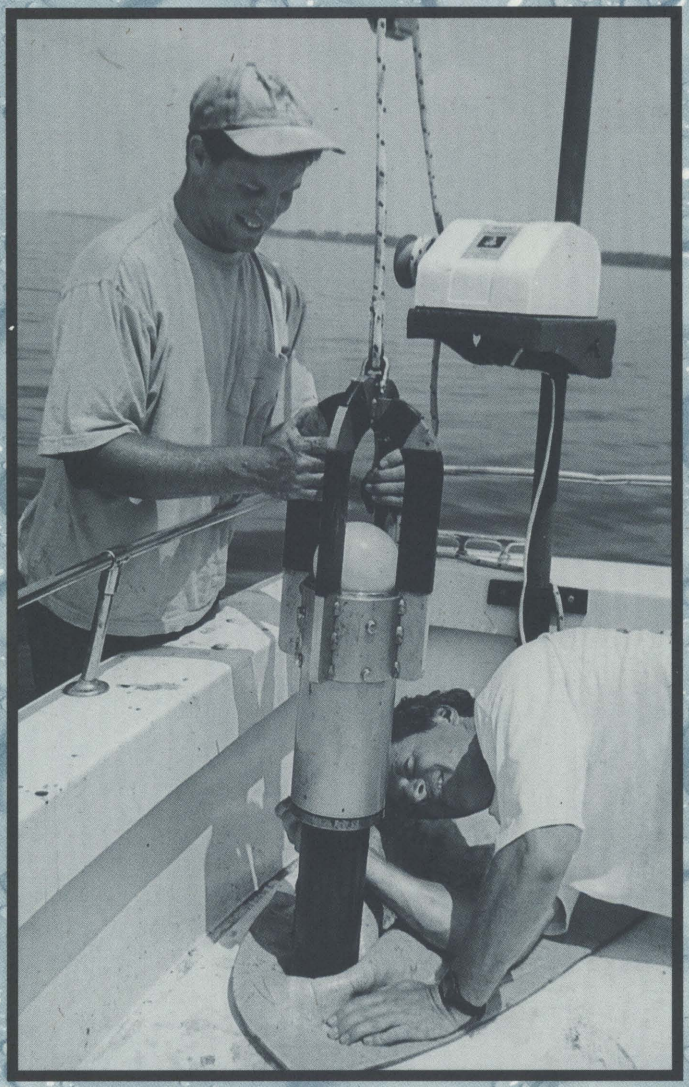
# WATER RESEARCH FOR THE NEXT CENTURY



1999-2000 Annual Program of the

Water Resources Research Institute

of The University of North Carolina

# WATER RESOURCES RESEARCH INSTITUTE LEADERSHIP

*Cover photo: UNC-Chapel Hill scientists Dan Albert and Jesse McNinch take a sediment core in the Neuse Estuary. Their work is part of the Neuse ModMon Project (see page 11). Photo by Chris Martens.*

*Most of the photographs in this publication were made by the late David Howells, former director of WRRI. The photo on page 10 was made by Herman Lankford of the Department of Communication Services, NCSU School of Agriculture and Life Sciences.*

*Forty-two hundred copies of this annual program were printed at a cost of $4,291.49 or $1.02 per copy.*

WRRI operates under the general policy guidance of a Board of Directors drawn from N.C. State University and UNC-Chapel Hill. Directors are appointed by the president of the University of North Carolina. Members of the founding board appointed by President William C. Friday in 1965 were: Dr. Ralph E. Fadum, Dean of the NCSU School of Engineering; Dr. H. Brooks James, Dean of the NCSU School of Agriculture and Life Sciences; Dr. Walter J. Peterson, Dean of the NCSU Graduate School; Dr. Daniel A. Okun, Head of the UNC-CH Department of Environmental Sciences and Engineering; and Professor Milton S. Heath, Assistant Director of the UNC-CH Institute of Government.

WRRI began operating under the guidance of the late F.J. Hassler of the N.C. State University Department of Biological and Agricultural Engineering, who served as acting director.

In 1966, the late David H. Howells was named the Institute's first permanent director. A former U.S. Public Health Service official, Howells served as director nearly 10 years. He established the WRRI Advisory Board to help identify areas where research can help solve water resources problems and the WRRI Technical Committee to peer review research proposals and select those of highest scientific merit and practical application. Through David Howells' vision and energy, WRRI became a highly respected source of scientific information about water resources issues in the state. After his retirement, Howells served a term on the N.C. Environmental Management Commission.

Howells was succeeded as director by Dr. Neil Grigg, a professor of civil engineering from Colorado State University. In 1979, N.C. Secretary of Natural Resources and Economic Development Howard Lee tapped Grigg to be assistant secretary for Natural Resources. From 1979 to 1982, while Grigg was on leave, James M. Stewart served as acting director of the Institute.

In 1982, Grigg returned to Colorado, and the WRRI Board of Directors selected David H. Moreau to head the Institute. A professor of City and Regional Planning at UNC Chapel Hill, Moreau served until 1995, when he returned to full time teaching and research at UNC-Chapel Hill. While he was director, Moreau served as chairman of the N.C. Sedimentation Control Commission and was appointed chairman of the N.C. Environmental Management Commission.

In 1996, Kenneth H. Reckhow became the fourth permanent director of WRRI. A professor in the Nicholas School of the Environment at Duke University, Reckhow specializes in environmental modeling and decisionmaking. He serves on the N.C. Sedimentation Control Commission and the N.C. Department of Environment and Natural Resources' Scientific Advisory Council on Water Resources and Coastal Fisheries Management, and recently chaired the Neuse Riparian Buffer Stakeholder Advisory Committee.

# OUR PAST: 35 YEARS OF SOUND SCIENCE FOR ENVIRONMENTAL PROTECTION

MOSQUITO CONTROL

In October 1965, Governor Dan Moore and University of North Carolina President William C. Friday announced the establishment of a unique new entity within the consolidated University of North Carolina—the UNC Water Resources Research Institute (WRRI). President Friday said the Institute would represent a unique concept in university organization and administration, with responsibilities and activities crossing disciplinary lines and campus boundaries. Governor Moore called WRRI's role as a link between universities and government agencies an important new arm of the State's efforts to protect North Carolina's water resources.

When WRRI was established in 1965, there was no U.S. Environmental Protection Agency and no N.C. Environmental Management Commission. The first Earth Day was still in the future, and Americans were just beginning to systematically and consciously take stock of their environment. Seeing a legion of environmental problems, ordinary citizens across the country were becoming anxious about an "environmental crisis" and curious about the factors that contributed to it. Soon they would demand to know the extent of the apparent deterioration of the water, air, and land around them and would demand solutions to the problems they saw.

Among the first institutions in North Carolina to answer citizens' and decision-makers' questions about environmental problems was WRRI. For 35 years the Institute has continued to listen attentively to the voices of the people and their appointed and elected officials and to provide scientific information to address their concerns.

Throughout the last three and a half decades, WRRI has sponsored a wide range of research projects dealing with the state's most pressing water-related problems. With regret for the many important issues that cannot be discussed and apologies to the many distinguished researchers that cannot be mentioned, WRRI presents the following selected research highlights of the last 35 years.

## The 1960s: Mosquito Control, Industrial Wastes, Urbanization

• **MOSQUITO CONTROL:** One of the major environmental concerns of the 1960s was the effects of pesticides. While Rachel Carson's *Silent Spring* had sounded the alarm about DDT and other pesticides in 1962, the need to control mosquitoes to combat malaria and viral diseases had kept the chemicals in use. Public health officials in North Carolina worried about whether these pesticides were getting into water supplies, and resource managers were concerned about the effects on fish and other wildlife. With funding from WRRI, T.J. Sheets of NCSU studied the persistence of DDT and its metabolites in soil to determine the potential for groundwater contamination. Sheets also designed and tested a system that the state Department of Water and Air Resources could use to monitor for pesticides in surface water.

Efforts to control mosquitoes in Eastern North Carolina in the 1960s also involved ditching or impounding irregularly flooded salt marsh. Wildlife managers and wetlands ecologists questioned the effectiveness of these practices in controlling mosquitoes and felt that they were destroying habitat and degrading the ecology of some of the state's most important wetlands. WRRI sponsored a workshop and

several projects led by NCSU entomologist Kenneth Knight and associates to determine the effects of ditching and impoundment on mosquito populations. UNC-Chapel Hill's Ed Kuenzler led a WRRI study of the effects of mosquito control ditching on estuarine ecosystems. The mosquito control strategy that eventually emerged from the studies relied less on widespread application of one method and more on surveillance to establish specific site conditions and integration of mosquito control with other facets of water-land resource management.

