

Water Resources Research Institute of the University of North Carolina Annual Technical Report FY 2003

Introduction

During 2003, WRI continued its regular program of fostering research, training, and information transfer responsive to water issues of the state and region. Research priorities continue to be identified by the WRI Advisory Committee, composed of federal, state, and local agency personnel and representatives of the business, industry, and environmental communities. High on the list of priorities identified for inclusion in the 2003-2004 call for proposal were topics related to sediment pollution, water supply in the NC Coastal Plain, water conservation, drinking water, and riparian buffers.

The information transfer program continued to focus on disseminating results of sponsored research and providing information on emerging water issues, regulations, and problems. Results of research are disseminated by publication of technical completion reports, summaries in the WRI newsletter, publication of summaries on the WRI website, and presentations by investigators at WRI seminars and Annual Conference. WRI continues to be a sponsor of continuing education credits by the NC Board of Examiners of Engineers and Surveyors. This allows WRI to offer Professional Development Hours for attendance at WRI seminars and the Annual Conference.

Research Program

The Water Resources Research Institute of The University of North Carolina is responsible for fostering and developing a research training and information dissemination program responsive to the water problems of the State and region. To develop its programs, the Institute maintains an aggressive effort to interact and communicate with federal, state, and local water managers. The close contact with water managers is a basis for determining the ever-changing water research priorities.

Priority water research needs for the FY 2003 program were developed in close consultation with the Institutes Advisory Committee. Following their annual meeting a statement of priority research needs was developed (enclosed). The proposal solicitation, as in the past, is mailed to all presidents and relevant department heads of senior colleges and universities in North Carolina to apprise them of the opportunity to submit proposals. The call for proposals is also sent to an email distribution list of about 250 university faculty across North Carolina. A special mailing is also sent to the historically black colleges and universities in North Carolina. The proposals received are then sent to the Advisory Committee, the Technical Committee, and outside peer reviewers to determine the relevancy, need for the proposed research, and relative strength and weakness. Federal and state agency representatives, local government officials, and other water resources leaders are also sent proposals for their comment. The Technical Committee meets to review all comments made by reviewers and to make recommendations regarding proposal funding. Factors considered in the review of proposals are: (1) scientific quality of the proposed work; (2) need for the results of the research in North Carolina and the region; (3) the probability that

useful results can be obtained in one-year; and (4) the potential for the continued support from other funding sources.

The only change that has taken place during the FY 2003 program is the priority research needs. The nine highest priorities focus on the areas of: sediment control, water conservation nutrient and BOD loading to surface waters from animal waste operations, the economic benefits of source water protection programs, wetlands mitigation, water reuse, regulated and unregulated contaminants in wastewater discharges upstream of water supplies, and appropriate riparian buffer characteristics for the three physiographic regions of North Carolina.

Reduced Cost Strategies for Regional Integration of Surface and Groundwater Use

Basic Information

Title:	Reduced Cost Strategies for Regional Integration of Surface and Groundwater Use
Project Number:	2002NC2B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	Water Quality, Models, Management and Planning
Descriptors:	
Principal Investigators:	Gregory W Characklis

Publication

1. Kirsch, B.R. and G.W. Characklis, April 2003, An Integrated Analysis of Water Use Alternatives in the Central Coastal Plain Capacity Use Area, Annual Conference North Carolina Water Resources Research Institute, Raleigh, NC.
2. Kirsch, B.R. and G. W. Characklis, November 2002, An Analysis of Water Supply Alternatives in the Central Coastal Plain Capacity Use Area: A Regional Supply Model, Annual Meeting of the American Water Works Association/Water Environment, Winston-Salem, NC.
3. Characklis, G.W., September 2003, Interface of Water Resource Engineering with Economics and Public Policy, Frontiers of Engineering Symposium, National Academy of Engineering, National Academics Beckman Center, Irvine, CA.
4. Characklis, G.W. and B.R. Kirsch, January 2004, Regional Water Supply Management in North Carolina, North Carolina Water Resources Research Institute Seminar Series, Raleigh, NC.

Title

Reduced Cost Strategies for Regional Integration of Surface and Ground-Water Use

Problem and Research Objectives

Fifteen counties in the eastern part of North Carolina have been classified as a “Capacity Use Area”, a designation that provides the legal framework for regulation of groundwater pumping withdrawals. This region, collectively known as the Central Coastal Plain Capacity Use Area (CCPCUA), has traditionally been dependent on groundwater for much of its water supply, however, increasing usage has led to concerns over reductions in aquifer levels and saltwater intrusion. Under rules recently put forth by the State, communities within the CCPCUA will be issued groundwater pumping permits and will subsequently be required to reduce their withdrawals by as much as 75% over the next 16 years. In order to meet this goal, new water sources must be developed and current sources used more efficiently. Conservation will play some role in improving efficiency, but conservation alone will not compensate for the severe reductions in regional groundwater pumping. Regional supply could be augmented via groundwater from the unregulated surficial aquifers, as well as the more distant Castle Hayne formation, however, the surficial aquifers are unlikely to be more than a stopgap measure for most communities, while the location of the Castle Hayne implies high conveyance costs. Surface water (e.g., Neuse, Tar, and Roanoke rivers) is likely to be the primary means of meeting future water demand in the region, but treatment and distribution of surface water is more expensive than that of groundwater and will involve vast amounts of new capital spending. Significant expenditures will also be required for conveyance infrastructure to transport surface water to those communities not in close proximity to surface sources.

