EXECUTIVE SUMMARY
LEGISLATIVE REPORT
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RIVERNET: Continuous Monitoring of Water Quality in the Neuse River Basin

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PURPOSE OF PROGRAM

Agricultural and urban land use has increased the fluxes of nutrients, sediments and different organic/inorganic chemicals into surface water and ground waters. As a consequence, many estuaries and wetlands are under various levels of environmental pressure as a result of diminished water quality (e.g., high nutrient concentrations, sediment loading, low levels of dissolved oxygen). The increased nitrogen flux to estuaries and coastal waters has affected water quality by enhancing phytoplankton blooms as part of the overall eutrophication process. This enhanced production modifies coastal food webs, reduces commercial species abundance, and in extreme cases produces zones of hypoxia and anoxia. Although extensive research has been done to understand nitrate contamination and attenuation processes in ground water, discharge rates of nitrate in streams are commonly not matched to different types of land use or to field application rates. To promote the long-term sustainability of natural and managed watersheds and to develop successful remediation strategies, fundamental processes that control water quality on a watershed scale must be investigated. RiverNet is a program that is designed to understand nitrogen fluxes in watersheds with different land uses.

BACKGROUND

The 2001 Session of the General Assembly appropriated $300,000 to the Department of Environment and Natural Resources (DENR) for transfer to North Carolina State University (NCSU) for the continued operation of the RiverNet Program. Due to budget reductions, $285,000 was available to operate the RiverNet program in 2005. The RiverNet Monitoring network has been operated over the past five years. During the first year several technological problems were solved. During the second year the system monitored nitrogen flux during a severe drought. During the third year the system monitored nitrogen flux as the drought ended and began to monitor groundwater nutrient flux from the Raleigh WWTP near Clayton, NC. During this past year we have applied a new tracer to measure the transfer of atmospheric deposition of nitrogen into surface waters (^{17}O). During the fourth year we have applied a new technology that will permit nutrient watershed mapping to investigate where groundwater inputs are entering the river system. Six stations are operating in the basin from Raleigh to Fort Barnwell, one station is in the Contentnea watershed, and five are along the Neuse Mainstem (Figure 1). Physical water quality property measurements are made every 15 minutes and nitrate analyses are made once an hour. The data is transferred to a server at the NCSU Raleigh campus once a day via a cell phone network, and mounted on a web site for public access (http://rivernet.ncsu.edu). This monitoring will continue for the next year with nutrient watershed mapping and groundwater monitoring at the Raleigh WWTP.

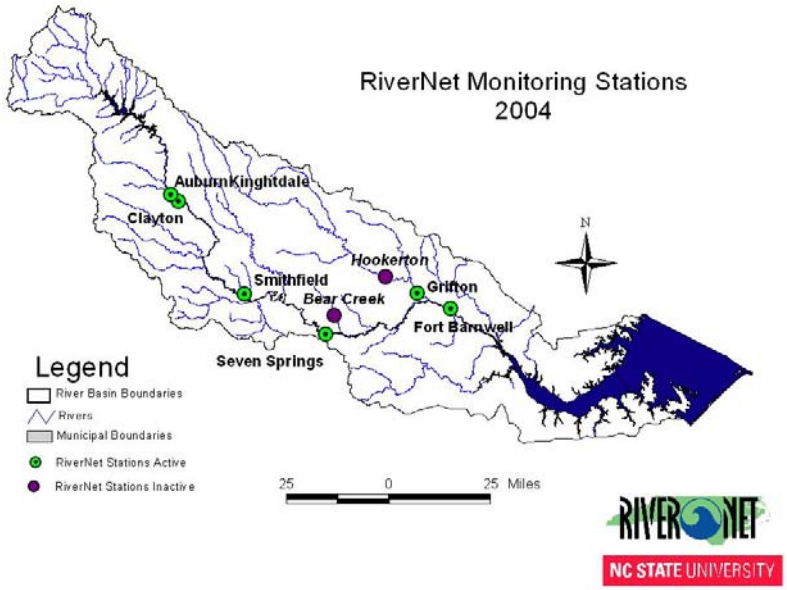

Figure 1. The RiverNet monitoring network with a new station located above the Raleigh Waste Water Treatment Plant (WWTP) to investigate the relationship of groundwater flux from this large Waste Application Field (WAF) in the piedmont. Due to continued budget restrictions, two lower basins stations were temporarily closed down.