URBANIZATION

• **INDUSTRIAL WASTES:** In the 1960s, the federal government was not a major force in water pollution control, and the quality of a state's streams and rivers depended heavily upon the initiative of its citizens and elected officials. In North Carolina, Governor Terry Sanford told the state's Stream Sanitation Commission that a visit to one of the more industrialized states would reveal what could happen in North Carolina if the state attracted the kind of industry it hoped to but did not have a strong program to deal with industrial wastes. In WRRI's 1967 assessment of research needs, solutions to the waste treatment problems of the textile, pulp and paper, food processing, and phosphate industries topped the list of priorities. The Institute launched a series of studies in which NCSU food scientist Roy Carawan began developing principles for water conservation and waste minimization in food processing, and scientists in the NCSU Schools of Textiles and Forestry began surveying waste treatment practices in their industries and researching ways to remove or treat the most harmful components of the waste streams.

• **URBANIZATION:** Even in the 1960s it was obvious that North Carolina was a growing, urbanizing state. It was also obvious to professional planners that state and local governments needed information about the likely demands that growth and urbanization would place on services and natural systems. In the 1960s planning specialist Ray Burby and associates at UNC-Chapel Hill began a series of WRRI-sponsored studies that alerted the state to safety and water quality problems that could arise from proliferation of lakeside residential communities, to the effects of second-home development on lakes and multipurpose government-sponsored reservoirs, and to the need to plan on a statewide basis for publicly accessible water-based recreation on public reservoirs.

## The 1970s: Channelization, Jordan Reservoir, and Animal Waste

The signing by President Richard Nixon of the National Environmental Policy Act in January 1970 foreshadowed the environmental activism that the decade would see. During the 1970s, North Carolina witnessed first-hand two landmark pieces of environmental litigation under NEPA—a suit to stop the channelization of Chicod Creek and a suit to prevent filling of the Jordan Reservoir. The activities that occasioned these suits helped shape water-related research sponsored by WRRI during the decade.

• **CHANNELIZATION:** By the 1970s stream channelization and straightening to drain flood waters from agricultural fields and low-lying residential areas had been practiced for more than 20 years, and the consequences in Eastern North Carolina were becoming evident. At a WRRI conference in 1970, wildlife scientists charged that channelization damaged fish and wildlife habitat, and ecologists asserted that it damaged hardwood forests, caused streambank erosion, and accelerated nutrient delivery to estuarine waters. The same charges were being made across the country, and government sponsorship of the practice was highly controversial. Following the 1970 conference, WRRI sponsored a series of studies by biologists at East Carolina University and UNC-Chapel Hill, forest scientists at NCSU, and fluvial experts at UNC-Charlotte. These studies confirmed

some of the problems thought to be associated with channelization and suggested ways of dealing with them.

• **JORDAN RESERVOIR:** Originally proposed to control flooding in the Cape Fear Basin, Jordan Reservoir was authorized in 1963, and dam construction was started in late 1970. Preimpoundment studies—one conducted under WRRI sponsorship—raised concerns about water quality in the proposed reservoir, and in 1971, conservation groups unhappy with the scientific detail in the Environmental Impact Statement (EIS) written by the Corps of Engineers sued to keep the dam from being built. While litigation continued, the Corps and WRRI sponsored additional studies by Charles Weiss of UNC-Chapel Hill to further characterize water quality of the reservoir and identify wastewater treatment practices needed upstream to avoid anticipated eutrophication. The Corps delivered a new EIS in 1976, and a consent agreement allowed impoundment of the reservoir.

• **ANIMAL WASTE:** In the 1970s, concentration of animal production in large confined units was underway, and questions were arising about management of wastes. Producers had adapted lagoons designed for municipal aerobic waste stabilization that were intended to provide complete treatment; however, producers overloaded their lagoons with high-oxygen-demand animal waste to the point that they became anaerobic. In 1970, George Kriz of the NCSU Biological and Agricultural Engineering Department and WRRI Director David Howells were recipients of an early EPA grant to study waste management at animal operations and effects on water quality. The results of that study showed lagoon effluent was not of a quality to be discharged to streams and indicated the need for long-term studies of land application of lagoon effluent. WRRI subsequently sponsored studies that helped characterize animal wastes and establish the basis for developing application rates and that identified the necessary technical components (including land and equipment) of lagoon-land application systems and the cost of installing and maintaining such systems.


URBAN STORM WATER

## The 1980s: Urban Stormwater, Nutrient Pollution, Aquatic Weeds

When President Jimmy Carter delivered the 11th annual report of the Council on Environmental Quality to the Congress in 1980, he reported that the quality of the nation's surface waters was no longer deteriorating as factories and municipal wastewater dischargers were gradually coming under control. He noted, however, that street and farm runoff and other nonpoint sources of pollution had become as serious a problem as wastewater discharges. At WRRI attention was already turning to nonpoint source pollution.

• **URBAN STORM WATER:** In the late 1970s, WRRI had convened a working group on urban storm water management and launched a major research and technology transfer initiative. The Institute began publishing *The North Carolina Stormwater Manager*, a newsletter to communicate scientific and technical information to public works directors, city engineers, consultants and others involved in storm water management. The Institute also sponsored a series of workshops that brought to North Carolina the nation's foremost experts on urban hydrology and sponsored a series of research projects. Researchers like NCSU engineer Rooney Malcolm documented the impacts of urban

runoff on receiving waters and investigated the effectiveness of various management practices.

• **NUTRIENT POLLUTION:** The effects of excess nutrients in Coastal Plain streams had been a concern for years, but critical problems in the Chowan River and increasing problems in the Neuse and Tar-Pamlico prompted WRRI to intensify research on nutrient impacts and nutrients in agricultural runoff in the 1980s. NCSU's Wendell Gilliam studied the movement of nutrients in groundwater under agricultural fields; NCSU's Wayne Skaggs studied the effects of controlling subsurface drainage from fields on nutrient reduction; Hans Pearl at the UNC Institute of Marine Sciences studied the responses of algae to nutrient levels; and ECU's Don Stanley and Robert Christian studied nutrient cycling in river sediments. The research contributed to a management strategy that put the Chowan on the road to recovery and laid the foundation for later management efforts in the Neuse and Tar-Pamlico.

• **AQUATIC WEEDS:** In 1980 the exotic aquatic plant hydrilla was discovered at Umstead Park near Raleigh and a subsequent survey revealed that North Carolina had a serious aquatic weed problem. WRRI joined the N.C. Department of Natural Resources and Community Development as sponsor of a major statewide workshop on weed control and as a partner in formulating a strategy to combat the spread of hydrilla and other aquatic weeds. Research to determine how hydrilla and other exotics survive and reproduce in North Carolina's environment and how they can best be controlled were carried out with WRRI funding by NCSU's Ron Hodson, K.D. Langeland, and Stratford Kay.

NUTRIENT POLLUTION

## The 1990s: Drinking Water, Wastewater Treatment, and Watershed Protection

• **DRINKING WATER:** Epidemiological studies conducted in the 1970s had indicated an association between drinking water with high levels of "disinfection by-products" (DBPs) and an increased risk of cancers of the colon, rectum, and bladder. The 1986 amendments to the Safe Drinking Water Act required EPA to set levels for DBPs in drinking water, and the coming regulations were expected to be particularly troublesome for municipal water suppliers in North Carolina. DBPs are formed when chlorine combines with natural organic materials in raw water, and most North Carolina surface waters have high levels of natural organic matter. WRRI had established a partnership with several municipal water and wastewater utilities, called the N.C. Urban Water Consortium (UWC), to conduct research to help prepare for these and other pending regulations. At UNC-Chapel Hill, Frances DiGiano, Philip Singer, and Russell Christman conducted a series of studies that told major N.C. water utilities what the level of DBPs in their finished water were likely to be under various treatment schemes, how these treatment schemes were likely to affect inactivation of microbial pathogens, and what utilities could do to remove organic matter and reduce DBPs.

• **WASTEWATER TREATMENT:** In the late 1980s, North Carolina began to implement limitations on toxics in wastewater discharges. Toxicity in

discharges was to be determined by a new kind of test using aquatic organisms rather than measurement of specific chemicals. The test and the toxicity reduction process that dischargers would have to go through if they failed the test were complex and unfamiliar requirements. WRRI and the UWC sponsored several projects by UNC-Chapel Hill scientist Frances DiGiano to help dischargers develop confidence in the testing procedure and establish the most efficient process for toxicity reduction.