This project focuses on the development of a model that minimizes water supply and treatment costs for regional groups of communities. The central contribution of this work is in estimating the cost savings achievable through development of regional drinking water treatment facilities. Results will specify a water asset “portfolio” for each community, composed of a combination of groundwater, surface water, and the yield from conservation activities. The objective of this work is the development of a model that will return combinations of these assets that minimize water supply and treatment costs over a multi-period time horizon as constrained by supply reliability.

Methodology

The model developed in this project will consider:

- (a) Source water(s) (i.e. groundwater, surface water);
- (b) Source water availability (and changes due to pumping restrictions);
- (c) Source water quality;
- (d) Municipal conservation activities;
- (e) Transfers of groundwater pumping permits;
- (f) Distance and elevation difference between source(s) and treatment plant(s);
- (g) Water demand;
- (h) Reliability targets;

- (i) Treatment plant capacity;
- (j) Treatment technology process chain;
- (k) Community characteristics (e.g., size, location, elevation).

Specifically, the model will:

- (1) Compute the *total cost and average cost (\$/1000 gallons) of water supply* for a community or group of communities based on specification of parameters (a)-(k).
- (2) Compute the *minimum total cost and minimum average cost of water supply* for an individually specified community or group of communities based on selection of an optimal combination from given sets of choice variables for (a), (d), (e), and (i).

The model consists of the treatment cost functions and a minimal spanning tree algorithm that optimizes pipeline network configuration. The costs of water supply and treatment for communities acting individually are compared with situations in which some or all of these communities participate in a regional approach.

Principal Findings

The model has been completed and all of the proposed scenarios have been run and results tabulated. Results describe the capital and operating (O&M) costs associated with employing regional systems as opposed to each community seeking to individually meet their needs. Also described are the number of cities joining the regional systems, and in the case of the scenario in which groundwater permit trading is allowed, the number of cities opting to purchase permits in order to meet their future demand. Results indicate that regional treatment facilities can provide substantial cost savings over scenarios in which communities act independently.

Significance

Results can be used by Coastal Plain water suppliers to optimize their regional growth plans to most cost-effectively provide water to their users. The modeling framework can be adopted for application in other regions to evaluate water supply scenarios for optimizing water supplies.

The Role of Flood Flows on the Lead Isotopic Composition of Stream Waters, Suspended Sediments, and Rainbow Trout Downstream of Lead Contaminated Soils in Barber's Orchard

Basic Information

Title:	The Role of Flood Flows on the Lead Isotopic Composition of Stream Waters, Suspended Sediments, and Rainbow Trout Downstream of Lead Contaminated Soils in Barber's Orchard
Project Number:	2003NC25B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	11
Research Category:	None
Focus Category:	Non Point Pollution, Geochemical Processes, Water Quality
Descriptors:	None
Principal Investigators:	Jerry R Miller, Peter F Galbreath

Publication

1. Miller, J.R., J.B. Anderson, P.J. Lechler, S.L. Kondrad, P. Galbreath, and E.B. Salter, 2004 in press, Influence of Temporal Variations in Water Chemistry on the Pb Isotopic Composition of Rainbow Trout (*Oncorhynchus mykiss*) in Richland Creek, Western North Carolina. *Science of the Total Environment*.
2. Miller, J.R., P.J. Lechler, K.A. Hudson-Edwards, and M.G. Macklin, 2002, Lead isotopic fingerprinting of heavy metal contamination, Rio Pilocmyo basin, Bolivia. *Geochemistry: Exploration, Environment, Analysis* 2:225-233.
3. USEPA, 2002. Risk Assessment Guidance for Superfund, Vol. 1, Human Health Evaluation Manual. Part B. Development of Risk-based Preliminary Remediation Goals (Interim), PB 92-963333. Publication 9285.7-01B. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington DC 1991.

Title

The Role of Flood Flows on the Lead Isotopic Composition of Stream Waters, Suspended Sediments, and Rainbow Trout Downstream of Lead Contaminated Soils in Barber's Orchard.

Problem and Research Objectives

Lead (Pb) is a toxic element that can severely affect human health, especially that of children. Unfortunately, there are numerous anthropogenic sources of Pb to the environment including industrial complexes, paint, automotive exhaust, mining and milling operations, wastewater treatment plants, and agricultural chemicals. In North Carolina, a commonly overlooked source of lead to the environment is lead arsenate, a pesticide utilized on fruit orchards from 1890 through the 1960s. In the fall of 2001, Barber's Orchard (Waynesville, NC) was added to the U.S. National Superfund Priorities List, increasing concerns of the potential impacts of lead arsenate contamination on both human and ecosystem health. Although the magnitude of lead arsenate contamination in North Carolina is currently unknown, recent studies in other areas have demonstrated that it can be significant. For example, in Washington State, another major fruit producing region, lead arsenate has contaminated an estimated 70-100 thousand acres. Given the number of possible sources of Pb to the environment, contaminated aquatic ecosystems often possess multiple Pb sources, and the determination of the significance of each source in a given water body has proven problematic. Historically, the identification of major Pb sources has relied on spatial patterns in total Pb concentrations within water, sediments, biota, and other media. However, the use of total Pb concentrations for these purposes is plagued by numerous confounding factors within aquatic environments. This has prompted some investigators to capitalize on recent advances in analytical chemistry to fingerprint specific Pb sources on the basis of their isotopic composition. Pb isotopes have been found to be excellent tracers of Pb contamination in a wide range of media types (e.g., air, soils, sediments, water, ice, and tree-rings). Nevertheless, Pb isotopic fingerprinting studies have been applied to relatively few contaminants, and the accumulation of Pb isotopes in aquatic biota, including fish, is poorly understood. As a result, the benefits of using Pb isotopes as a tracer of metal contamination in freshwater systems has yet to be fully realized. This is particularly true of non-point source contaminants, such as lead arsenate.

