establishing stockpiles, litter in each will be sampled for an array of constituents to provide information on the impact of stockpiling and environmental conditions on the transformation and mobility of constituents. Hourly temperatures will be monitored, and litter moisture content will be monitored every two weeks. At the end of each 5-month period, litter will again be sampled, then removed. The upper 3 feet of soil beneath and adjacent to the stockpiles will be sampled using a grid sampling pattern extending about 3 meters (10 feet) beyond the stockpile perimeter to determine movement of arsenic, copper, zinc, manganese, phosphorus, and nitrogen species into the soil and the potential impact on groundwater quality over time. Information gained from this project could

New research

Multi-institutional project will develop new tools for fecal coliform TMDLs for shellfish waters

There are 117, 659 acres of shellfish harvest waters (SA) in the White Oak River Basin, and many of those acres are classified as Outstanding Resource Waters. Yet 28,058 acres of SA waters are rated as impaired—primarily by fecal coliform—in the NC Division of Water Quality's 2001 White Oak River Basinwide Water Quality Plan. Total maximum daily loads (TMDLs) for fecal coliform must be developed for many miles of streams and acres of estuarine waters in the basin. Development of a successful TMDL requires identification of fecal coliform sources and determination of load reductions that will achieve compliance with water quality standards. Water quality monitoring is necessary to identify and quantify pollutant sources, and water quality modeling is necessary for prediction of the allowable pollutant load.

In estuarine environments, development of a TMDL for fecal coliform has several complicating features, including identification of sources, assessment of the impact of factors affecting coliform survival in the environment, and characterization of water movement due to freshwater flows, tides, and wind. More effective modeling strategies than those currently available are needed for development of fecal coliform TMDLs for estuarine waters.

In this project, investigators will combine Bayesian modeling techniques and molecular monitoring methods to develop new tools for fecal coliform TMDL development and adaptive implementation in the Newport River and adjacent Bogue and Core Sounds. Monitoring using quantitative polymerase chain reaction (Q-PCR) and bacterial source tracking (BST) will be conducted to complement ongoing ambient water quality monitoring by the NC Divisions of Water Quality and Shellfish Sanitation. Q-PCR and BST will allow more rapid detection of contamination and distinction between human and animal sources, which are needed to improve model prediction of human health risk.

Water quality modeling will be conducted using Bayes networks. Bayes nets facilitate decomposition of complex relationships into a linked set of smaller models that can then be fitted using mechanistic expressions, statistical characterizations, and/or expert probability elicitation. The Bayes net model will link sources of fecal coliform to fecal coliform concentrations for purposes of prediction to develop a TMDL.

In the Newport River, investigators will draw heavily on ongoing studies focused on characterization and assessment of land use, land cover, hydrology, land management practices, wildlife and pets, and pollutant sources. The investigators will use data from these studies and an initial version of the Bayes net model to guide Q-PCR, BST, and routine bacteriological monitoring. As the model is refined, monitoring may be modified.

Using these innovative monitoring and modeling techniques, the investigators will assist the NC Division of Water Quality in developing a TMDL for the Newport River and will design post-implementation monitoring to integrate with modeling for adaptive implementation. Based on what they learn through application of the new tools in the Newport River, the investigators will also assist with TMDL development and implementation planning for the North River.

Development of Fecal Coliform TMDLs using Bayesian Modeling and Novel Molecular Monitoring Techniques (50355)
Kenneth H. Reckhow, Nicholas School of the Environment and Earth Sciences, Duke University; Rachel T. Noble, Institute of Marine Sciences, UNC-Chapel Hill; and Nancy White, UNC Coastal Studies Institute
April 1, 2004, to May 31, 2007
Funded by a 319 grant from the NC Department of Environment and Natural Resources

UNC-G biologist *continued from page 6*

natures of terrestrial and aquatic food sources to quantify the contribution of riparian subsidies to fish growth.

At one reach of each type on both streams (six sites) macroinvertebrates will be sampled using techniques designed to collect both aquatic taxa and terrestrial invertebrates that fall from the riparian canopy. The health of the aquatic macroinvertebrate community will be assessed, and isotope analyses will be conducted on aquatic and terrestrial taxa.

Fish will be collected from each site, sorted by species, weighed, and measured. Some will be saved for gut analysis and isotope analyses and the rest will be released. The portion of fish diets due to aquatic versus terrestrial sources will be calculated for each site using isotope mixing models and compared using two-way ANOVA. The results of this project will be useful directly to local water quality managers, and both the techniques used and the results obtained should be readily applicable for planning and implementation in other stream restoration projects.