• **WATERSHED PROTECTION:** In March 1989, the N.C. General Assembly had passed the Water Supply Watershed Classification and Protection Act and the N.C. Environmental Management Commission began the process of developing rules to implement the law. Land use restrictions that the rules would require were controversial, and opposition to the proposed rules was strong. Central to many of the objections was the assertion that the rules would limit the supply of land for residential construction and increase the cost of housing for middle and working class people. In fall 1991, WRRI Director David Moreau undertook an independent analysis of the impact of the watershed protection rules on land availability and housing costs in watersheds. He reported his findings to the legislative Environmental Review Commission, telling legislators that under the proposed rules an additional 21 million people (three times N.C.'s current total population) could build homes and live in the state's watersheds.

As the decade, the century and the millennium draw to a close, some of North Carolina's water-related problems have been mitigated: wastewater discharged to N.C. streams is generally of much higher quality than only a decade ago; a stream and wetland restoration movement is underway to correct years of channelization; and a state program to monitor and control aquatic weeds is in place. However, many of the water-related problems North Carolina has struggled with for decades remain: sedimentation and urban storm water pollution, nutrient pollution, and development pressure on water supply watersheds and groundwater supplies. As it has done for 35 years, WRRI will continue to work with government agencies, industry, and environmental groups to identify the most pressing water research needs, bridge the gap to the university scientific community to produce information to address the needs, and get the information to the people who can put it to work to manage wisely the state's water resources. •

WASTEWATER TREATMENT

# OUR FUTURE: LEADING THE SEARCH FOR SOLUTIONS TO NORTH CAROLINA'S WATER PROBLEMS

Citizens of North Carolina are accustomed to having plentiful supplies of high-quality water for recreation and personal and industrial uses. They expect unlimited potable supplies at low cost, and they expect to swim, boat, and fish in streams and lakes without fear of environmental contamination. For the most part, their expectations are met. However, in parts of the state, there are indications that the resource is threatened.

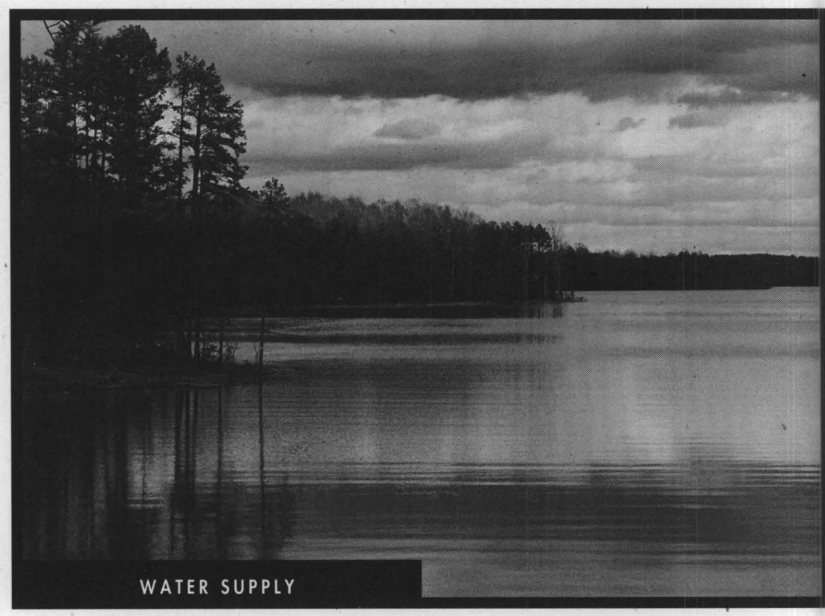
• **WATER SUPPLY:** In the 1990s North Carolina's growth rate accelerated, averaging 1.7% per year between 1990 and 1998. During that time the state welcomed nearly 1 million new residents, almost as many as it gained in the 20 years between 1950 and 1970. To serve those new residents—most of whom moved into metropolitan areas—municipalities and other providers have had to increase *daily* water deliveries by nearly 170 million gallons.

In the state's fastest-growing areas—located in the headwaters of Piedmont river basins, competition among local governments for available water supply sources is intensifying, and friction between these high-growth areas and downstream neighbors who receive their effluents is increasing. Water conservation and reuse will be crucial in the decades ahead if growth is to continue in the state's urbanized areas. Yet, questions continue to be raised about safe standards for reuse, and local planning rarely includes the necessary infrastructure to accommodate reuse. While some cities are mounting conservation programs, approaches to conservation seldom begin with thorough analysis of actual conservation potential.

Even with statewide watershed protection regulations, continuing development in water supply watersheds and resulting storm water runoff, sedimentation, nutrient enrichment, and algal growth raise short-term concerns about the cost of treating water to make it safe to drink and long-term concerns about the viability of water supplies. Lack of good sites for construction of additional water supply reservoirs intensifies the concern about protecting existing resources. Lack of stronger efforts at watershed protection stem from the tendency to emphasize the cost and ignore the economic benefits of protecting water quality.

Evidence of aquifer dewatering in areas of the Coastal Plain suggests that groundwater resources there may not be sufficient in high-growth areas. Interest in augmenting supplies by aquifer storage and recovery is high among local governments, and the potential needs to be investigated.

• **WASTEWATER DISPOSAL:** North Carolina's population growth in the 1990s has meant that municipalities and other service providers have had to increase *daily* wastewater treatment and disposal capacity by nearly 140 million gallons. The capacity of streams to assimilate wastes is being reached and exceeded in some areas, and advanced wastewater treatment—including in many areas expensive nutrient removal technology—is becoming increasingly necessary. At the same time, numerous incidences of overflows from municipal wastewater treatment plants and spills from sewage lines and pumping stations reveal a lack of


WATER SUPPLY


WASTEWATER DISPOSAL

attention to maintenance of existing environmental infrastructure. A study by the N.C. Rural Economic Development Center shows that North Carolina will need $11 billion over the next 20 years to meet its water and sewer needs. The $800 million in bonds approved by the N.C. General Assembly and N.C. voters in 1998, must be followed by increasing public investment in environmental infrastructure or alternative financing arrangements.

• **URBAN STORM WATER AND SEDIMENTATION:** Population growth and the resulting urbanization continue to take a toll on the state's streams. The important hydrologic consequences of urbanization are poorly understood or ignored by local planning bodies and land developers, and poorly planned urban development is increasing incidences of urban stream degradation and localized flooding. With growth running in double digits in some urban areas, such problems promise to intensify.

In some watersheds, hydrologic changes and streambank erosion appear to be counteracting the positive effects of efforts to control agricultural erosion and sedimentation. Sedimentation is the most widespread cause of use support impairment in N.C. streams, yet there is intense disagreement about the primary sources of sediment. Lack of good information about the effectiveness of various agricultural and construction BMPs in controlling sediment and related pollutants fuels this disagreement.

• **GROUNDWATER MANAGEMENT:** Widespread incidences of ground water contamination by leaking underground storage tanks, pesticides, agricultural chemicals, and other sources together with dramatic water level drops in the state's Central Coastal Plain aquifer system illustrate that North Carolina still has not adequately addressed the need to protect and manage its groundwater. More than half the state's population relies on groundwater, but few localities have adopted wellhead protection programs, and the State still has no comprehensive program for assessing the quality of groundwater or the risks posed to the health of citizens by lack of groundwater protection. In the Central Coastal Plain, lack of a thorough documentation of aquifer recharge and discharge as well as consequences of aquifer dewatering make efforts to manage water resources in this area difficult.

• **EFFECTS OF THE SWINE INDUSTRY:** Explosive growth of the hog industry in the N.C. Coastal Plain, lack of strong evidence about the effects of these operations on water quality, and the lack of economical alternatives to traditional waste disposal methods raise questions about the ability of current management efforts to reduce nutrient inputs to coastal rivers. The hog population in the state exceeds the human population. Still few questions have been answered regarding the effects of waste lagoons on groundwater, the movement of nutrients from spray fields through shallow groundwater to surface waters, the possibility of microbial contamination of water supplies from animal operations, and the atmospheric contribution to nutrient pollution from volatilized lagoon waste, spray fields, and houses.