The project will determine the effectiveness of using Pb isotopes to track the movement of lead arsenate from Barber's Orchard into waters and sediments of Richland Creek, and ultimately into rainbow trout. The investigation will concentrate on Pb isotopic variations in suspended sediments and waters that result from fluctuating discharges, the role of changing isotopic ratios on Pb accumulation in trout, and the partitioning of Pb isotopes between bone and fleshy tissues. An understanding of these processes is critical to the use of Pb isotopes as biogeochemical tracers in aquatic systems and the design of monitoring programs. The primary objectives of this investigation are to quantify the variations in Pb isotopic values in water and suspended sediments in Richland Creek located downstream of Barber's Orchard, and to use Pb isotopic ratios to determine differences in the rate at which Pb is incorporated into and dissipates from different tissues in trout. More specifically, field and laboratory data will be combined to test four hypotheses generated from our previous work. These hypotheses include (1) that short-term shifts in the isotopic composition of water and sediments within Richland Creek occurs during

floods as a result of erosion and transport of contaminated soils from Barber's Orchard, (2) that Pb is sequestered in bone of trout, whereas it is readily excreted by fleshy tissues, (3) that the bone reflects the contaminant Pb because of the relatively high concentrations and bioavailability of the metal to which the fish are subjected during flood events, and (4) that the bone provides a long-term record of Pb loadings and can be used as a stable biomarker of contamination to the aquatic system, whereas the liver and muscle reflect the isotopic composition of the water within a few days of sampling.

Methodology

The objectives will be accomplished by combining field data that characterize the isotopic variations in water and suspended sediment in Richland Creek as a function of flow conditions, with laboratory studies that more precisely document tissue-specific patterns of accumulation and partitioning of Pb isotopes in rainbow trout. A permanent monitoring site will be established on Richland Creek immediately downstream of Barber's Orchard. Both water and sediment samples will be collected at the site during low, moderate, and high discharge conditions. A limited number of samples may also be obtained approximately 10 km downstream of the Orchard, near the eastern edge of Waynesville. The quantity of samples that can be collected will depend on the number of rainfall/runoff events that occur. However, it is anticipated that it will be possible to collect at least 30 to 40 sets of water and suspended sediment samples over a wide-range of discharge values. Also, an effort will be made to collect samples over the entire hydrograph of at least 1 to 2 flood events. Once analyzed, total Pb and selected Pb isotopic ratios will be related to the discharge conditions at the time of sampling to determine if systematic changes in Pb concentrations and isotopic values occur. If changes in isotopic values are identified, the nature of the changes will be compared with the isotopic composition of known Pb sources in the area (e.g., lead arsenate, sediments within the modern channel bed, and uncontaminated sediments within the floodplain and terrace deposits) to determine the probable cause for the changes in isotopic abundances. In addition, these geochemical data will be compared to suspended sediment concentrations that existed at the time of sampling to evaluate whether the variations in isotopic values are consistent with erosion of upland soils.

Fertilized eggs of rainbow trout (Erwin X Arlee strain) pooled from multiple pairings were obtained from Erwin National Fish Hatchery, Erwin, TN in September 2002. The eggs were transported to facilities at the Mountain Aquaculture Research Center (MARC), WCU, Cullowhee, NC, where they are currently being incubated. At first feeding, the fry will be transferred to a common tank and reared following standard hatchery practices using commercial trout diets to a large fingerling size (approx. 50 g/fish) by the time experimentation begins in the summer of 2003. Two experiments to test tissue-specific rates of Pb uptake and depuration will be conducted simultaneously. One test will involve exposure to a constant low (0.025 mg/L) concentration of Pb in the rearing water, and the other to a pulsed exposure (twice-a-week for 6 hours) to Pb at a relatively high (0.350 mg/L) concentration. The low concentration is similar to dissolved Pb concentration levels measured in Richland Creek during low flow periods (Kondrad 2002).

Principal Findings

Stream waters are characterized by relatively low Pb concentrations during periods of base flow exceeding 10 days in length. Greater than 65% of the Pb is derived from orchard soils located upstream of the monitoring site which are contaminated by lead arsenate. Pb from lead arsenate in an 8-10 year (overbank) event in May 2003 was minimal during peak flow conditions, suggesting that discharge-source relations are dependent on flood magnitude. The hydrologic and geochemical data demonstrate that aquatic biota in Richland Creek are subjected to short-term variations in Pb concentrations and isotopic composition of the dissolved load ranging from a few hours to a few weeks. Laboratory studies demonstrated that when rainbow trout were exposed to elevated Pb concentrations with a distinct isotopic fingerprint, the bone and liver rapidly acquire isotopic ratios similar to that of the water.

Significance

Results indicate that it may be possible to use the Pb isotopic composition of bone as an indicator of the long-term sources of Pb to the systems, and liver as a biomarker for short-term Pb exposures.

A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control

Basic Information

Title:	A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control
Project Number:	2002NC3B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	Non Point Pollution, Surface Water, Water Quality
Descriptors:	
Principal Investigators:	Richard A McLaughlin

Publication

1. Bartholomew, Nathaniel, 2003, Polyacrylamide to Reduce Turbidity in Runoff as Affected by Soil and Polyacrylamide Properties, MS Dissertation, Soil Science, College of Agriculture and Life Science, North Carolina State University, Raleigh, NC.
2. Bartholomew, N., R.A. McLaughlin and D.L. Hesterberg, 2002, Polyacrylamide to Reduce Turbidity in Runoff. Agronomy Society of American Annual Meetings.
3. Hayes, S.A., R.A. McLaughlin, N. Bartholomew, and D.L. Osmond, 2002, Polyacrylamide Use of Erosion and Turbidity Control. Agronomy Society of American Annual Meeting.
4. McLaughlin, R.A., S.A. Hayes, N. Bartholomew, and D.L. Osmond, 2002, Testing Polyacrylamides for Erosion and Turbidity Control. Soil and Water Conservation Society Annual Meetings.
5. McLaughlin, R.A., 2002, Measures to Reduce Erosion and Turbidity in Construction Site Runoff. N.C. Dept of Transportation & Center For Transportation & Environment, Joint Project 201-05 Final Report, 131 pgs.

