

EXECUTIVE SUMMARY **LEGISLATIVE REPORT** **2013**



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, and then provide data to help engineer cost effective solutions to reduce and mitigate the nutrient footprint of businesses, towns and municipalities.

BACKGROUND

The 2001 Session of the General Assembly appropriated funds 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. RiverNet expanded into the Cape Fear Basin in 2009, and \$286,500 was allocated to the program for operations in the 2013-14 period. The RiverNet Monitoring network has been operated over the past 13 years. During this past year we have employed novel nutrient mapping techniques in water supply lakes as well as critical "at-risk" rivers. RiverNet continues to monitor nitrate flux in the Neuse basin, and continuously operates 2 stations in the Cape Fear River Basin where municipalities and agribusinesses are located. Five stations are operating in the basin from Raleigh to Fort Barnwell, with one station in the Contentnea watershed, and four along the Neuse main stem (Figure 1). Two stations are also operating in the Cape Fear watershed on the Black River, and on the Haw River (Figure 1). Physical water quality property measurements with nitrate concentrations are made every 15 minutes. The data is transferred to a server on the NCSU campus via a digital cell network, and mounted on a web site for public access (<http://rivernet.ncsu.edu>). This monitoring will continue for the next year with nutrient mapping critical rivers and lakes. The nutrient mapping technology spatially quantifies

nitrate, pH, Eh, temperature, conductivity, Chl a, Phaeophytin, and CDOM in surface waters. During the past year nutrient maps were compiled in Lake Jordan and Falls Lake, which are drinking water sources for Cary and Raleigh, NC (Figure 7).

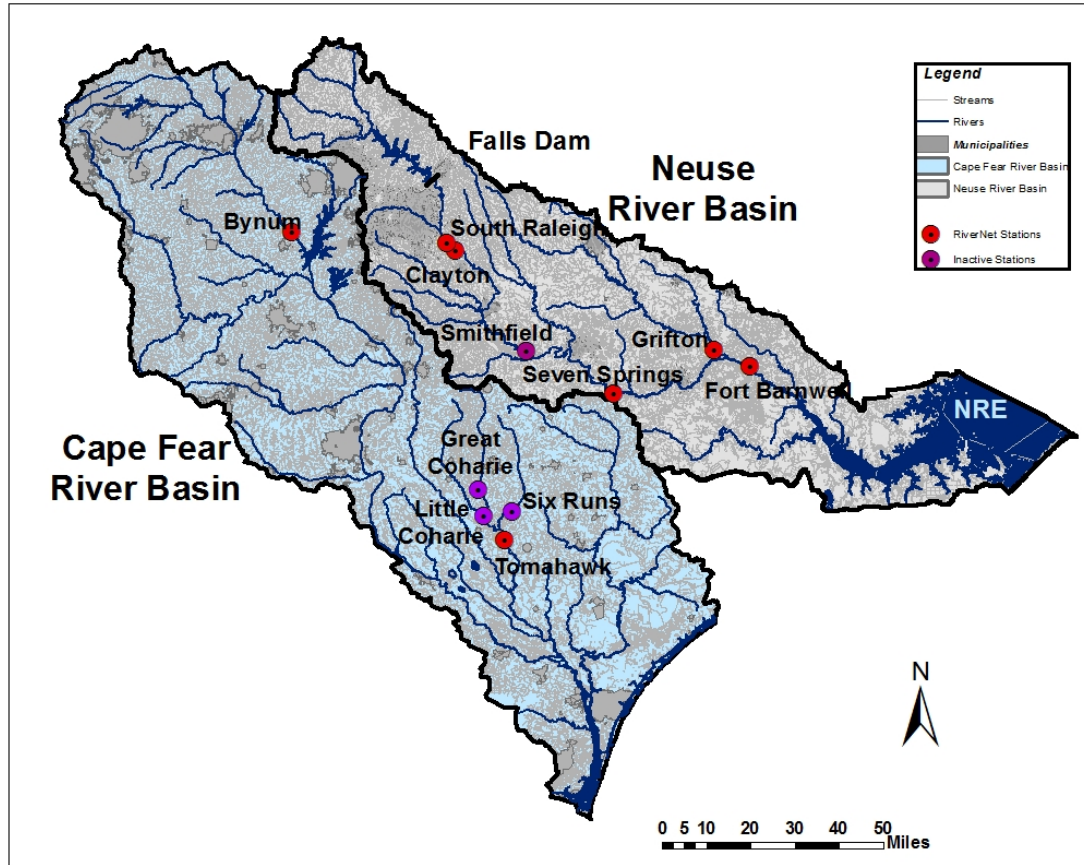


Figure 1. The RiverNet monitoring network with stations located in the Neuse and the Cape Fear River Basins. Stations will monitor water quality in the nutrient sensitive Neuse River Basin and on major rivers in the Cape Fear River Basin. One station was added in the Cape Fear above Jordan Lake, while three stations were damaged by Hurricane Irene in August 2011 and are inactive along with one Cape Fear Station that was vandalized in 2013.