• **PFIESTERIA:** Discovery in North Carolina coastal rivers of the toxic dinoflagellate *Pfiesteria piscicida* raises concerns about the safety of recreational waters, the health of fisheries, and the attractiveness of the N.C. coast as a tourist destination. What environmental conditions have lead to the emergence of the organism, what its effects on human health are, and what can be done to control it are still being debated in the scientific community.

All these issues plus intense citizen concerns about specific streams, lakes, and estuaries vie for attention from policy makers and resources from the State. Providing policy makers scientific information they need to make decisions and allocate resources will continue to be the mission of the Water Resources Research Institute. •

# NEW RESEARCH IN 1999 - 2000

## PROTECTING BLACKWATER RIVERS

Although North Carolina's Coastal Plain blackwater rivers are not considered nutrient sensitive, studies have shown that blackwater streams can and do support phytoplankton blooms under certain conditions. In earlier work, the investigators on this study demonstrated that nutrient additions can stimulate both bacterial and algal communities in blackwaters. Moreover, monitoring has shown that nutrient concentrations in blackwater streams of the Lower Cape Fear River system are often high and that these streams suffer from chronic hypoxia from June through September or October. The N.C. Division of Water Quality (DWQ) has noted in its 305(b) report and basinwide planning documents that low dissolved oxygen is particularly problematic in the Cape Fear River Basin. The investigators on this project hypothesize that — contrary to conventional wisdom — increased nutrient loading from wastewater discharges and nonpoint sources, including animal waste management systems, stimulates bacterial growth and algal blooms, thereby indirectly exacerbating hypoxia in the Cape Fear basin and other blackwater rivers. To test their hypothesis, they will conduct a series of nutrient-loading bioassays using water from two stations on the Black River. The Black River is classified as Outstanding Resource Waters by DWQ but runs through several of the state's largest hog-growing counties. Water for the experiments will be collected from Colly Creek, whose watershed receives low anthropogenic loading, and Great Coharrie Creek, whose watershed contains numerous confined animal operations. To the experimental waters the investigators will add nitrogen or phosphorous or both using a gradient up to 5.0 milligrams per liter. They will then measure chlorophyll *a*, bacteria, and biological oxygen demand. By selecting a gradient that brackets what they think is the key concentration level for both nutrients — the concentration at which bacterial and algal communities show a positive response — the investigators expect to provide a scientific basis for establishing total maximum daily loads for nutrients in blackwater systems.

### Algal, Bacterial, and BOD Responses to Nutrient Gradients in Coastal Plain Watersheds

- *Michael A. Mallin - Center for Marine Science Research and*
  *Lawrence B. Cahoon - Department of Biological Sciences;*
  *University of North Carolina at Wilmington*
- *Project 70177*
- *Starting date: May 1, 1999*
- *Completion date: June 30, 2000*
- *Funded by WRRI*

## PROTECTING SANTEETLAH LAKE

Santeetlah Lake is an oligotrophic (nutrient-poor, oxygen-rich) mountain reservoir on the Cheoah River in Graham County. The lake is fed by five principal streams and has recently suffered incidences of nuisance algal blooms. Studies conducted by the N.C. Department of Environment and Natural Resources indicated that the algal blooms were associated with short-term nutrient overloading, a primary source of which was trout-farm effluent. Management practices have recently been undertaken at commercial trout farms to lower nutrient levels in effluents, but the effectiveness of these practices has yet to be evaluated. In this project investigators will evaluate nutrient concentrations in the five tributary streams and compare phosphorous loads in streams which receive trout farm effluent to loads in streams without trout farms but with various levels of unquantified nutrient input from residential, road construction, and agricultural activities. This project should provide a sufficiently detailed base of data to identify sources and relative magnitudes of nutrient input to the lake and aid in establishing nutrient management guidelines for maintaining the B Trout classification of Santeetlah Lake.

### Evaluation of Nutrient Loading from Tributaries to Santeetlah Lake

- *Peter F. Galbreath*
  *Mountain Aquaculture Research Center*
- *J. Roger Bacon*
  *Department of Chemistry and Physics*
  *Western Carolina University*
- *Jeffrey M. Hinshaw*
  *Department of Zoology and*
  *N.C. Cooperative Extension Service*
  *North Carolina State University*
- *Project 70179*
- *Beginning date: June 1, 1999*
- *Completion date : June 30, 2000*
- *Funded by WRRI*

## VALUING WATER QUALITY

When economics is brought into debates about water quality, it is typically to describe costs of cleaning up pollution. However, to determine the "efficient" level of water quality improvement — that is the point at which benefits are equal to costs — one must be able to also measure the benefits. This project will focus on measuring the direct-use value to recreational users of North Carolina's water resources and the changes in these values associated with changing water quality. The investigator will combine behavioral data with various sources of

physical data on water quality to format an up-to-date data set on the recreational use of N.C. water resources. He will then use travel cost models to characterize demand for water-based recreation in the state. Using these results, he will estimate benefits associated with policies to improve water quality and compare these benefits with examples of costs. The end product of this investigation will be useful to policy makers in setting water quality improvement goals.

**Benefits of Quality Improvements in North Carolina's Water Resources**

- *Dr. Daniel J. Phaneuf*
  *Department of Agricultural and Resource Economics*
  *North Carolina State University*
- *Project 70178*
- *Starting date: May 1, 1999*
- *Completion date: June 30, 2000*
- *Funded by WRRI*

## PROTECTING PIEDMONT GROUNDWATER

Because groundwater is the primary source of drinking water in the N.C. Coastal Plain and because there is an obvious pesticide threat to the aquifers in this region from intense agricultural and horticultural activity, most research on groundwater contamination has focused on this region of the state. Relatively little is known about the potential for contamination by pesticides of Piedmont groundwater resources. However, several counties in the southern and central Piedmont are also highly dependent on groundwater, and recent surveys have detected pesticides in shallow groundwater of several of these highly populated counties. Evaluating the potential for groundwater contamination requires not only knowledge of the leaching potential of contaminants but also the susceptibility of soils to leaching. Susceptibility of soils to leaching depends upon soil properties, and little information is available about the principles and mechanisms governing contaminant fate in the organic-matter-poor and iron-oxide-enriched clays of the Piedmont. In this project, the investigator will study the important chemical and physical activities that take place in the well-developed red/yellow clay B horizons of Appling and Georgeville soils and identify processes that contribute to attenuation and mobilization of 2,4-D, norflurazon, and quinmerac in these soils. The results will contribute to models that evaluate vulnerability of Piedmont groundwater to pesticide contamination and will be useful for the protection of well-head areas and identification of the best placement for buffer strips for pollution reduction.

**Soil Processes Impacting Groundwater Quality in the North Carolina Piedmont: Contamination by Organic Agrochemicals**

- *Dharni Vasudevan*
  *Nicholas School of the Environment*
  *Duke University*
- *Project 70174*
- *Starting date: March 1, 1999*
- *Completion date: June 30, 2000*
- *Funded by WRRI and the U.S. Geological Survey*

## IDENTIFYING "JURISDICTIONAL" WETLANDS

It is very difficult to identify freshwater wetlands that are subject to regulation under Section 404 of the Clean Water Act and, therefore, difficult to establish boundaries of "jurisdictional" wetlands. To be considered "jurisdictional" wetlands, areas must be saturated to within 30 cm of the surface for 5% of the growing season in 5 or more years out of 10. To directly document that these conditions exist on a site requires 5-10 years of monitoring and measurement. Recently, however, DRAINMOD, which computes water table depth on the basis of rainfall inputs and soil properties, has been modified to evaluate wetland hydrology. This new version predicts water table depths and relates them to wetland hydrologic criteria. Data for DRAINMOD simulations can be obtained in less than 6 months and the model assessments are considered acceptable by EPA. Investigators in this project propose to build on DRAINMOD's accepted powers of simulation to develop a tool that can be applied on site in a single day to evaluate wetland hydrology in the N.C. Coastal Plain. They will create this tool by correlating soil color patterns — and the redoximorphic features of the soils such as concentrations of $NO_3$, Mn, Fe(II) and $SO_4$ — to long-term saturation frequency and duration predicted by DRAINMOD for benchmark soils in the Coastal Plain. These correlations, and training in using them, will be useful not only for wetland delineation but also for estimating depths to which denitrification and sulfate reduction will occur in buffer strips and for evaluating soils for on-site wastewater disposal.