Title

A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control

Problem and Research Objectives

Properly installed and maintained sediment control devices, such as silt fences and sediment traps, are intended to remove the sand and coarse silt fractions from sediment in runoff. Although they may retain the majority of the sediment carried by runoff, a substantial portion of the silt and clay fractions are not retained and contribute to high turbidity in streams, lakes, and estuaries. None of the devices currently required provide turbidity control. Polyacrylamide (PAM) has been proven to reduce erosion and turbidity under agricultural conditions. Our current laboratory and field tests have shown that PAM can also substantially reduce turbidity in sediment basins and traps, even to or near the current 50 NTU standard. Under the current WRI grant, we are determining a number of factors involved in maximizing PAM effectiveness: sediment trap modifications, electrolyte interactions, and environmental conditions. These are primarily using the log format to introduce PAM into runoff. However, there are many other methods to introduce PAM into runoff which may be more reliable and effective. Further testing on these is needed to determine the optimal configuration for reducing turbidity.

We will evaluate the effectiveness of a series of sediment and turbidity control systems that can be used as part of a typical sediment trap as well as innovative modifications. The objectives are: 1. Compare the relative effectiveness of modifications to a typical sediment trap to optimize the effectiveness of PAM in reducing turbidity at the outlet. 2. Evaluate combinations of PAM and an electrolyte source for synergistic effects. 3. Evaluate the effects of moisture condition and temperature on PAM release from logs

Methodology

Most of the work will be conducted at the Sediment and Erosion Control Research and Education Facility at the NCSU Lake Wheeler Road Field Laboratory. This site is ideally located as it is convenient to campus for research and it is centrally located for training and demonstrations. We have already installed the infrastructure for testing sediment and erosion control systems under controlled conditions. Some of the work will be conducted under laboratory conditions in the NCSU Soil Science Department. We have three sediment traps with dimensions of 10' x 20', 15' x 30', and 20' x 40'. Each has a rock outlet consisting of large stone (Class B) with a 2:1 slope and a 1' layer of gravel (1/2"– 3/4" dia.) on the inside face, which is the "typical" outlet in the North Carolina DENR Land Quality Section Design Manual. The dewatering times are 1-2 hours once the trap is full to the top of the outlet dam (3-4'), or 0.1-0.3 cubic feet per second (cfs). The rock outlets can be closed off and sealed in order to dewater the basin through a skimmer (or other device) attached to 6" PVC pipes buried within the outlet dam. Dewatering times are 10-20 hours for the basins fitted with skimmers. Water for generated storm events is provided from a 10,000 cubic foot pond located 200' uphill from the testing area. The storage pond is in turn supplied through the farm irrigation system which taps into a large source pond. A 12" pipe brings the water downslope to the testing area by gravity flow, with an overall drop of 8-10' depending on where the tests are conducted, and flows of up to five cfs are

possible. A “T” is located in the pipe at 140’ from the pond with the open end up. Soil is added manually to the water flowing through the pipe at this point. Stockpiles of two different sediment types are presently available for our experiments, including a sandy loam surface soil and a clay subsoil. The soil is first screened through a 1” coarse screen to remove large rocks and debris before it is used for experiments. Water flow in the pipe is regulated manually by a valve between the source pond and the “T” and measured by an Isco Area Velocity flow module attached to an Isco 6700 sampler. The sampler obtains samples at set intervals from the head of the sediment basin near the pipe outlet. The water leaving the basins is channeled into either 1.5 or 2.0’ H-flumes fitted with an Isco bubbler flow meter and sampler. Water sampling occurs at set intervals, usually 5-10 minutes depending on dewatering times, at the head of the flume. The discharged water is then dispersed using a level spreader into relatively flat areas of either pine plantation or grass cover. These areas generally retain the discharge, but there is a three-cell constructed wetland below these areas if the flow exceeds their capacity.

Principal Findings

Results indicate that PAM users must match the type of PAM to the soil or suspended sediment and water chemistry. To be effective, users must first remove sediment, then treat turbidity. PAM systems work best with high flow on floc logs or PAM powder spread on ditch liners followed by turbulence to get PAM to react with the suspended sediment. Basins and traps can be made more effective at a low cost and a low labor requirement. Jute/coir baffles in basins dampen vertical and forward velocity better than traditional silt fence. Tree protection fence is a good choice for the first in a series of baffles because it is tougher and stands up better under high velocities. Improved effectiveness results by using a skimmer instead of a stone outlet on sediment traps. Basin and trap inlets need good erosion protection.

Significance

Although not widely used yet, the approach currently available is primarily using PAM logs to dispense the material into the runoff stream and then use various filtering and settling systems to remove the flocs. This research provides information to expand the current application of PAM to reduce turbidity in construction site runoff. This is expected to add flexibility and reliability to the use of PAM in these applications.

Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina

Basic Information

Title:	Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina
Project Number:	2002NC1B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	12
Research Category:	Water Quality
Focus Category:	Groundwater, Water Quality, Solute Transport
Descriptors:	Riparian Buffer, Nutrients, Fecal Coliform Bacteria, Sediments, Water Quality, Surface-Groundwater Flowpaths, Groundwater Modeling
Principal Investigators:	Craig J. Allan, Jy S Wu

Publication

1. Allen, Donna, Craig J. Allan and Jy Wu, 2003, Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina, in NC WRI Annual Meetings, Raleigh, NC, www.ncsu.edu/ncsu/wri.Allen.pdf.