RiverNet: Results 2005

Previous years results have shown that there are significant nitrate concentration variations in the Neuse River basin, and these variations were also observed in 2005 at the uppermost RiverNet Station (Figure 2). These variations are found in drought and non-drought conditions and are associated with large NPDES dischargers. These nitrate concentration variations are

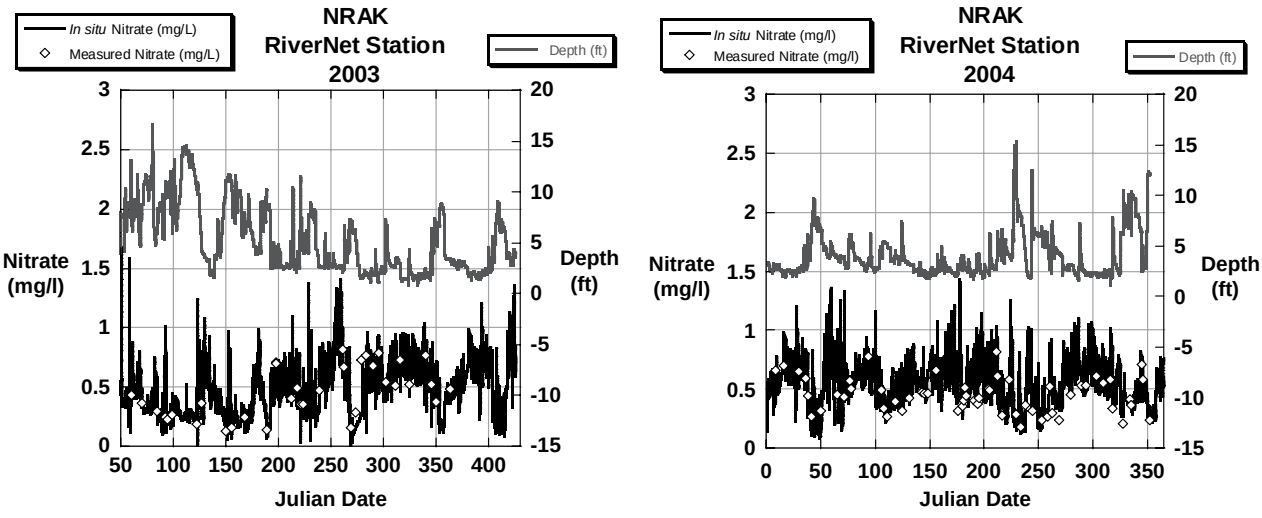

Figure 2. River nitrate variations during the 2001 to 2003 period. Notice the high frequency variations are not related to drought

found in the upper, middle and lower portions of the basin. To evaluate how important hourly measurements are to accurately assess N flux, RiverNet measurements were compared to daily flux measurements similar to those produced by the ambient monitoring programs (Figure 3). N Flux errors in the upper basin were the largest varying by ± 40%. The central portion of the Neuse basin had about the same N Flux error, while in the lower basin at Fort Barnwell the error was ± 30%. In Bear Creek, an agricultural watershed with no large point sources, the N flux error is approximately ± 10 % when hourly calculations are compared to daily N flux estimates. This data indicates we know the agricultural N flux fairly well with previous monitoring programs, but have significantly underestimated the municipal point source N fluxes in the basin.