RiverNet: RESULTS 2013

Summary:

Previous year's results have shown that there are very rapid nitrate concentration changes in the Neuse River in the upper, middle and lower basin. During the last year the ENSO and NAO climate oscillations were in neutral phases, and the nitrogen flux in the Neuse River Basin was average, similar to 2006, 2009 and 2012 which were also periods of neutral climate phases. Nitrate concentrations have been increasing in the Neuse River since the 2009 Warm phase, and fluxes during the neutral climate phases have increased since 2006. It is not likely that there will be water quality problems this summer in the Neuse River Estuary unless a storm event (hurricane) hits North Carolina, given these winter flux conditions.

Significance of Watershed Nitrogen Flux Measurements

To accurately measure nitrate flux to coastal waters, high temporal resolution nitrate concentration measurements must be compiled. The USGS compiles discharge measurements on a

15 minute time interval to capture hydrographic events produced by storm flows. The RiverNet Program has shown that this short time interval is also required to calculate accurate nitrogen flux measurements during storm events (Figure 2). A large proportion of the nitrogen flux to coastal waters occurs during these storm events. But discharge alone does not control water quality in North Carolina rivers, nitrogen flux is also modulated by climate oscillations. These climate oscillations vary over a 1 to ten year period, so long term monitoring programs like RiverNet are needed to understand the efficacy of new regulations.

The RiverNet program results indicate that the ENSO (El Nino Southern Oscillation) and the NAO (North Atlantic Climate Oscillation) modulates water quality in the Neuse River Basin and the downstream estuary (Figure 3). Nitrate flux increases with positive El Nino oscillations or warm water conditions in the equatorial Pacific. Warmer waters in the equatorial Pacific intensify the southern jet stream, which brings Gulf of Mexico moisture to North Carolina. This causes increased precipitation, higher groundwater elevations, and increased N flux in watersheds. North Carolina precipitation is also affected by the North Atlantic Oscillation. The North Atlantic oscillation (NAO) is a climatic phenomenon in the Atlantic Ocean that primarily affects northern Europe and Mediterranean climates. When the North Atlantic Oscillation index is positive, the westerly flow across the North Atlantic and Western Europe is enhanced. For North Carolina, in the NAO positive phase warm ocean waters occur off the eastern US, and rainfall is enhanced in our region. During the negative phase storm tracks are forced further south and northern Europe and the east coast of the US is dry. The surface waters of the South Atlantic Bight off the coast of North and South Carolina is cold yielding lesser amounts of rainfall to our region.

El Nino or warm central Pacific conditions occurred in 2002, 2006, 2009 and 2012 (Figure 3). Highest annual nitrate fluxes to coastal North Carolina with degraded water quality conditions occurred after these events. The magnitude of flux and water quality degradation correlates to the strength and duration of the El Nino event and the position of the NAO phase. The largest nitrate flux to coastal waters occurred after the 2009-10 El Nino event which had a long duration with a positive NAO phase (Figure 2). In 2012 a small warm event occurred in the equatorial Pacific, but

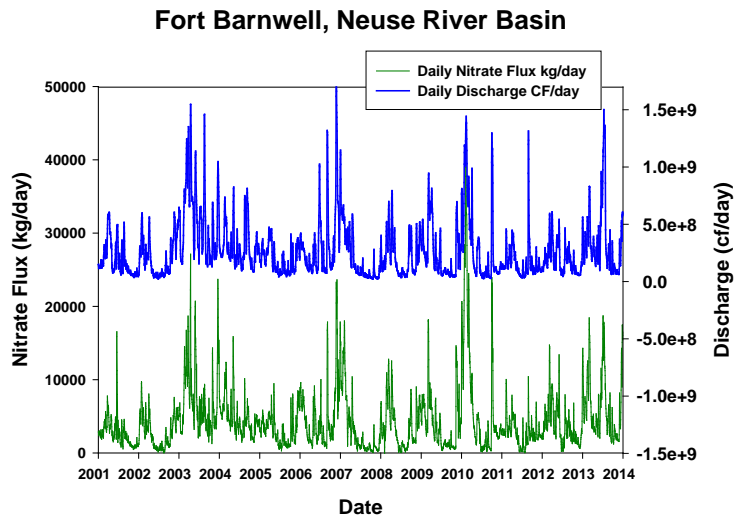


Figure 2. Daily discharge and Monthly N flux at Fort Barnwell North Carolina at the bottom of the Neuse River Basin. This graph represents over 461,000 individual measurements at this one station.

the NAO was in a negative phase and nitrate flux in the basin was low, similar to the 2002 event (Figure 3). However, if the El Niño index and the NAO stay in a neutral phase increases, fluxes will be average during 2014.