Title

Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina (70194)

Problem and Research Objectives

The ongoing research project is quantifying the pollutant removal efficiency and hydrologic characteristics of vegetated riparian buffers in the western Piedmont and the Blue Ridge physiographic regions of the North Carolina. Data from the project will be used to help determine the effectiveness of riparian buffers in reducing Non Point Source (NPS) pollutant loadings to surface waters in hydrogeologic regions of the state where their use has not been fully investigated. The research will also be used to evaluate the potential of riparian buffers in controlling the NPS loadings of bacteriological contaminants to surface waters. Both aspects of the project will provide information with regard to the water quality benefits associated with vegetated riparian buffers to assist planners and resource managers when faced with decisions regarding development within floodplains. The objectives are to: 1) Define the subsurface hydrogeologic conditions at each study site through the construction of flow nets to identify subsurface flow paths, 2) Quantify subsurface flow inputs of nutrients to the receiving stream channel, and finally 3) Measure the attenuation of groundwater transported pollutants moving from field edge through the riparian buffer; and parameterize the numerical flow model.

Methodology

Two transects running from the field edge to the center of the stream channel have been instrumented at each of the two study sites. Transects at each site were sited in areas representing average slope, width and vegetative cover. Surface flow is sampled and quantified through samplers consisting of plastic bottles inserted in the ground with an opening at ground level. The objective is to quantify surface water inputs into the streamside buffer and monitor the attenuation of pollutants as they pass through the buffer. Two to three samplers are installed along each sampling transect. Piezometers and groundwater wells have been installed at various locations along each transect including the streambed. Each piezometer is screened and water levels determined manually with an electronic depth sensor. Hydraulic conductivity is determined through Hvorslev water level recovery method (Freeze and Cherry 1979). Groundwater levels are continuously recorded at select sites with Druck Pressure transducers logged by a Campbell Scientific (CS) data logging system. Cl⁻ (a conservative element) and dissolved O₂ concentrations will be measured along with the pollutants of concern to delineate zones where conditions are favorable for pollutant removal. Groundwater flow through the riparian buffers will be calculated by three different methods to bracket our flow estimates. Firstly, two dimensional flow nets will be constructed from the piezometric head data and combined with the hydraulic conductivity data to measure ground water flow (Freeze and Cherry 1979, Roulet 1990). Secondly, a series of detailed dilution gauging measurements will be made at different groundwater stages along each channel to directly quantify net ground water inputs to the stream channel. A third approach involves the use of the numeric model to predict hydrochemical transport at each site. The utility of this final approach is dependent upon a sufficient length of field data to both calibrate and test the model. Infiltration rates are being

determined with flooding ring infiltrometers. Hydraulic conductivity (K_u) in the unsaturated zone is profiled through the unsaturated zone with a Guelph Permeameter and relations established between soil moisture content and hydraulic conductivity (Reynolds and Elrick 1985). Soil moisture levels are being continuously recorded at each site with logged CS soil moisture reflectometry probes. Tension lysimeters have been installed at two depths at each site to monitor soil solution chemistry. The purpose of this phase of the project is to quantify the transport of water and pollutants through the vadose zone of the riparian buffer and assess changes in volumetric soil moisture content to aid in the solution of the water balance. Stream flow through each buffer is monitored with an automatic water sampler/flow meter below each study area. Streamflow and water samples are recorded at the EPA downstream gauging station at the Kiser Dairy site. Stage discharge relationships are being established for the Blue Ridge site through manual gauging at different stream stages.

Principal Findings

Field sites have been instrumented with the following data collection progress: 1. Analysis of Brevard and Kiser Dairy samples for major ions by IC, pH conductivity, nitrogen, and total phosphorus; 2. Sedimentological and mineralogical analysis of Core Samples from Kiser Dairy and Brevard sites; 3. Topographic surveys at the Kiser Dairy and the Brevard Piezometer networks have been completed and monitoring network templates have been developed; 4. The field measurement of hydraulic conductivity (K_{sat}) are ongoing.

Significance

Results can be used to design and manage stream buffers to most effectively protect water quality in Piedmont and Blue Ridge regions.

Information Transfer Program

In addition to activities related to specific research projects, WRI maintains a strong information transfer program by cooperating with various state agencies and professional organizations to sponsor workshops and other events and by seeking grants for relevant activities. During the current fiscal year, WRI continued to be designated by the N.C. Board of Examiners for Engineers and Surveyors as an Approved Sponsor of Continuing Professional Competency activities for Professional Engineers and Surveyors licensed by the State of North Carolina. This allows WRI to offer Professional Development Hours to engineers and surveyors for attending our water resources research seminars and our Annual Conference.

WRI Research Seminar Series

Basic Information

Title:	WRI Research Seminar Series
Project Number:	2003NC49B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

Publication

Organized and sponsored the following seminars by investigators working under WRRRI grants:

- March 2003 – An Assessment of North Carolina Water Reuse Regulations by Dr. Helene A. Hilger, UNC- Charlotte
- April 2003 – Using Natural and Landscaped Buffers to Reduce Pollution Loading from Agricultural Runoff by Dr. Richard A McLaughlin, NC State University.
- May 2003 – From Pfiesteria to Micro Arrays: New Tools for Water Quality Assessment by Dr. Parke A Rublee, UNC- Greensboro.
- September 2003 – Water Reuse in North Carolina by Dr. Helene Hilger, UNC-Charlotte.
- October 2003 – Innovative Stormwater Best Management Practice Evaluations by Dr. Bill Hunt, NC State University.
- November 2003 – Sediment Sources and Impacts on Water Quality in the North Carolina Mountains by Jerry Miller, Western Carolina University.
- January 2004 – Regional Water Supply Management in North Carolina by Greg Characklis, UNC- Chapel Hill.
- February 2004 – Land Application of Municipal Biosolids by Dr. Bob Rubin, NC State University.