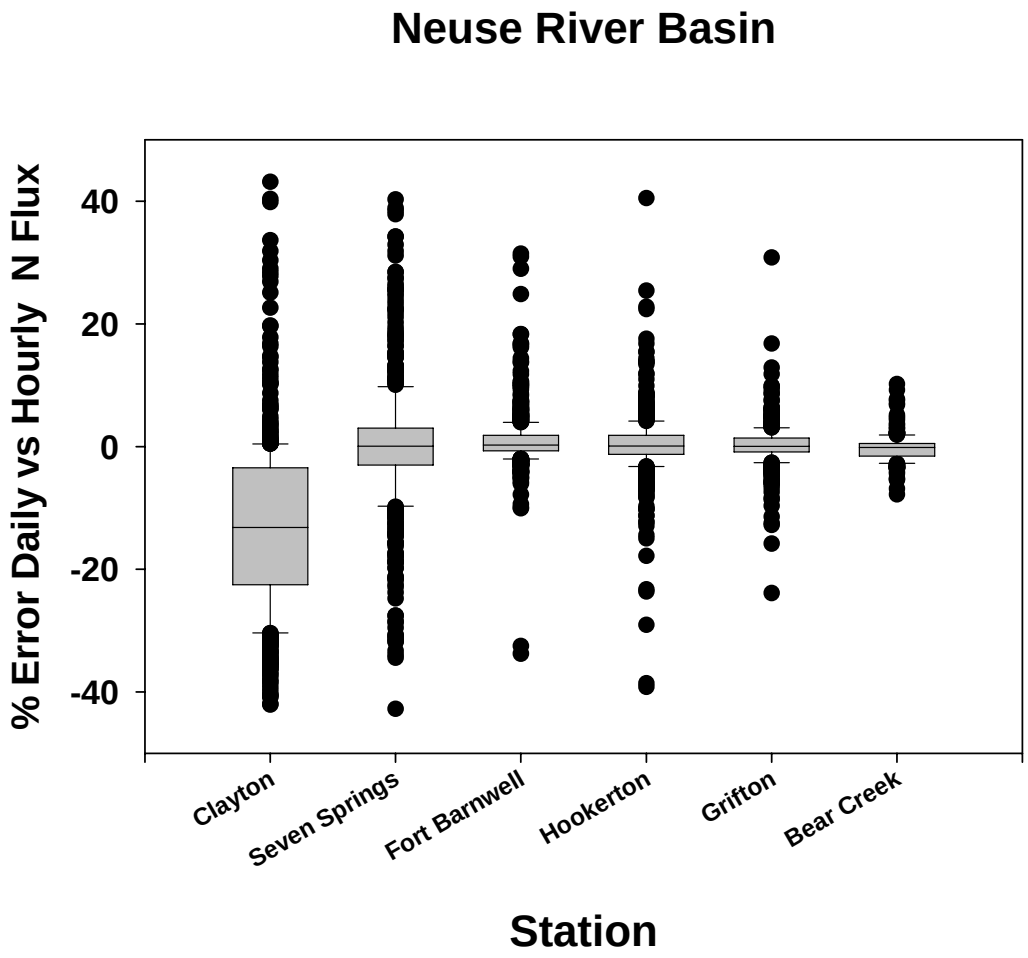

Figure 3. Daily versus hourly N flux measurements in the Neuse River, NC. The error without a RiverNet program is 40% in the upper basin to ~10 % in the smaller agricultural tributaries. Over the year the nitrate flux calculation error with daily measurements in the Neuse Basin is ~ -12% indicating that we have underestimated the N flux out of the Neuse Basin with ambient monitoring programs.

CONTAMINATED GROUNDWATER FLUX OF NITRATE TO THE NEUSE RIVER

Waste application fields accumulate nitrate, but the movement of nitrate from under these fields to surface waters is not well understood. We have investigated the movement of groundwater nitrate from under the Battle Bridge Road treatment plant operated by the City of Raleigh into the Neuse River over the past year with two RiverNet Stations above and below the plant. Biosolids have been land applied at this site for the past 24 years. We have also mapped the river nitrate concentrations with the new ISUS UV nitrate sensor and determined that the nitrate is entering the River along the northern boundary of the plant. The amount of nitrate entering

the river from contaminated groundwater is 50% the flux of nitrate released from the plant via the discharge pipe (Table 1). This contaminated groundwater flux is significant to river nitrate flux, and is event driven. The inputs occur over a 1-5 day periods, and are related to river stage not precipitation. This relationship suggests that groundwater levels drive the Biosolid Waste N flux into the river. To evaluate the effect of groundwater or surface water drainages into the river, NC DENR, USGS, and NCSU are now installing a groundwater observatory at the Neuse River Waste Water Treatment Plant with co-operation by the City of Raleigh, Public Utilities Division. Three sets of monitoring wells at three locations on the northern slope of the plant will be installed and groundwater will be monitored real time by the USGS. Initial results of the core logging at two locations show that the subsurface soil layers under these fields are not homogeneous, but layers of impermeable clay mixed with layers of gravel and sand. Water and nitrate that moves down slope towards the river is funneled into the permeable layers. Surface stream bypass the riparian buffers where surface drainages cut into the permeable gravel layers and discharge nitrate contaminated waters into the Neuse River. If this observation can be substantiated with high-resolution N flux data, then remediation efforts can be initiated by reconstruction wetlands to intercept the nitrate enriched surface drainages to reduce