Trophic Basis for Restoration of Fish Fauna in Restored Urban Streams (70210)
Anne E. Hershey, Biology Department, UNC-Greensboro
March 1, 2004, to February 28, 2005
Funded by WRRI

WRRI Continuing Research

Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina (70194) *Craig J. Allan, Department of Geography and Earth Sciences, and Jy S. Wu, Department of Civil Engineering, UNC-Charlotte. March 1, 2002, to September 15, 2004. Funded by WRRI and the U.S. Geological Survey.* The investigators have completed sampling and continue to analyze collected data that assess the effectiveness of vegetated riparian buffers in controlling the export of nitrogen, phosphorus, suspended sediment, and fecal coliform bacteria from agricultural operations to surface waters in the western Piedmont and Blue Ridge regions of North Carolina.

Reduced Cost Strategies for Regional Integration of Surface and Ground-water Use (70195) *Gregory W. Characklis, Department of Environmental Sciences and Engineering, UNC-Chapel Hill. March 1, 2002, to August 31, 2004. Funded by WRRI and the U.S. Geological Survey.* The investigator has constructed a model that reflects all the costs of conjunctive use of surface and ground water in the NC Central Coastal Plain Capacity Use Area. Minimum costs of water supply for individual communities have been determined, and minimum regional cost scenarios have been generated. The investigator is currently completing a sensitivity analysis of results to fully characterize the impacts of varying inputs.

A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control (70196) *Richard A. McLaughlin, Department of Soil Science, NC State University. March 1, 2002, to August 31, 2004. Funded by WRRI and the U.S. Geological Survey.* The investigator has received a second year of funding to continue to investigate practices that will aid polyacrylamide (PAM) in accomplishing under field conditions the same turbidity reduction it has accomplished under highly controlled experimental conditions. The investigator is testing additional brands of PAM logs, other forms of PAM, a possible system to deliver PAM to basins, and a filter bag that may have the potential to replace small sediment traps.

Improving Dewatering of Wastewater Biosolids Using Innovative Approaches (70205) *Francis de los Reyes III, Department of Civil, Construction and Environmental Engineering, NC State University. June 1, 2003, to December 31, 2004. Funded by WRRI.* The goal of this project is to increase the dewatered solids content of biosolids by incorporating various treatments with traditional dewatering processes using the moisture distribution in sludge as a theoretical framework. A variety of experiments have been conducted to determine the effect of heat treatment combined with cation addition on sludge dewaterability. The investigators continue to do centrifugation tests to predict sludge dewaterability.

Sources, Transport and Fate of Sediment and Nutrients from a Redeveloping Watershed: Hydrology of the Central UNC Campus (70206) *Lawrence Band, M. Doyle, and M. Alperin, UNC-Chapel Hill. June 1, 2003, to May 31, 2005. Funded by WRRI.* This project is investigating water quality patterns and retention in the major stream network draining the UNC-Chapel Hill campus in order to determine sources and fate of runoff, sediment and nutrients. The investigators will continue to measure and develop cross sectional profiles and bed and bank morphology and material in the Meeting of Waters Creek, work with Facilities Management on evaluation of watershed restoration and redevelopment planning, and implement nutrient retention studies in selected reaches.

Sediment Removal Demonstration and Evaluation for Mountain Streams (50330) *Gregory D. Jennings, WRRI. February 27, 2003, to December 31, 2004. Funded by the U.S. EPA and the NC Department of Environment and Natural Resources with matching support provided by Streamside Systems, LLC, and Balsam Mountain Trust.* The project objective is to demonstrate and evaluate technologies for removing excess sediment from mountain streams impaired by historic logging operations, thereby improving and protecting aquatic habitat and stream quality. Equipment being evaluated includes four Series II Contractor's Collectors from Streamside Systems, LLC, and a Sand Wand with Drop Box Filter. Data collection will continue to evaluate the performance of the sediment removal technologies.