**Predicting Long-Term Wetland Hydrology Using Hydric Soil Field Indicators**

- *Michael J. Vepraskas and David L. Lindbo*
  *Department of Soil Science*
  *North Carolina State University*
- *Project 70175*
- *Starting date: March 1, 1999*
- *Completion date: June 30, 2000*
- *Funded by WRRI and the U.S. Geological Survey*

# CONTINUING PROJECTS

**Denitrification and Nitrification in Agricultural Soils Fertilized with Liquid Lagoonal Swine Effluent** *(Project 50232) July 1, 1997, to June 30, 2000 — Funded by the N.C. Department of Environment and Natural Resources.*
Stephen C. Whalen of UNC-Chapel Hill and associates at other universities continue their collaborative effort to document the fate of nitrogen in the waste stream produced in a representative, large-scale swine production facility.

**Effectiveness of Four Best Management Practices for Reducing Nonpoint-Source Pollution from Piedmont Tobacco Fields** *(Project 70163) June 15, 1997, to December 31, 1999 — Funded by WRRI*
E. Carlyle Franklin and Gregory D. Jennings of N.C. State University are completing their investigation of the ability of integrated systems of best management practices to reduce pollutants in runoff from tobacco fields in Piedmont North Carolina

**Water Flow Analysis for Large Septic Systems** *(Project 70168) June 1, 1998, to June 30, 2000 — Funded by WRRI*
Aziz Amoozegar, David L. Lindbo, and David Evans of N.C. State University continue their project to develop new methodology that will allow regulators and septic system designers to take site hydrology into account in evaluating sites for and designing large septic systems.

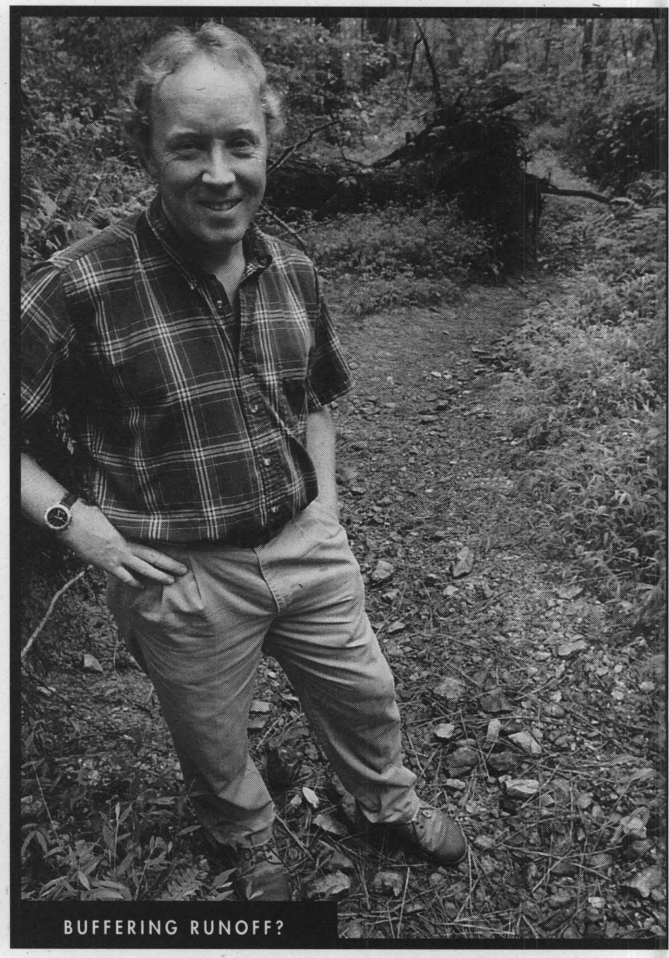
**Using Natural and Landscaped Buffers to Reduce Pollutant Loading from Agricultural Runoff** *(Project 70169) June 1, 1998, to June 30, 2000 — Funded by WRRI*
Because the drought has dried up runoff Richard A. McLaughlin and Wendell Gilliam of N.C. State University have been granted an extension to complete their study. They are conducting investigations designed to determine if buffers of acceptable size and design for landscapes can perform the functions of a forested riparian buffer in retention of pollutants in runoff.

- **REPORTS IN PREPARATION**

The following projects are essentially complete, and technical completion reports are being written.

**The History of Water Quality in North Carolina Estuarine Waters as Documented in the Stratigraphic Record** *(Project 70161) Sherri Rumer Cooper, Duke University*

**Historical Trends in Watershed Nutrient Production, Nutrient Loading, and Water Quality in the Neuse and Tar-Pamlico River Estuaries** *(Project 70167) Donald W. Stanley, East Carolina University*


BUFFERING RUNOFF?

**An Improved Characterization of a Fractured-Rock Aquifer by the Transient Flowmeter Test** *(Project 70165) Zbigniew J. Kabala, Duke University*

**Mass Balance and N Cycling Dynamics in Field Plots Experimentally Fertilized with Liquid Lagoonal Swine Waste** *(Project 70170) Stephen C. Whalen, UNC-Chapel Hill (Results of this project will be combined with project 50232 to produce a final report.)*

**Effect of Management Practices on Denitrification in Soils Fertilized with Lagoonal Swine Waste** *(Project 70151) Stephen C. Whalen, UNC-Chapel Hill*

**Seeking Science-Based Nutrient Standards for Coastal Blackwater Systems** *(Project 70171) Michael A. Mallin and Lawrence B. Cahoon, UNC-Wilmington (Results of this project will be combined with the results of Project 70177 to produce a final report.)*

**Hog Waste Treatment to Control Microbial Contamination** *(Project 70173) Mark D. Sobsey, UNC-Chapel Hill*

# NEUSE RIVER MODELING AND MONITORING (ModMon) STAGE II AND RELATED PROJECTS

In 1997, with funding from the N.C. Department of Environment and Natural Resources, scientists at four universities undertook a massive research effort to determine how the ecology of the Neuse River Estuary will respond to the 30% reduction in nitrogen mandated in legislation and regulations. The research program (dubbed ModMon) includes intense monitoring and ecological research in the estuary, a short-term modeling effort to calibate and improve an estuarine nutrient response model, and a long-term modeling effort to predict on a basinwide basis the likelihood that a 30% nitrogen reduction will be accomplished by current regulations. The first stage of the Neuse ModMon Program ended in December 1998, and reports on those investigations are nearing publication. With new funding provided by the N.C. General Assembly, the Neuse ModMon project enters its final stage, in which scientists address knowledge gaps identified in the first stage and synthesize data from many different sources. Other organizations, including WRRI, are funding related investigations.

- **NEW PROJECTS**

**Impact of Sediment Processes on Water Quality in the Neuse River Estuary** *(Project 70176) March 1, 1999, to June 30, 2000. Marc J. Alperin, UNC-Chapel Hill and James D. Bowen, UNC-Charlotte — Funded by WRRI and the U.S. Geological Survey*

Studies have clearly demonstrated that release of stored nutrients from estuarine bottom sediments drives production of algae during certain times, and that when bottom waters become anoxic (oxygen depleted), flux of ammonium from sediments increases exponentially. Studies have also shown that during the summer, large areas of Neuse Estuary bottom sediments may be anoxic for long periods. Under the Neuse Modeling and Monitoring (ModMon) project, an off-the-shelf process model has been calibrated to predict the change in water quality in the Neuse Estuary to a 30% reduction in nitrogen loading. Unfortunately, the Neuse Estuary Eutrophication Model (NEEM) simulates biogeochemical processes that take place in and near bottom sediments in a way that ignores nutrient releases from sediments when bottom waters become anoxic. However, output from the NEEM model does provide key parameters that can be used to better model sediment processes. Investigators on this project will conduct experiments to more completely characterize the sediment nitrogen cycle in the Neuse Estuary, use these results to construct a more accurate model of sediment physical and chemical processes, and use output from the NEEM model to establish boundary conditions for the model. They will then compare diagenetic model predictions of sediment ammonium flux to NEEM predictions. The difference in the predictions will allow investigators to gage the magnitude of uncertainty in the NEEM predictions of water quality response and establish a more reliable estimate of how long it may take for a 30% nitrogen reduction to be seen in improved water quality in the estuary.

**Denitrification and Sediment-Water Nutrient Exchange in the Upper Neuse River** *(Project 50266) July 1, 1999, to December 31, 2000. Stephen C. Whalen and Marc J. Alperin, UNC-Chapel Hill — Funded by WRRI*

Research in the first stage of ModMon identified an important gap in knowledge about processes in the Neuse River—the magnitude of and controls on denitrification in the upper Neuse. In this project, the investigators will close that gap by sampling sediments and water at Crabtree Creek in Wake County, the Neuse River at Smithfield, Nahunta Swamp, and Fort Barnwell and conducting analyses to determine denitrification rates in Piedmont and Coastal Plain tributaries and sections of the mainstream river. They will also measure nitrogen, oxygen, and carbon to learn what controls denitrification rates at these representative sites. This study will enhance the ability of models to predict decay of nitrogen as it moves downstream.