The Institute NEWS

Basic Information

Title:	The Institute NEWS
Project Number:	2003NC50B
Start Date:	1/1/1997
End Date:	1/1/1997
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray, Kelly Porter

Publication

Published the *WRI News* six times during the reporting period. The *WRI News* is a 16-page newsletter that covers a wide range of water-related topics from current federal and state legislation and regulatory activities to new research findings, water-related workshops and conferences, and reviews of water-related publications. The *WRI News* is 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.

New WRI Research Reports

Basic Information

Title:	New WRI Research Reports
Project Number:	2003NC51B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H. Reckhow

Publication

New WRI Research Reports – A strong demand for Institute reports continues. During the year, the Institute published the following reports for distribution to users throughout the state and nation. In addition, a new Journal Article Series (JA) was started in which journal articles are submitted to peer reviewed journals in lieu of institute final reports. This new series is the Journal Article Series.

WRI-341- Seeking Science-Based Nutrient Standards for Coastal Blackwater Stream Systems.

WRI-344 – The Economics of Structural Stormwater BMPs in North Carolina.

WRI-345 – Assessment of Changing Land-Use Practices on Basin Sediment Yields and Provenance in Western North Carolina Using Multivariate Finger Printing Techniques.

WRI-346 – An Assessment of the North Carolina Water Reuse Regulations: Their Application to a New Reclamation Facility and Their Key Features Compared to National Water Reuse Regulation Trends.

WRI-347 – Lumped Parameter Models for Predicting Nitrogen Loading from Lower Coastal Watersheds.

WRI-348 – Land Use Patterns and Pollution in the Upper Neuse River.

WRI-JA1 – Optimizing Ferric Sulfate Coagulation of Algae with Streaming Current Measurements.

WRI-JA2 – Tracing Nitrate Transport and Environmental Impact from Intensive Swine Farming Using Delta Nitrogen-15.

WRI-JA3 – Atmospheric Concentrations of Ammonia & Ammonium at an Agricultural Site in the Southeast United States.

WRI-JA4 – Interplay of Science and Stakeholder Values in Neuse River Total Maximum Daily Load Process.

WRI-JA5 – Greening Development to Protect Watersheds. Does New Urbanism Make a Difference?

Stormwater Solution for N.C Communities and Valuing NC Water Resources

Basic Information

Title:	Stormwater Solution for N.C Communities and Valuing NC Water Resources
Project Number:	2003NC520
Start Date:	3/31/2003
End Date:	4/1/2003
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H Reckhow

Publication

Convened the Preconference “Stormwater Solutions for North Carolina Communities” on March 31, 2003 and the Annual WRI Conference, “Valuing NC’s Water Resources” on April 1, 2003. Drs. Bill Holman, Executive Director of the NC Clean Water Management Trust Fund, V. Kerry Smith, University Distinguished Professor of Agricultural and Resource Economics and Director of the Center for Environmental and Resource Economic Policy at NCSU and Ken Reckhow, WRI Director, delivered plenary addresses. Investigators from universities, agencies, industry, and consulting firms presented results of work on topics ranging from erosion and sedimentation control technologies to air borne water pollutants. Some 224 people participated in the conference. Participants had 36 technical presentations in 9 concurrent sessions from which to choose, as well as 20 technical posters to view. Abstracts were made available on the WRI website.

Erosion & Sediment Control for Basic Design Workshops

Basic Information

Title:	Erosion & Sediment Control for Basic Design Workshops
Project Number:	2003NC530
Start Date:	10/14/2003
End Date:	11/15/2003
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H Reckhow

Publication

Organized and co-sponsored with the N.C. Division of Land Resources “Erosion and Sediment Control Basic Planning and Design Workshop” in September 2003 in Hickory, NC, and October in New Bern, NC. One hundred eighty-one design professionals attended the Hickory seminar; one hundred forty-one attended the New Bern seminar.

Advanced Erosion and Sedimentation Control Workshop

Basic Information

Title:	Advanced Erosion and Sedimentation Control Workshop
Project Number:	2003NC54O
Start Date:	2/1/2004
End Date:	3/1/2004
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H Reckhow

Publication

Organized and co-sponsored with the N.C. Division of Land Resources “Advanced Erosion and Sediment Control Planning and Design Workshops” February 2004 in Wilmington. One hundred fifty-eight attended the Wilmington workshop.

Workshop for Local Programs in Erosion & Sediment Program

Basic Information

Title:	Workshop for Local Programs in Erosion & Sediment Program
Project Number:	2003NC55O
Start Date:	2/4/2004
End Date:	2/6/2004
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H. Reckhow

Publication

Organized and co-sponsored with the N.C. Division of Land Resources a “Workshop for Local Erosion and Sediment Control Programs” in Southern Pines for February which was snowed out but rescheduled for early March. Eighty plan reviewers, inspectors, and managers of local programs attended.

Neuse River Basin: Five Years of Progress

Basic Information

Title:	Neuse River Basin: Five Years of Progress
Project Number:	2003NC560
Start Date:	11/1/2003
End Date:	11/3/2003
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H Reckhow

Publication

Organized and co-sponsored with NC State University, Neuse River Education Team, NC Association of Environmental Professionals and the Soil Science Society of North Carolina “The Neuse River Basin: Five Years of Progress” in November 2003.