Water Quality Indicators: Nutrient Impacts on Chlorophyll or Algae Species Composition (50340) *Kenneth H. Reckhow, WRRI and Duke University. June 1, 2003, to June 1, 2005. Funded by the Water Environment Research Foundation.* Drs. Curtis Richardson (50341) of Duke University, Robert Wetzel (50342) of UNC-Chapel Hill, Hans Paerl of UNC-CH Institute of Marine Sciences, and Russell Gosnell (50343) of North Carolina Central University continue to assist Dr. Kenneth Reckhow in identifying and acquiring water quality data sets covering waterbodies in several ecoregions that allow examination of nutrient-phytoplankton relationships. This research is expected to help states adopt appropriate nutrient criteria for improvement of state water quality standards.

- Dr. Kenneth H. Reckhow has developed and applied a procedure for identifying predictive nutrient criteria on four data sets: Neuse River Estuary, Lake Washington, Lake Mendota, and the San Francisco Bay. This coming year he will apply this procedure to new data sets involving multiple elicitations.
- Drs. Robert Wetzel and Hans Paerl have summarized data on detailed chlorophyll, dominant phytoplankton species, seasonal dynamics, and major limnological parameters for 18 lakes of Michigan, Indiana, and Alabama for use in the comparative database models. They have also done comparative analysis on the absorption of solar radiation by phytoplankton and chromophoric dissolved organic matter (CDOM) in a major river ecosystem of eastern North Carolina. This coming year they will continue their analyses.
- Dr. Russell Gosnell will work cooperatively with Duke University statisticians to analyze water quality data sets.

North Carolina Water Quality Workgroup

In 1999, the NC General Assembly established the North Carolina Water Quality Workgroup to select and recommend collaborative studies between the NC Department of Environment and Natural Resources and constituent institutions of The University of North Carolina that "collectively close knowledge policy gaps with regard to the State's water quality." Funds in the amount of $45,000 were appropriated to fund research projects recommended by the Water Quality Workgroup for the current year. WRRI is providing administrative support for the Water Quality Workgroup, facilitating the call for proposals, proposal review, and contract administration. New research funded by the Water Quality Workgroup is described on this page. Continuing projects are listed below.

Continuing Research Funded by the NC Water Quality Workgroup

Hydrologic, Biologic, and Geomorphic Character of Headwaters Streams in North Carolina (50334) *James D. Gregory, Department of Forestry, NC State University. July 1, 2003, to March 31, 2005.*

Impact of Microbial-Particle Interaction on Microbial Fate and Transport in Stormwater (50335) *Gregory W. Characklis, Mark D. Sobsey, and Otto D. Simmons II, Department of Environmental Sciences and Engineering, UNC-Chapel Hill. July 1, 2003, to December 31, 2004.*

Harmful Algal Species from the New River – Composition and Dynamics (50337) *Carmelo R. Tomas, UNC-Wilmington. July 1, 2003, to December 31, 2004.*

New research

NCSU researchers delve further into relationship between urbanization and stream life

Biomonitoring of stream systems has established the negative effects of urbanization and other land use changes on both invertebrates and fish. Some researchers hypothesize that there is a threshold at which urbanization (measured by impervious area) begins to negatively affect stream biotic communities but below which negative effects are negligible. Others think that there is a strict linear "dose-response" relationship between urbanization and stream life. Little research has been directed at exploring these hypotheses, and none has considered the possibility that invertebrates and fish may differ in their responses to urbanization. In this project, the investigators will quantify the joint responses of invertebrate- and fish-based indices to two measures of urbanization (percent impervious area and an urbanization index) and determine the correlation between invertebrate- and fish-based indices.

This project builds upon and complements one completed by one of the investigators (Dr. Gilliam) under an earlier Water Quality Workgroup grant. In that project, Dr. Gilliam cooperated with the Biological Assessment Unit of the NC Division of Water Quality (DWQ), which has an ongoing program to assess the invertebrate and fish communities in wadeable streams throughout North Carolina. He merged DWQ's database on invertebrate bioindicators for 334 sites in Piedmont North Carolina with GIS databases, mapping the upstream watersheds and calculating landscape characteristics for each watershed. He then analyzed statistically the relationship between urbanization and invertebrate indices using both linear and threshold models. The results from the pooled data support the hypothesis that the relationship is strictly linear—or that if there is a threshold, it is so low as to be statistically insignificant.

In this project, the investigators will cooperate with personnel of DWQ's Biological Assessment Unit to supplement the existing database on invertebrates with data on fish indices to produce a database of 100 sites that have both invertebrate and fish data. Using GIS analysis, they will calculate percent impervious area and an urbanization index for the watersheds of any sites not covered in the earlier project. Using the database of invertebrate, fish and urbanization measures, they will use the standard product-moment correlation coefficient and test whether it is different from zero to assess the correlation between invertebrate- and fish-based water quality indices. They will use four alternative function forms to assess the quantitative relationship between the fish index and the urbanization measures. These alternative forms allow for nonlinear relationships but permit an assessment of whether a putative nonlinear relationship has a threshold.