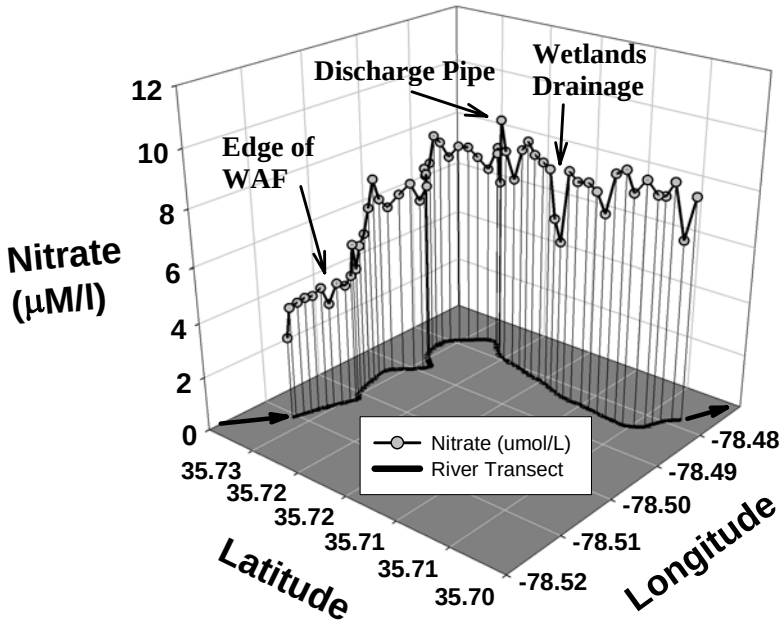

Figure 4. Two RiverNet stations monitor groundwater additions and nitrate flux at the Raleigh NRWWTP. Groundwater nitrate flux to the Neuse River is event driven and occurs over a 1-5 day period after heavy rainfalls.

the nitrate concentrations that drain through the wetlands into the river. Conversely, if nitrate is entering the river via groundwater where permeable layers are eroded by the river, then other remediation efforts with have to be employed. High-resolution sampling with the RiverNet stations and N watershed mapping are needed here to design the proper remediation approach.

Table 1. Nitrate Fluxes at the Raleigh WWTP

	% Norm Flux
Surface Flux NO3 Input % Clayton	**68.48**
RWWTP Flux NO3 % Clayton	**21.27**
Groundwater Flux NO3 % Clayton	**10.26**
Total Inputs NO3	**100.00**
Surface Flux Q Input % Clayton	**90.81**
RWWTP Flux Q % Clayton	**4.40**
Groundwater Flux Q % Clayton	**4.80**
Total Inputs Q	**100.00**

ATMOSPEHRIC DEPOSITION OF NITROGEN

We have applied a new stable isotope tracer (^{17}O) to estimate the flux of atmospherically deposited nitrogen to the flux of river N. Initial sampling of ground and surface waters indicates that atmospherically deposited nitrogen (A.D.N.) is significant in groundwater in forested areas. It may also be used to determine drinking well integrity in rural areas. When ^{17}O is high in drinking water wells, it indicates that the well is not properly constructed or maintained and surface rainwater is leaking down into the well with other contaminates. In river basins, discrete sampling indicates that A.D.N. is only significant in urban watersheds and makes up about 10% of the N flux. However, event sampling in one urban watershed indicates that over a storm event, approximately 23% of the N flux is due to A.D.N. (Figure 5). To properly evaluate the importance of atmospheric sources to river N flux, high-resolution sampling is required.