**Development of GIS-Based Nitrogen Budget for the Neuse River Basin** *(Project 50259) Wayne P. Robarge, N. C. State University,* and **Ammonia/Ammonium Monitoring and Modeling in Eastern North Carolina** *(Project 50258) Hans W. Paerl, UNC-CH Institute of Marine Sciences, March 11, 1999, to March 10, 2000 — Funded by the N.C. Department of Environment and Natural Resources*

Efforts to rescue the Neuse Estuary from problems caused by nutrient over-enrichment involve restoring the nitrogen balance of the entire ecosystem and the entire region, not just selected streams. Restoring the nitrogen balance requires establishing

a nitrogen budget—that is, accounting for all inputs and outputs. To develop a nitrogen budget for eastern North Carolina, work by many different university and agency scientists in many disciplines, who have developed many different databases, must be integrated. In this project, the investigator will use the multi-layering capability of a geographic information system (GIS) to integrate data on regional nitrogen inputs and outputs to calculate a nitrogen budget for the Neuse River Basin ecosystem. The completed project will incorporate new data from several ongoing research projects, including projects to quantify nitrogen inputs from septic systems and groundwater and to more accurately estimate nitrogen inputs from land disposal of animal wastes. As part of the effort to measure the impact of animal waste disposal on atmospheric nitrogen in the Neuse Basin and nearby sounds, two new monitoring sites will be established, one to be operated by the UNC-CH Institute of Marine Sciences at Morehead City.

**A Conceptual Framework for the Assessment of Nitrogen Assimilation Capacity of Coastal Plain Aquifers** *(Project 50254) January 26, 1999, to December 31, 1999. Kenneth H. Reckhow and Kirsten Hofmockel, WRRI — Funded by N.C. Department of Environment and Natural Resources*

In this project, investigators will provide information and develop a framework which can be used to determine if current waste land-application practices in the Coastal Plain may be contributing to excessive nutrient concentrations in shallow aquifers and, through groundwater discharge, adding to nutrient loading of Coastal Plain streams, including the Neuse River. An intensive literature search will document the impact of nutrient application practices on groundwater. Diagrammatic representations of the pathways traveled by nutrients as they migrate from field to stream and of processes that attenuate or reduce nutrient loading to ground and surface waters will provide the conceptual framework for determining whether application practices are exceeding the assimilative and attenuative capacity of soils and groundwaters. Important gaps in knowledge will be identified and available management controls to reduce contamination will be outlined.

**Quantification of *Pfiesteria piscicida* in the Neuse Estuary** *(project number pending) JoAnn Burkholder and Howard Glasgow, N.C. State University — Funded by the N.C. Department of Environment and Natural Resources and the Neuse River Foundation*

Several species that closely resemble *Pfiesteria piscicida* make it impossible to identify this toxic species using standard light microscopy. The investigators have developed a fluorescent in situ hybridization molecular probe that allows them to label *P. piscicida* for counting. Using this probe and a recently acquired flow cytometer, the investigators will quantify *P. piscicida* in water samples taken throughout an annual cycle in the mesohaline Neuse Estuary. This information will improve understanding of environmental controls on the growth and toxic activity of *P. piscicida*

- **CONTINUING PROJECTS**

**Neuse River Modeling and Monitoring: Stage II** *(Projects 50255/57) January 1, 1999, to December 31, 2000. Kenneth H. Reckhow, Tyler Joscelyn, and Mark Borsuk, WRRI — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*

This project will synthesize information produced by all the various Neuse River research projects to (1) estimate (with uncertainties stated) the annual nitrogen load from major sources and from sub-watersheds in the Neuse River Basin; (2) develop and test models that can predict how various nitrogen reduction percentages may affect variables of concern (water clarity, algal blooms, and fish health/abundance) in the Neuse Estuary; and (3) use these predictive models to evaluate proposed nitrogen total maximum daily loads (TMDLs) for the Neuse River and answer other questions about probable estuarine responses to nitrogen reductions.

**Neuse River Estuary Modeling and Monitoring Project: Stage II Monitoring** *(Project 50261) May 1, 1999, to December 31, 2000. Richard A. Leuttich and Hans W. Paerl, principal investigators; Marc J. Alperin, Christopher P. Buzzelli, Christopher S. Martens, Tammi Lee Richardson, cooperating investigators, UNC-CH Institute of Marine Sciences — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*

This project continues the cooperative water quality monitoring effort in the Neuse River Estuary that began in 1997. The investigators also seek to provide additional information on algae nutrient uptake and growth needed for the estuarine response model and to quantify across-estuary sloshing and upwelling and other physical conditions that precede significant fish kills in the Neuse Estuary. They will also investigate interactions between particulate organic matter input and sediment/water oxygen and nitrogen cycling over an annual cycle.

**Additional Development of the Neuse Estuary Eutrophication Model for Prediction of Water Quality** *(Project 50262) January 1, 1999, to December 31, 2000. James D. Bowen, UNC-Charlotte — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*

In ModMon Stage I, the investigator adapted the CE-Qual-W2 model to the Neuse Estuary and conducted preliminary simulations to predict the impact of a 30% reduction in nitrogen loading. In this stage, he will expand the capabilities of the model to simulate biogeochemical processes that occur in bottom sediments, conduct analyses to estimate the uncertainties involved in model predictions, and conduct long-term simulations to examine the effects of year-to-year variability in weather and climate conditions and to estimate how long it might take for nutrient reductions to bring about observable improvement in estuarine water quality.

**Neuse River Estuary Modeling and Monitoring Project Stage II: Benthic Fisheries Habitat** *(Project 50263) May 1, 1999, to December 31, 2000. Charles H. Peterson, UNC-CH Institute of Marine Sciences — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*
In this stage, the investigator will continue studying how oxygen depletion in bottom sediments changes the number and kinds of sediment-dwelling creatures that many fish rely on for food, focusing on learning how long it takes a benthic community to recover adequately from anoxic events to be valuable to fish. He will also relate the output of predictive models being developed to changes in benthic habitat and subsequent fish production.

**Neuse River Estuary Fish Monitoring Project: Stage II Monitoring** *(Project 50264) May 1, 1999, to December 31, 2000. Larry B. Crowder, Duke University Marine Laboratory — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*
To improve knowledge generated in the last year about how long oxygen depletion occurs in areas of the estuary and how large the areas of depletion are, the investigator will continue mapping hypoxic and anoxic events for another year. To see if there is a pattern in the way fish respond to hypoxia and anoxia, he will release tagged flounder during events and track them. He will also conduct studies with caged croaker to determine effects of anoxia/hypoxia on feeding and growth of fish.

**Interrelationships of Water Quality Characteristics in the Neuse River Basin** *(Project 50265) June 1, 1999, to May 31, 2000. Craig A. Stow, Duke University — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*
Continuing his statistical analyses of long-term monitoring data for the Neuse River Basin, the investigator will examine changes in NPDES-permitted point-source loads over time as well as ambient monitoring data to identify the locations of important nutrient sources and how these sources have changed. He will also examine statistical relationships among water quality characteristics, focusing on changes in nutrient loading and chlorophyll levels.

**Contribution to Long-Term Modeling Tier of the Neuse River and Estuary as Functional Assessment of Environmental Phenomena through Network Analysis** *(Project 50267) July 1, 1999, to December 31, 2000. Robert R. Christian, East Carolina University — Funded by N.C. General Assembly through the Department of Environment and Natural Resources*
Continuing his network analysis of the ecological webs of the Neuse Estuary, the investigator will describe the food webs that exist under a variety of summer conditions, including hypoxia, and how conditions affect trophic structure, with particular attention to commercially important species. These analyses can be used by policy makers and stakeholders to assess the ecological significance of various environmental phenomena.

**Biologically Mediated Nitrogen Dynamics in Eutrophying Estuaries: Assessing Denitrification and $N_2$ Fixation Responses to Proposed N Loading Reduction in the Neuse River Estuary** *(Project 70172) August 1, 1998, to February 29, 2000. Hans Paerl and James L. Pinckney, UNC-CH Institute of Marine Sciences — Funded by WRRI and the U.S. Geological Survey*
The investigators continue experiments to determine if nitrogen reductions in the Neuse Estuary will favor the growth of $N_2$-fixing cyanobacteria.