The results of this project can provide critical information for guiding land use planning, regulatory decision making, and mitigation efforts.

Stream Fish as Bioindicators of Water Quality: Assessing Threshold Responses to Urbanization and Correlations with Invertebrate Indices (50352)
Garrick T. Skalski, Department of Statistics, and James F. Gilliam, Department of Zoology, NC State University
July 1, 2004, to June 30, 2005
Funded by WRRI and the NC Water Quality Workgroup

THE NORTH CAROLINA URBAN WATER CONSORTIUM

In 1985, WRRI in cooperation with several of North Carolina's larger cities established the North Carolina Urban Water Consortium to provide a program of research and development and technology transfer on water problems that urban areas share. In 1998, several members of the partnership formed a special group to sponsor research and technology transfer on issues related to urban stormwater management. Through these partnerships, WRRI helps individual facilities and regions solve problems related to local environmental or regulatory circumstances. The NC Urban Water Consortium (http://www.ncsu.edu/wrri/uwc/) and Stormwater Group (http://www.ncsu.edu/wrri/stormwater/) are administered by WRRI. Participants support the program through annual dues and enhancement funds and guide the program through representation on an advisory board, selection of research topics, participation in design of requests for proposals, and review of proposals. Current Consortium members are the Cities of Burlington, Charlotte, Durham, Fayetteville, Greensboro, Greenville, High Point, Raleigh, Wilmington, and Winston-Salem and the Orange Water and Sewer Authority. Members of the Stormwater Group are the cities of Charlotte, Durham, Fayetteville, Greensboro, High Point, Raleigh, Wilmington and Winston-Salem. Current research projects sponsored by these partnerships are described on the following pages.

New research

NCSU investigators will survey stormwater BMPs for mosquitoes

North Carolina's climate supports 59 species of mosquitoes. Only a few of these species are a problem to humans, but some are carriers of arborviruses that can cause serious diseases such as West Nile virus. There is a perception among some people—both within and outside the stormwater management community—that stormwater treatment wetlands and wet ponds are sources of mosquitoes. Because of public perception and concern, recently installed stormwater wetlands incorporate features to control mosquitoes, including mosquito fish (*Gambusia affinis* and *Gambusia holbrooki*) and vegetation attractive to mosquito predators such as dragonflies. Anecdotal evidence indicates these new features reduce or even eliminate mosquitoes. However, no surveys have been done in North Carolina to determine the extent to which stormwater BMPs breed mosquitoes or to document the effectiveness of recently adopted control methods.

In this project, technicians in the NCSU Department of Entomology and the NC Cooperative Extension Service will survey approximately 50 stormwater wetlands and wet ponds across North Carolina for presence of mosquitoes. They will visit ponds three times (to coincide with prevalence of various species) to search for and potentially collect and quantify mosquito populations. If surveys document serious mosquito problems with stormwater wetlands and/or wet ponds, the investigators will recommend design revisions to limit or eliminate mosquitoes.

Quantifying Mosquito Presence at Stormwater Treatment Wetlands and Innovative Wet Ponds (50354)
William F. Hunt, Department of Agricultural and Biological Engineering, and Charles Apperson, Department of Entomology, NC State University
May 15, 2004, to December 13, 2004
Funded by the NC Urban Water Consortium, Stormwater Group

New research

UNC-Chapel Hill investigator will develop model for cost-effective, reliable regional water supply in the Research Triangle

Increasing water demands associated with population growth have made maintaining a high level of water supply reliability increasingly challenging and costly for many utilities throughout North Carolina. The reliability challenge is magnified by the highly variable nature of water demand and the fact that system design is often driven by peak usage, which can exceed average rates by a factor of two or more. Some demand variability, such as seasonal fluctuations, is predictable, but weekly and/or monthly variability due to weather often remains highly unpredictable. Moreover, recent research suggests that increasing variability in the hydrological cycle may be altering the timing and amount of precipitation (that is, water supply) in many regions as well as raising the probability of drought and flooding. Competition for water for environmental, recreational, and hydropower uses adds to the complexity of water supply planning. This places communities and utilities in a difficult position.