Wetlands Restoration Conference

Basic Information

Title:	Wetlands Restoration Conference
Project Number:	2003NC570
Start Date:	5/15/2003
End Date:	5/15/2003
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

Publication

Organized and co-sponsored with the N.C. Wetlands Restoration Program a conference titled "Compensatory Mitigation: Lessons Learned and Future Directions" in May 2003. The conference was funded by a Wetland Program Development Grant from the U.S. EPA. It provided a forum for state and federal agencies, academic institutions, mitigation practitioners, and others to discuss topics related to watershed planning and compensatory mitigation. WRRRI produced a report on the conference which is available on the Institute website at http://www.ncsu.edu/wrri/conference/report_index.htm in both html and pdf formats.

Southeastern Regional Small Drinking Water Technical Assistance Center

Basic Information

Title:	Southeastern Regional Small Drinking Water Technical Assistance Center
Project Number:	2003NC580
Start Date:	3/1/2003
End Date:	2/1/2004
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Completed a project funded by the Southeastern Regional Small Drinking Water Technical Assistance Center to provide information to schools, day care centers and businesses operating non-transient non-community public water systems to help them comply with requirements of the Safe Drinking Water Act. Cooperating on the project were the N.C. Public Water Supply Section and the N.C. Rural Water Association. The publication is available on the WRRI website at <http://www.ncsu.edu/wrri/NTCNguide.pdf>.

NC Water Resources Association Luncheon Forums

Basic Information

Title:	NC Water Resources Association Luncheon Forums
Project Number:	2003NC590
Start Date:	4/1/2003
End Date:	2/29/2004
Funding Source:	Other
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

Publication

Organized and coordinated the following luncheon-forums for the N.C. Water Resources Associations:

- April 2003 – Airborne Water Pollutants
- September 2003 – Land Use and Water Quality Interactions Using GIS
- December 2003 –Water Reuse
- February 2004 – Morgan Creek and Little Creeks Local Planning Initiative

We maintain an NCWRA listserv of approximately 85 members.

WRI Annual Program

Basic Information

Title:	WRI Annual Program
Project Number:	2003NC60B
Start Date:	3/1/2003
End Date:	2/1/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Published the 2003-2004 WRI Annual Program. This 16-page publication includes synopses of all new research projects and updates on continuing projects, a review of technology transfer activities, and the announcement of the upcoming year's research seminars. It is sent to all newsletter subscribers.

The Sediments News

Basic Information

Title:	The Sediments News
Project Number:	2003NC61O
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray, Kelly Porter

Publication

Published four issues of the *Sediments* newsletter. WRRI publishes this newsletter for the N.C. 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 5,800.

WRI Website

Basic Information

Title:	WRI Website
Project Number:	2003NC62B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray, Kelly Porter

Publication

Maintained the WRI website (<http://www.ncsu.edu/wri>). The website provides on-line access to the WRI News, the WRI Annual Program, technical report summaries, the schedule of water research seminars, a water resources research expertise directory, and information on workshops, conferences, calls for papers, and public hearings.

WRI Listerves

Basic Information

Title:	WRI Listerves
Project Number:	2003NC63B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kelly Porter

Publication

Maintain two electronic mail lists (listserves): Water Research list and WRRI-News list. The Water Research list is used to inform water researchers from North Carolina universities about calls for papers, grants, upcoming conferences, student internship opportunities, EPA news, etc. There are approximately 125 subscribers to this list. The WRRI-News list is used to distribute an electronic version of the WRRI-News publication as well as inform subscribers about upcoming conferences and workshops, water-related research in North Carolina. There are approximately 465 subscriptions to the WRRI-News list.

Functional Assessment Workshop

Basic Information

Title:	Functional Assessment Workshop
Project Number:	2003NC64O
Start Date:	6/1/2003
End Date:	6/3/2003
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

Publication

Organized and co-sponsored with the N.C. Division of Water Quality and Ecosystem Enhancement Program a two-day workshop “GIS and Field-Based Functional Assessment of Streams and Wetlands in North Carolina”, January 21-22, 2004. Thirty to forty people were in attendance each day.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	8	0	0	0	8
Masters	5	0	0	0	5
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	14	0	0	0	14

Notable Awards and Achievements

Dr. Greg Characklis and Graduate Student B.R. Kirsch received the 2nd prize in the Graduate Research Competition at the American Water Works Association/Water Environment Association Conference in Winston Salem, NC, November, 2002.

Dr. Craig Allan research project description received external publicity in the March, 2003, Water Resources Research Institute News. The project was presented to the Brevard High School Environmental Science Class in September of 2002.

Dr. Jerry Miller was invited to comment on the Proposed Cleanup for the Barber Orchard Superfund Site, Waynesville, NC for the USEPA in 2003. Proposed plan fact sheet Barber Orchard Superfund Site.

Publications from Prior Projects

1. 2000NC1B ("An Assessment of the North Carolina Water Reuse Regulations") - Water Resources Research Institute Reports - Hilger, Helene and Mark Sobsey, 2003, An Assessment of the North Carolina Water Reuse Regulations: their application to a new reclamation facility and their key features compared to National Water Reuse Regulation Trends, North Carolina Water Reuse Regulation Trends, North Carolina Water Resources Research Institute, North Carolina State University, Raleigh, North Carolina, 139 pp.
2. 2000NC9B ("Impact of Sediment Processes on Water Quality in the Neuse River Estuary") - Dissertations - Clesceri, Erika, 2003, Quantification of Particulate Organic Matter Sources in an Eutrophic River Estuary by Stable Carbon and Nitrogen Isotopes and Phtopigments (Neuse River Estuary, NC USA), Ph.D. Dissertation, Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC 179 pp.
3. 2000NC9B ("Impact of Sediment Processes on Water Quality in the Neuse River Estuary") - Articles in Refereed Scientific Journals - Clesceri, Ericika, Marie Krief, Marc Alperin, Chris Martens, and Hans Paerl. 2004 in press. Stable Isotope Evidence for Hurricane-driven Changes to the Source of Particulate Organic Matter in the Neuse River Estuary, North Carolina (USA): Impact of Three

Consecutive Hurricanes. Estuaries.