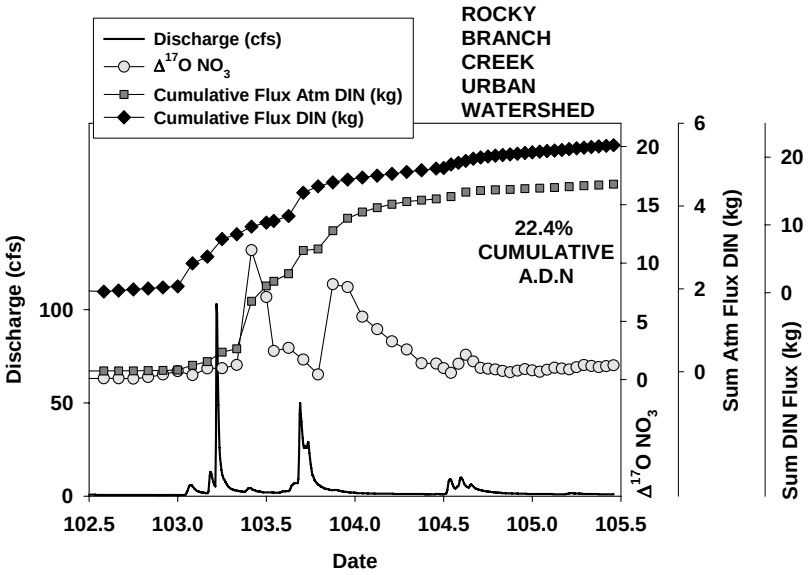

Figure 5. Atmospheric N flux in an urban watershed must be evaluated on an event basis. Discrete samples do not capture the falling discharge A.D.N. flux and underestimate the importance of atmospheric sources.

Future Directions for RiverNet: Watershed Nutrient Mapping

This year we have successfully tested and deployed the ISUS, a new optical UV sensor developed by Satlantic Inc. This UV sensor has the ability to make measurements of extremely

short duration over the period of seconds to minutes or hours. We have two units deployed in the Upper Neuse Basin and this year we will test the durability of the units. These units can be co-located with USGS gauging stations to accurately estimate nitrate flux in other river basins, and be used in watershed mapping projects to understand where contaminated groundwater is entering the river basins.

Summary:

RiverNet is a monitoring system that has significantly evolved and given researchers and water quality regulators a new understanding of fundamental processes affecting water quality on a watershed scale. At the present time we are combining RiverNet monitoring efforts with a new Piedmont Groundwater Observatory being installed at the Neuse River Waste Water Treatment Plant near Clayton NC. We are also mapping where contaminated groundwater enters the river with a new ISUS UV nitrate sensor. These efforts have so far proven to be very successful. These efforts will help design a remediation effort to protect river water quality. We are also in year #2 of an NSF funded program for the enhancement of diversity in Geosciences entitled "Enhancing Diversity in Geosciences in North Carolina". This is a collaborative effort between NCSU and NCA&T to recruit minority students to Geosciences graduate programs. Two NCSU undergraduates will be working with the RiverNet program this summer, and minority students from NCA&T and Robeson Community College will work in the program and with the Piedmont Hydrographic Observatory this summer and next fall.

Major findings of the program to date include:

- Nitrate and sediment concentrations in the Neuse River Basin change rapidly with and without stage changes. These variations are correlated to discharge and precipitation variations that are controlled by the ENSO (El Nino Southern Oscillation) cycle, which has a 5-7 year time period.
- Hourly RiverNet flux measurements are significantly more accurate than flux estimates made from daily concentration measurements. Daily flux estimates have a 10 to 40% error depending upon the location in the river basin.
- Measurement of groundwater nitrate fluxes with the RiverNet technology has shown that groundwater N additions are episodic with time periods of hours to days.
- Groundwater nitrate flux at the Raleigh WWTP is about 50% the nitrogen flux from the discharge pipe, demonstrating that N groundwater flux is important and cannot be ignored.
- New optical measurement techniques are less expensive than the chemical measurement techniques and will allow the RiverNet program to expand statewide for reasonable costs.
- Nutrient mapping on a watershed scale can identify where groundwater nitrate fluxes enter the river. The groundwater quality in these groundwater discharge zones has a direct effect upon surface water quality in these regions.
- Identification of the location and processes that discharge contaminated groundwater into the river is the crucial first step towards remediation of contaminated surface and ground waters.
- The importance of atmospheric N to river flux must be evaluated over storm events with high-resolution sampling, and not with discrete samples.

The progress towards watershed N flux and N mapping that the RiverNet program made this year is an important next step in evaluating and designing remediation strategies to protect our surface, estuarine and coastal water quality.

By wisely using state and national resources and by emphasizing results focused on the systematic application of research-based knowledge, we can expedite the timely resolution of

our water quality problems and protect our invaluable water resources without economic impairment. By combining research efforts with educational outreach programs, we can train the scientists, regulators and policy makers of the future. In the end we will improve the public's understanding of water resource issues and the essential social, economic, and environmental value of local water resources for all persons and sectors of society.