A view of Falls Lake - one of the major water sources in the Triangle

Communities have traditionally maintained a high level of supply reliability by developing water supply infrastructure at a large enough scale to meet peak demand under all but the most extreme circumstances. However, the cost of this approach is becoming prohibitive in many areas. In a growing number of places in North Carolina, communities can no longer rely on a single, large-scale water supply structure but must integrate multiple water assets, some of which can be used on an "as needed" basis to reduce the size of major supply infrastructure. For a single system this may be as simple as using a groundwater source to augment a variable surface water source during periods of high demand. At a regional level, however a much wider range of possibilities is often available, including such things as cooperative development of supply infrastructure (reservoirs or aquifer storage and recovery projects), interconnects between systems, and long-term or contingent contracts for water purchases between systems.

In this project, the investigator will develop a water supply model for the Research Triangle region of North Carolina that minimizes cost and meets a specific reliability target. He will first collect data to fully characterize the location and historic availability of water sources throughout the region, as well as any future development potential for these resources (including conservation projects). Using these data, he will formulate relationships that describe the probability of obtaining a given yield from both proposed and existing sources depending upon the magnitude of each project. These relationships will be combined with cost relationships that describe the expense of infrastructure projects as a function of capacity or size. Together, these analyses will provide information on the cost, volume, and reliability of supply derived from any single source. He will then characterize demand throughout the region. Using information on peak flows, seasonal fluctuations, and long-term growth trends, he will create a demand profile for each community and for the region as a whole. Finally, a set of potential "linking" projects, both real, as in the case of interconnects between systems, and virtual, such as exchanges of withdrawal capacity between upstream and downstream systems, will be defined. He will then evaluate the cost and reliability of combinations of water supply infrastructure and linking projects to quantify potential advantages of "regional" solutions. A range of results will be generated to provide useful information on the impact of different projects or activities on both individual communities and the region as a whole.

Reducing the Cost of Maintaining Regional Water Supply Reliability
(50353)
Gregory W. Characklis, Department of Environmental Sciences and Engineering, UNC-Chapel Hill
June 1, 2004, to May 31, 2006
Funded by the NC Urban Water Consortium and the Carolina Environmental Program at UNC-Chapel Hill

New research

NCSU engineers will develop cost information and guides for maintenance of stormwater BMPs

Stormwater BMPs are widespread throughout the jurisdictions of NC Urban Water Consortium, Stormwater Group members, and innovative practices are becoming more common. Many communities must maintain BMPs, particularly on municipally owned properties, and municipal officials need to know inspection and maintenance requirements to schedule and direct the work. In this project, the investigators will develop inspection and maintenance requirements for ten stormwater BMPs: (1) wet ponds, (2) stormwater wetlands, (3) sand filters, (4) bioretention devices, (5) level spreader/riparian buffer systems, (6) green roofs, (7) underground detention, (8) grass swales, (9) dry detention, and (10) permeable pavements.

The investigators will first survey members of the Stormwater Group and other NC communities, NC DOT, and communities in Alabama, Florida, Maryland and Virginia to identify well-maintained stormwater BMPs in each community's jurisdiction and the inspection and maintenance practices used. For each BMP, a guide will be developed that includes (1) type of maintenance, (2) frequency, (3) maintenance procedures, (4) threshold for performance of maintenance, (3) consequences of not maintaining, and (5) time and equipment needed for maintenance. A detailed checklist will be provided to help communities perform inspection and maintenance.

A bioretention area in Wilson, NC

The guides can be used to determine the number of employees to dedicate to BMP maintenance. Communities can also use the cost information to set reasonable escrow account limits for property owners responsible for maintenance of private land. Cost information will also enable municipal officials to select BMP types with lower inspection and maintenance costs.

Developing Standards and Associated Costs for Stormwater BMP Inspection and Maintenance (50349) William F. Hunt and Jonathan T. Smith, Department of Biological and Agricultural Engineering, NC State University
January 1, 2004, to December 31, 2004
Funded by the NC Urban Water Consortium, Stormwater Group

UNC-Charlotte engineer continues work on local small watershed flood warning system

Precipitation data is the single most important time-variable input to hydrologic models. Its reliability is of critical importance to successful hydrologic model development, calibration and, ultimately, application to solve engineering problems. In contrast to single-point input of rain gage data, radar-derived rainfall estimates provide a better spatial resolution and distribution of rainfall data for hydrologic modeling. The investigator on this project recently completed a feasibility study in which he evaluated the use of radar data from the National Oceanic and Atmospheric Administration's WSR-88D (Weather Surveillance Radar 88 Doppler) as a means of minimizing the installation of numerous and expensive rainfall gauges. He studied radar-rainfall conversion algorithms using Watads software and validated the radar-derived rainfall estimates against ground-level measurements. He also successfully tested the use of artificial neural networks to perform flood forecasts for two streams within the cities of Raleigh and Greensboro.