**Measurement and Modeling of Ammonia/Ammonium Flux and Dry Deposition Velocity above Natural Surfaces in Eastern North Carolina** *(Project 50242) May 1, 1998, to April 30, 2001. S. Pal Arya and Viney P. Aneja, N.C. State University — Funded by the N.C. Department of Environment and Natural Resources*
The investigators continue work to measure the rate at which ammonia is deposited onto significant land cover types in North Carolina and to parameterize these rates for use in atmospheric transport and deposition models.

**Lumped Parameter Models for Predicting Nitrogen Loading from Lower Coastal Plain Watersheds** *(Project 70162) June 1, 1997, to December 31, 1999. R. Wayne Skaggs, G.M. Chescheir, D. M. Amatya, G. Fernandez, and J. Wendell Gilliam, N.C. State University — Funded by WRRI*
The investigators wind down their project by testing new watershed-scale models for predicting nutrient contributions to surface waters in the Neuse Basin based principally on hydrology and hydraulics. •

# INFORMATION AND TRAINING

In addition to its technology transfer activities, WRRI publishes newsletters, maintains web sites, and sponsors or co-sponsors conferences, workshops , and forums to provide policy, regulatory, scientific and technical information about water resources issues in North Carolina to agency personnel, policy makers, consultants, and the interested public. As a service, the Institute also helps the N.C. Office of Waste Reduction; the N.C. Division of Land Resources, Land Quality Section; the N.C. Division of Soil and Water Conservation; and the U.S. Geological Survey find and hire qualified university student interns.

## • WRRI NEWS

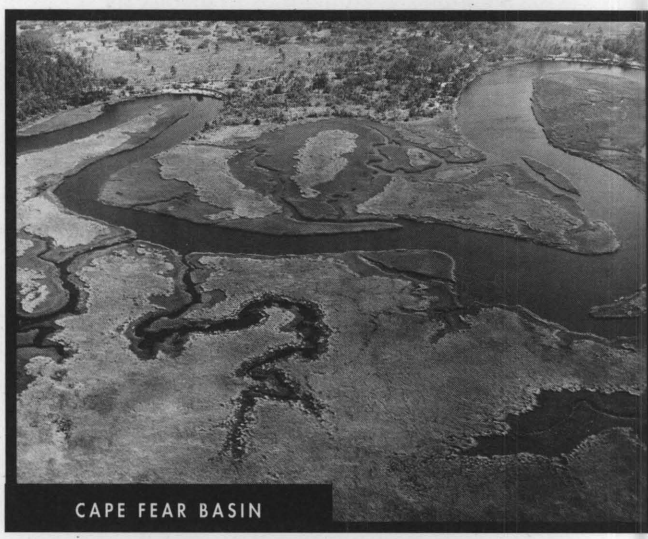
The *News* is published every other month and sent to more than 4100 federal and state agencies, university personnel, multi-county planning regions, local officials, environmental groups, consultants, businesses, and individuals. The *News* regularly covers activities of the N.C. Environmental Management Commission and other environmental policy-making bodies, environmental action of the N.C. General Assembly, environmental regulatory activities at the federal level, and other water resources news. This newsletter is free to residents of North Carolina.

## • SEDIMENTS

WRRI produces the quarterly *Sediments* 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 5600. This newsletter is free.

## • WORLD WIDE WEB

WRRI maintains a web site (*http://www2.ncsu. edu/ncsu/CIL/WRRI*) providing online access to its newsletter, technical report summaries, an expertise directory, and frequently updated information on workshops, conferences, calls for papers, public hearings and other opportunities for public participation in water resources related rule- or policy-making activities. In the coming year, WRRI expects to begin making full-text reports available online.



CAPE FEAR BASIN

Part of the WRRI web site is the Neuse River Homepage (*http://www2.ncsu.edu/ncsu/CIL/WRRI/neuse.html*), a gateway to information on the web about the Neuse River, including research, management, and education/outreach programs.

During 1998-99, WRRI also developed web pages for its N.C. Urban Water Consortium (*http://www2.ncsu.edu/ncsu/CIL/WRRI/uwc*), the Urban Water Consortium's Storm Water Group (*http://www2.ncsu.edu/ncsu/CIL/WRRI/stormwater*), and the N.C. Land Quality Section and its Erosion and Sediment Control Program (*http://www.dlr.enr.state.nc.us/*).

## • CONFERENCES AND WORKSHOPS

WRRI will sponsor or co-sponsor the following conferences, workshops, and forums in 1999-2000.

**Luncheon and Forum on Effects of the Neuse Rules on Urban Storm Water,** *Sept 13, 1999, McKimmon Center, Raleigh; With N.C. Water Resources Association*

**Erosion and Sedimentation Control Design Workshop,** *Oct 18-19, 1999, Fort Bragg, NC; With N.C. Sedimentation Control Commission, N.C. Land Quality Section, and Fort Bragg*

**Urban Stormwater Management Conference and Symposium,** *Nov 1, 2, 3, 1999, McKimmon Center, Raleigh; With N.C. Sedimentation Control Commission and N.C. Land Quality Section*

**Luncheon and Forum on Cape Fear Basin Water Quality Issues,** *Dec 6, 1999, McKimmon Center, Raleigh; With N.C. Water Resources Association*

**Erosion and Sedimentation Control Local Programs Workshop,** *Jan 25-26, 2000, Greensboro; With N.C. Sedimentation Control Commission and N.C. Land Quality Section*

**Luncheon and Forum on Mitchell River Watershed Project,** *Feb 14, 2000, McKimmon Center, Raleigh; With N.C. Water Resources Association*

**Annual North Carolina Water Resources Research Conference,** *March 30, 2000, McKimmon Center, Raleigh*

# TECHNOLOGY TRANSFER

WRRI transfers results of research it sponsors to technical professionals, agency personnel, scientists, and others who can make use of the information by two primary methods: (1) peer-reviewed reports and (2) seminars in which investigators present their work and answer questions about it. (The WRRI Water Resources Research Seminar schedule for 1999-2000 can be found on Page 16 of this program.)

## • WHY PEER-REVIEWED REPORTS?

Environmental science is rarely certain, and conclusions drawn from scientific research are sometimes based on statistical analysis and sometimes on professional judgment reflecting the weight of evidence. Moreover, scientific fields have proliferated and become highly specialized, requiring deep knowledge of a very narrow field and of arcane technical language. Given these circumstances, how can a layperson (say a journalist or a policy maker) who is not familiar with the procedures by which the scientific community acquires, evaluates, and reports scientific information determine the reliability of any piece of scientific research? The answer is that nonscientists cannot evaluate scientific research. That is why the process of peer-review is recognized as essential to establish the credibility of both research data and conclusions. Peer review is imperative in academia and is mandated by law for much research performed by or for federal regulatory agencies, including the U.S. Environmental Protection Agency.

Peer review is the evaluation by unbiased specialists in the same field of the data collection procedures, experimental procedures, and analytical procedures used in research and of the plausibility of conclusions drawn from the experimental results. Peer review is intended to confirm for the nonscientist that the research has produced "sound science" and that the conclusions may be relied upon as representing the current state of knowledge.


RESTORING SHELLFISH WATERS

In an effort to assure that it sponsors and produces sound science, WRRI requires principal investigators on its projects to write a report detailing methodology and stating results, conclusions, and recommendations. Draft reports are then subjected to peer review by three experts, at least one of whom is outside the state of North Carolina. Reports are also subjected to thorough editing, during which figures, tables, references, and language are all evaluated for internal consistency and adherence to accepted form.