4. 2000NC10B ("Predicting Long-term Wetland Hydrology Using Hydric Soil Field Indicators") - Articles in Refereed Scientific Journals - He, X., M.J. Vepraskas, D.L. Lindbo, and R.W. Skaggs, 2003, A Method to Predict Soil Saturation Frequency and Duration From Soil Color. Soil Society of American Journal 67: 961-969.
5. 2000NC10B ("Predicting Long-term Wetland Hydrology Using Hydric Soil Field Indicators") - Articles in Refereed Scientific Journals - Vepraskas, M.J., X. He, D.L. Lindbo and R.W. Skaggs, in press. Predicting Soil Saturation Frequency and Duration Using Soil Color in Two Toposequences. Soil Science Society of America Journal.
6. 2000NC10B ("Predicting Long-term Wetland Hydrology Using Hydric Soil Field Indicators") - Conference Proceedings - Lindbo, D.L., M.J. Vepraskas, E. Severson, and X. He, 2004, A Comparison of Soil Wetness by Morphological and Modeling Methods "In" On-Site Wastewater Treatment X, Conference Proceedings, Sacramento, CA, American Society of Agricultural Engineers, St Joseph, MI, p. 52-58.
7. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Articles in Refereed Scientific Journals - Ulseth, A.J., and A.E. Hershey. 2004 in press, Stable Isotope Natural Abundances Trace Anthropogenic Nitrogen and Carbon in An Urban Stream. Journal of North American Benthological Society.
8. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Dissertations - Ulseth, A.J., 2003, Use of the Natural Abundance of ¹⁵N to Evaluate the Effects of Anthropogenic N on the Components of a Headwater Urban Stream. MS. Thesis, Department of Biology, University of North Carolina at Greensboro, Greensboro, NC.
9. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Dissertations - Bishop, B. 2004. Effects of riparian buffers on removal of nutrients and sediment in urban streams. M.S. Thesis, Department of Biology, University of North Carolina at Greensboro, Greensboro, NC.
10. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Water Resources Research Institute Reports - Mou, Paul P., Blair Bishop, and Anne E Hershey, 2003. Effects of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams. North Carolina Water Resources Research Institute, North Carolina State University, Raleigh, NC 31 pps.
11. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Other Publications - Ulseth, A.K. Fortino and A.E. Hershey, 2003, The Use of the Natural Abundance of ¹³C and ¹⁵N to determine trophic differences between two coexisting species of crayfish. Bulletin of the North American Benthological Society 20(1): 214-215.
12. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Other Publications - Hershey, A.E., A.J. Ulseth, and K. Fortino. Use of Stable Isotopes to Trace Sewage Effluent through a Forested Low-Order Stream in the Vicinity of Greensboro, NC. Bulletin of the North American Benthological Society 20(1):281.
13. 2001NC1441B ("Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams") - Other Publications - Bishop, B., P. Mou and A.E. Hershey, 2003, Retention and Mitigation of Anthropogenic Nitrogen and Phosphorus in Headwater Riparian Systems. Bulletin of the North American Benthological Society 20(1):308-309.
14. 2001NC801B ("Reuse of Wastewater from Septic Systems") - Conference Proceedings - Amoozegar, A., S. Warren, C. Niewoehner, W. Robarge, M. Hoover, D. Hesterberg and R. Rubin, 2003, Effect of graywater on soil hydraulic properties, "in" Proceedings of the 10th National Symposium on Individual and Small Community Sewage Systems, Am. Soc. Agric. Engr., Sacramento, CA.

15. 2001NC801B ("Reuse of Wastewater from Septic Systems") - Conference Proceedings - Warren, S.L., A. Amoozegar, W.P. Robarge, C.P. Niewoehner, W.M. Reece, 2004, Effect of graywater on growth and appearance of ornamental landscape plants, "in" Proceedings of the 10th National Symposium on Individual and Small Community Sewage Systems, Am. Soc. Agric. Engr., Sacramento, CA.
16. 2001NC34B ("Assessment of Changing Land-Use Practices on Basin Sediment Yields and Provenance in Western North Carolina Using Multivariate Fingerprinting Techniques") - Articles in Refereed Scientific Journals - Miller, Jerry, Mark Lord, Steve Yurkovich, Gail Mackin, and Lawrence Kolenbrander, 2004, in press, Sediment Provenance Determinations Using Geochemical Fingerprinting Techniques in Western North Carolina, Journal of the American Water Resources Association.
17. 2001NC43B ("Assessment of Changing Land-Use Practices on Basin Sediment Yields and Provenance in Western North Carolina Using Multivariate Fingerprinting Techniques") - Water Resources Research Institute Reports - Miller, Jerry, Mark Lord, Steve Yurkovich, Gail Mackin, and Lawrence Kolenbrander, 2003, Assessment of Changing Land-Use Practices on Basin Sediment Yields and Provenance in Western Carolina using Multivariate Fingerprinting Techniques, Water Resources Research Institute Report No. 345, The University of North Carolina, North Carolina State University, Raleigh, NC, 50 p.