In this project, the investigator will develop tools for implementing local flood warning systems using radar data. The primary goal is to develop and implement a near real-time precipitation data processing tool for the participating municipalities. He will investigate software needed to receive online and store data from the Level II Radar Distribution Network and will test the software. He will further validate radar-derived rainfall estimates on a near real-time basis, testing at least 10-15 storm events. The software will be made available to participating municipalities, along with a manual and training.

The secondary goal of the project is to develop a preliminary flood forecasting system. To accomplish this goal, the investigator will review current methods for urban flood forecasts, and, after discussion with participating municipalities, will select a modeling approach. He will use radar-derived rainfall rates to run existing stormwater models used by participating municipalities and compare results to observations to determine how much the models can be improved by use of radar data. He will continue work on the use of neural nets to further refine the rainfall-stream flow forecasting relationships, and will begin development of a watershed-level finite element stormwater management model that can be used for instantaneous assessment of critical areas that are likely to flood.

Developing and Implementing a Near Real-Time Precipitation Estimation Tool and Preliminary Flood Forecasting System at Local Levels (50356)
Jy S. Wu, William States Lee College of Engineering, UNC-Charlotte
July 1, 2004 to June 30, 2006
Funded through the NC Urban Water Consortium by the Cities of Durham, Raleigh and Greensboro

Urban Water Consortium Continuing Research

RIVERNET Monitoring (50328) *William J. Showers, NC State University. January 1, 2003, to December 31, 2006. Funded by the City of Raleigh.*

Biosolids and Realistic Yield Expectations (50338) *Noah N. Ranells, James T. Green, Jr., and Wei Shi, NC State University. March 15, 2003, to December 31, 2004. Funded by the Urban Water Consortium.*

Monitoring Study and Maintenance Plan Development for 12 Stormwater BMPs for the City of Charlotte (50344) *William Hunt and Jonathan T. Smith, NC State University. June 27, 2003, to December 30, 2006. Funded by the City of Charlotte.*

Compliance with Stage 2 DBP Rules for Urban Water Consortium Utilities (50345) *Philip C. Singer, UNC-Chapel Hill. September 1, 2003, to December 31, 2004. Funded by the NC Urban Water Consortium.*

Membrane Treatment of Secondary Effluent for Subsequent Use, Phase II (50346) *Francis A. DiGiano and Michael D. Aitken, UNC-Chapel Hill. September 1, 2003, to February 28, 2005. Funded by the NC Urban Water Consortium and the Water Environment Research Foundation.*

TECHNOLOGY TRANSFER

WRRI disseminates information and promotes adoption of new technology and practices through publication of newsletters and technical completion reports on its projects, support of a World Wide Web site and an email list serve, and sponsorship and cosponsorship of conferences, workshops and seminars. The Institute also conducts technology transfer projects under grants from other organizations.

WRRI reports are distributed to libraries, and summaries of reports are published in the WRRI newsletter, and distributed to interested research faculty, other state water institutes, and relevant government agencies. Single copies of publications are available to North Carolina residents at a cost of $4 per copy prepaid ($6 per copy if billed) and to nonresidents at a cost of $8 per copy prepaid ($10 per copy if billed). A listing of all WRRI technical reports is available on the website or by calling WRRI. Summaries of more than 100 WRRI technical reports are available on the Institute's website at http://www.ncsu.edu/wrri/reports/. During the past year the following peer-reviewed technical completion reports were published:

New Publication Policy: Effective March 2003, WRRI instituted a new policy regarding publication of technical completion reports. To fulfill the obligation of providing a final project completion report the Principal Investigator may submit a refereed journal publication. A refereed publication that meets all of the following criteria will be accepted in fulfillment of the final project completion report obligation:

(a) the refereed journal article must be from a journal generally recognized in the field;

(b) the article must report the work done under the WRRI grant;

(c) 25 reprints of the article must be provided along with clear evidence that the journal will allow WRRI to distribute the reprints to interested individuals and institutions without payment of any fees or royalties to the journal or its publisher.