## • PEER-REVIEWED REPORTS PUBLISHED IN 1998-1999

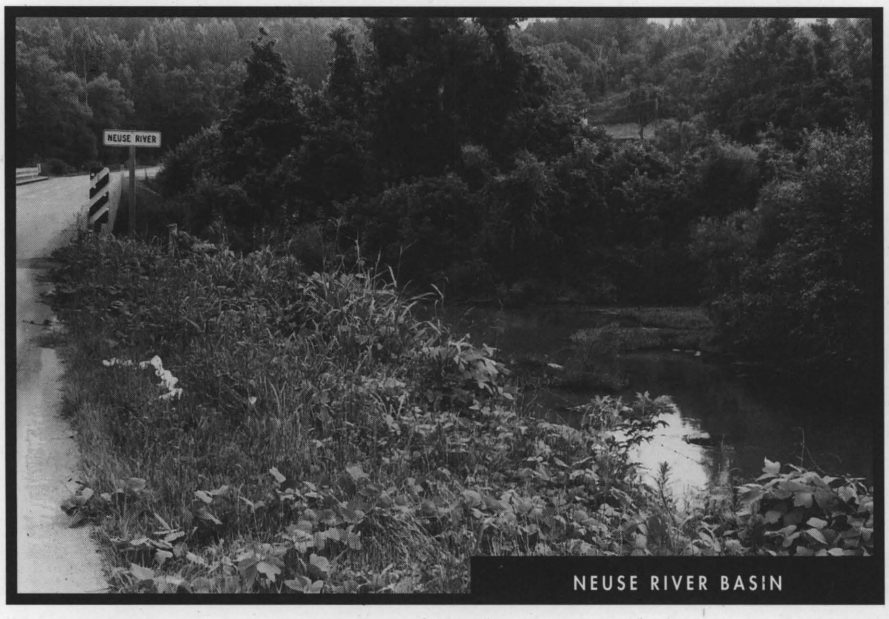
*Report 318*
**An In Vitro Test for Estrogenicity Combining Cultured Hepatocytes and an Enzyme-Linked Immunosorbant Assay,** *G.H. Monteverdi and R.T. DiGiulio, Duke University, Sept 1998*

*Report 319*
**A New Method for Characterizing Aquatic Organic Matter,** *R.F. Christman, et al., UNC Chapel Hill, Nov 1998*

*Report 320*
**Slurry-Phase Bioremediation of Contaminated Soil,** *M.D. Aitken, et al. UNC-Chapel Hill, Nov 1998*

*Report 321*
**Development of the Technical Basis and a Management Strategy for Reopening a Closed Shellfishing Area,** *James D. Reilly and William W. Kirby-Smith, Duke University Marine Laboratory, June 1999*

*Report 322*
**Compliance with EPA's Information Collection Rule for North Carolina Surface Water Supplies: Bench-Scale Testing of the Efficacy of Carbon Adsorption and Membrane Separation,** *F.A. DiGiano et al., UNC-Chapel Hill, June 1999*



NEUSE RIVER BASIN

## • 2000 – WATER RESOURCES RESEARCH SEMINAR SERIES

Following is the schedule for WRRI's continuing seminar series on water resources research in North Carolina. Presentations take place in the Ground Floor Hearing Room of the Archdale Building in downtown Raleigh or in Room 1132 of Jordan Hall on the N.C. State University campus. Presentations begin at 3 pm unless otherwise noted. For additional information contact Associate Director Robert Holman at (919) 515-2815 or *Robert_Holman@ncsu.edu*.

**Remediation of Groundwater Contaminated by Industrial Solvents,** *Monday, Sept 20, 1999, Archdale Building; Professor Casey Miller; UNC-Chapel Hill Department of Environmental Sciences and Engineering*

**Network Analysis for Evaluating the Consequences of Nitrogen Loading,** *Monday, Oct 11, 1999, Jordan Hall; Professor Robert Christian; East Carolina University Department of Biology*

**Examination of Long-Term Nutrient Data in the Neuse River Watershed,** *Monday, Nov 22, 1999, Archdale Building; Professor Craig Stow; Duke University Nicholas School of the Environment*

**Algal, Bacteria, and BOD Responses to Nutrient Gradients in Coastal Plain Watersheds,** *Tuesday, Jan 18, 2000, Jordan Hall; Research Associate Michael Mallin; UNC-Wilmington Center for Marine Science Research*

**Predicting Long-term Wetland Hydrology Using Hydric Soil Field Indicators,** *Monday, Feb 21, 2000, Archdale Building; Professor Michael Vepraskas; North Carolina StateUniversity Department of Soil Science*

**Soil Processes Impacting Groundwater Quality in the North Carolina Piedmont: Contamination by Organic Agrochemicals,** *Monday, Mar 27, 2000, Jordan Hall; Asst. Professor Dharni Vasudevan; Duke University Nicholas School of the Environment*

**Impact of Sediment Processes on Water Quality in the Neuse River Estuary,** *Monday, April 24, 2000, Archdale Building; Asst. Professor Marc Alperin; UNC-Chapel Hill Department of Marine Sciences*

**Benefits of Quality Improvements in North Carolina's Water Resources,** *Monday, May 22, 2000, Jordan Hall; Asst. Professor Daniel Phaneuf; North Carolina State University Department of Agricultural and Resource Economics*

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**Kenneth H. Reckhow** (Ex-Officio) Director, Water Resources Research Institute

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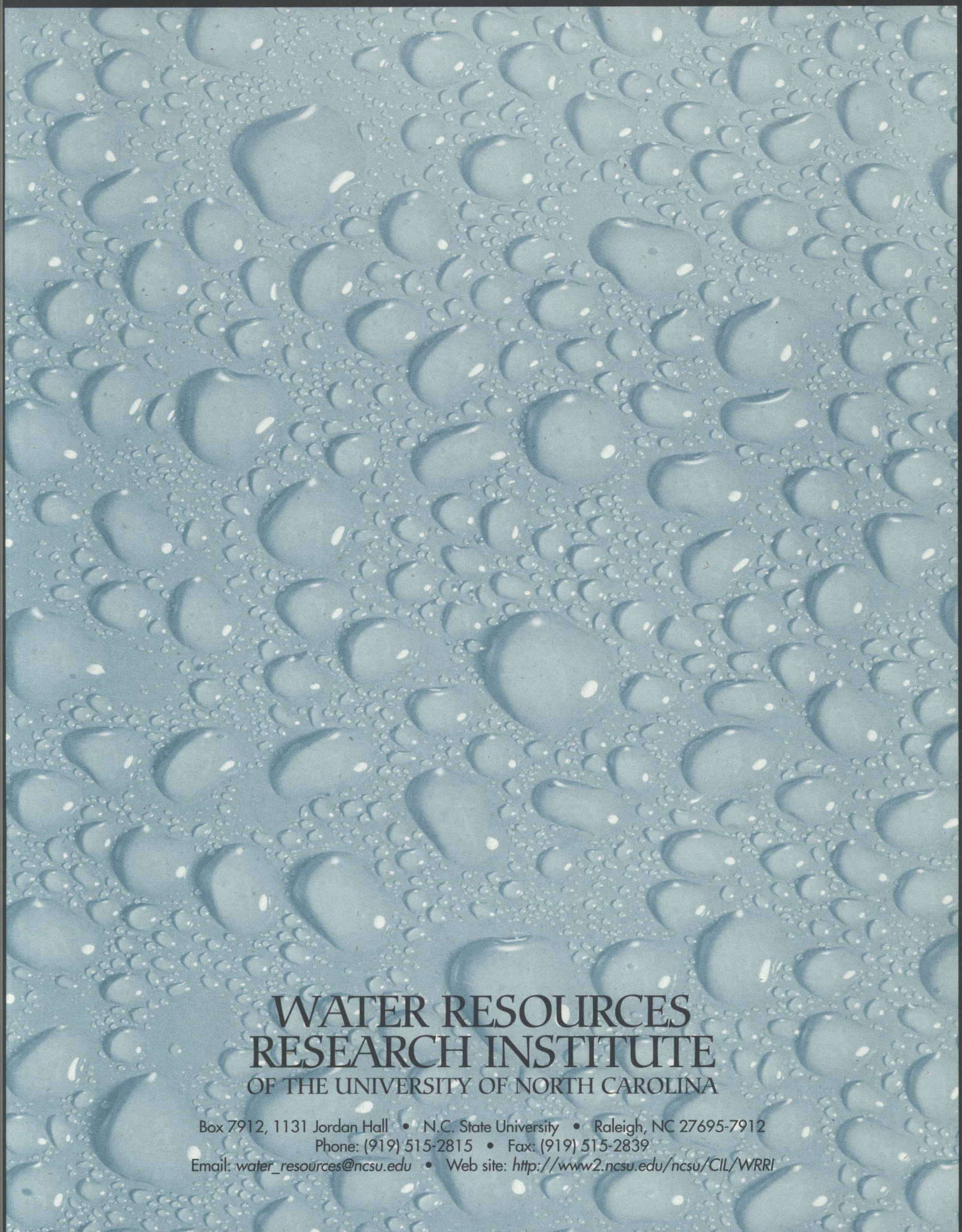

# WATER RESOURCES RESEARCH INSTITUTE

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