(d) WRRI is acknowledged as a/the source of funding, and the WRRI report number is listed (in the final, accepted version).

Under this new policy, WRRI accepted the following journal articles in fulfillment of completion report obligation during the past year:

q **Consequences of Hypoxia on Estuarine Ecosystem Function: Energy Diversion from Consumers to Microbes**. Robert R. Christian, East Carolina University; Daniel Baird, University of Port Elizabeth; Charles H.Peterson and Galen A. Johnson, UNC-Chapel Hill. Published in *Ecological Applications* 14(3): 805-822. Accepted as final report on WRRI project 50267, *Contribution to Long-Term Modeling Tier of the Neuse River and Estuary as Funtional Assessment of Environmental Phenomena through Network Analysis*. Robert Christian, East Carolina University. Report WRRI-2004-JA8.

q **Modified Serial Analysis of Gene Expression Method for Construction of Gene Expression Profiles of Microbial Eukaryotic Species.** Kathryn J. Coyne, David A. Hutchins and S. Craig Cary, University of Deleware; JoAnn M. Burkholder, NC State University; Robert A. Feldman, Amersham Biosciences, Inc. Published in *Applied and Environmental Microbiology* 70(9): 5298-5304. Accepted as final report on WRRI project 50285, *Routine Quantification of Pfiesteria Piscicida in Water Samples from the Mesohaline Neuse Estuary*. JoAnn M. Burkholder, NC State University. Report WRRI-2004-JA9.

q **Construction of Platinum-tipped Redox Probes for Determining Soil Redox Potential**. Carrie C. Wafer, J. Barrett Richards, and Deanna L. Osmond, NC State University. Published in *Journal of Environmental Quality* (33): 2375-2379. Accepted as final report on WRRI project 50318, *Determining the Effectiveness of Shrub Buffers to Reduce Nitrate-Nitrogen from Agricultural Fields in a Coastal Plain Setting*. Deanna L. Osmond, NC State University. Report WRRI-2004-JA10.

q **Artificial Neural Networks for Forecasting Watershed Runoff and Stream Flows**. Jy S. Wu, UNC-Chapel Hill; Jun Han;

Shastri Annambhotla and Scott Bryant, Stormwater, City of Greensboro. Published in *Journal of Hydrologic Engineering* 10(3): 216-222. Accepted as final report on WRRI project 50315, *A Feasibility Study for Developing Real-Time Flood Forecast Systems*. Jy S. Wu, UNC-Chapel Hill. Report WRRI-2005-JA11.

Newsletters: WRRI produces two newsletters. The *WRRI NEWS* is published every other month and sent to nearly 4,300 federal and state agencies, university personnel, multi-county planning regions, city and local officials, environmental groups, consultants, businesses and individuals. The *NEWS* regularly covers a wide range of water-related topics from current federal and state legislation and regulatory activities to new research findings. The *WRRI NEWS* is available free to residents of North Carolina. To be added to the mailing list, call or write WRRI.

Access to the electronic version of the newsletter and other announcements is provided through the *WRRI NEWS* electronic mail list. The newsletter may be viewed at the WRRI web site: http://www.ncsu.edu/wrri/news/

The Institute also produces a quarterly newsletter, *SEDIMENTS*, published by the NC Sedimentation Control Commission to provide information and assistance to the regulated community and to facilitate communication among personnel of state and local erosion and sediment control programs. Current circulation is about 5,700. This newsletter is free. To be added to the mail or email list contact WRRI. Past issues of the newsletter may be viewed on the NC Division of Land Resources Land Quality Section web site at: http://www.dlr.enr.state.nc.us/pages/sedimentnewsletters.html

WRRI's web site, http://www.ncsu.edu/wrri/, has been given a new design. It provides on-line access to the *WRRI NEWS*; the WRRI Annual Program; technical report summaries; the Water Resources Research Seminar Series schedule; a water resources research expertise directory; and information on upcoming workshops, conferences, and calls for papers.

***WRRI NEWS* electronic mail list.** WRRI also operates an email list that has become an important communications vehicle for the water community in North Carolina. The list serve provides almost daily information on conferences, workshops, calls for papers, grant opportunities, job opportunities, public hearings, public meetings, and recently posted material on the WRRI website, including the WRRI News. Currently there are approximately 675 subscribers to the list. To be added to the list, send an email message to mj2@lists.ncsu.edu with the following command in body (nothing in the subject line) exactly as seen: subscribe wrri-news

Workshops:

2005 - 2006 Water Resources Research Seminar Series

These free seminars will be presented in 1132 Jordan Hall on the NC State University Campus. Updates to the seminars will be sent out on the WRRI-News list as well as posted on the WRRI web site: http://www.ncsu.edu/wrri/. Professional Engineers and Land Surveyors can receive one Professional Development Hour for attendance. Questions regarding location or seminar content should be directed to water_resources@ncsu.edu.

Dr. Phil Singer, UNC-Chapel Hill
"Estimated Compliance with the Proposed Stage 2 Disinfection By-products Rule for Eleven Water Utilities in North Carolina"
Wednesday, September 28, 2005, 3:00 pm

Dr. Francis de los Reyes, NC State University
"Improving Dewatering of Wastewater Biosolids Using Innovative Approaches"
Tuesday, October 18, 2005, 3:00 pm

Dr. Sanjay Shah, NC State University
"Pollutant Leaching Potential from Turkey Litter Stockpiled on Bare Soil"
Tuesday, November 15, 2005, 3:00 pm

Dr. Craig Allan, UNC-Charlotte
"Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina"
Tuesday, November 29, 2005, 3:00 pm

Dr. Greg Characklis, UNC-Chapel Hill
"Microbial Partitioning and its Impact on Stormwater Management"
Tuesday, January 17, 2006, 3:00 pm

Dr. Larry Cahoon, UNC-Wilmington
"Is There a Relationship Between Phosphorus and Fecal Microbes in Aquatic Sediments?"
Tuesday, February 7, 2006, 3:00 pm

Dr. Jim Gilliam, NC State University
"Stream Fish as Bioindicators of Water Quality: Assessing Threshold Responses to Urbanization and Correlations with Invertebrate Indices"
Tuesday, February 21, 2006, 3:00 pm

Dr. Bill Hunt, NC State University
"Stormwater Best Management Practice Performance Evaluations"
Tuesday, March 7, 2006, 3:00 pm

Dr. Jy Wu, UNC-Charlotte
"Developing and Implementing a Near Real-time Precipitation Estimation Tool and Preliminary Flood Forecasting System at Local Levels"
Tuesday, March 21, 2006, 3:00 pm

Dr. Rory Maguire, NC State University
"Validating the Phosphorus Loss Assessment Tool for the Organic Soils of North Carolina"
Tuesday, April 18, 2006, 3:00 pm

2005 - 2006 WORKSHOPS AND CONFERENCES

NCWRA Luncheon & Forum: New Approaches for Measuring Pathogens and Indicators in Environmental Waters September 12, 2005, Jane S. McKimmon Center, NC State University, Raleigh, NC. With the NC Water Resources Association (NCWRA).

Basic Erosion and Sedimentation Control Basic Planning and Design Workshop. September 14-15, 2005, Hilton Wilmington Riverside, Wilmington, NC. With NC Sedimentation Control Commission (SCC) and NC Land Quality Section (LQS), Division of Land Resources.

Basic Erosion and Sedimentation Control Planning and Design Workshop. October 26-27, 2005, Holiday Inn Select, Hickory, NC. With SCC and LQS.

NCWRA Luncheon & Forum. December 5, 2005, Jane S. McKimmon Center, NC State University, Raleigh, NC. With the NCWRA.

NCWRA Luncheon & Forum. February 6, 2005, Jane S. McKimmon Center, NC State University, Raleigh, NC. With the NCWRA.

Erosion and Sedimentation Control Local Programs Workshop. February 2005, Mid Pines Inn, Southern Pines, NC. With SCC and LQS.

Advanced Erosion and Sediment Control Planning and Design Workshop. March 2005, Greenville, NC.(Location and dates TBA). With the SCC and LQS.

Advanced Erosion and Sediment Control Planning and Design Workshop. April 2005, Charlotte, NC. (Location and dates TBA). With the SCC and LQS.

WRRI Annual Conference. April 4-5, 2005, Jane S. McKimmon Center, NC State University, Raleigh, NC.

STUDENT INTERNSHIPS

WRRI coordinates internship programs which provide college students opportunities to work with the following government agencies to gain practical experience in various areas of environmental protection:

- NC Division of Pollution Prevention and Environmental Assistance
- NC Division of Land Resources, Land Quality Section
- U.S. Geological Survey