WATER QUALITY FORECAST FOR 2014

Legislative committees and NC voters have asked “why are there good and bad water quality years”? Is water quality improving or degrading in the Neuse Basin, which had massive fish kills in the 1990’s? High nitrate fluxes and bad or good water quality years correlate with the ENSO (El Niño – warm and La Niña – cold) 3-5 year oscillations modulated by the North Atlantic Oscillation (3 to 6 months). To compare water quality between different years, similar climatic states must be compared. This is why long term high resolution data sets like the RiverNet program are important and need to be continued. There are two indications that water quality conditions in the Neuse are not getting better so that high resolution monitoring needs to continue. The average nitrate concentrations in the basin have increased over the past decade in a stepwise fashion (Figure 4). Concentrations were lower prior to 2005, increased from 2005 to 2009, and then have increased again in the 2010 to 2014 period. The large nitrate flux of 2010 in the Neuse Basin was associated with a strong El Niño event in the Pacific Ocean, and with increased discharge in the basin (Figure 5). The cold climate phases show better water quality conditions and lower discharge levels, so the climate oscillation effects are well illustrated by comparing the discharge, nitrate flux, and El Niño Index (Figures 5). Basin wide fluxes during neutral phases have increased since 2006, indicating the importance of these ongoing monitoring efforts.

Climate Variations and Nitrate Flux

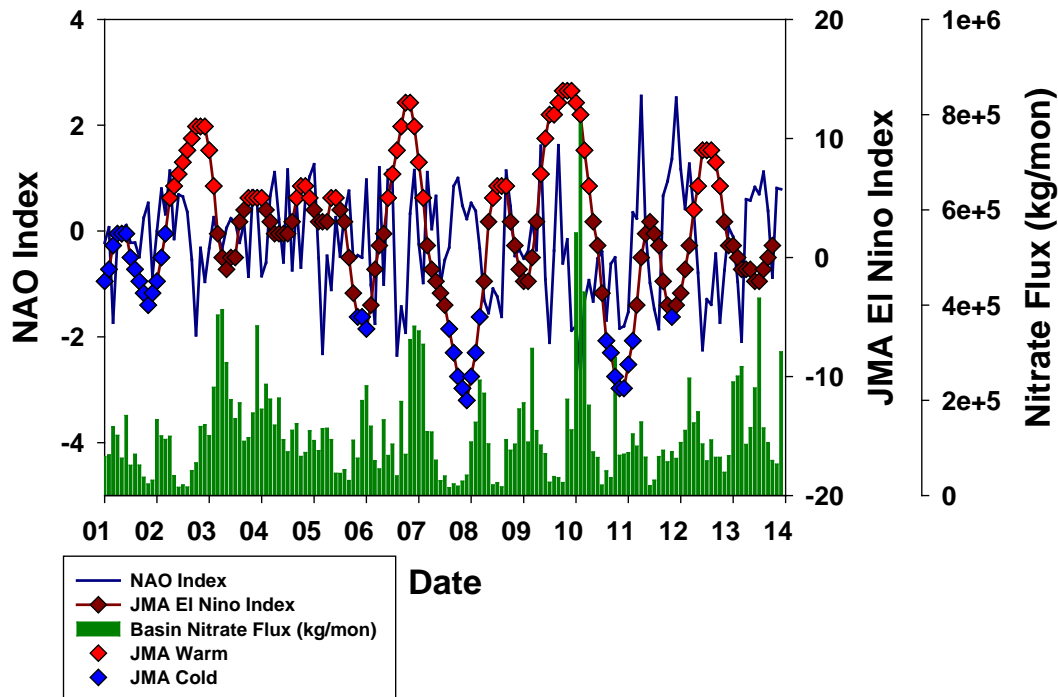


Figure 3. Monthly N flux at Fort Barnwell North Carolina versus nitrate concentration. Nitrate concentration is a poor predictor of water quality trends, but nitrate concentrations in the lower Neuse have increased over the past decade with the highest values observed after 2010.

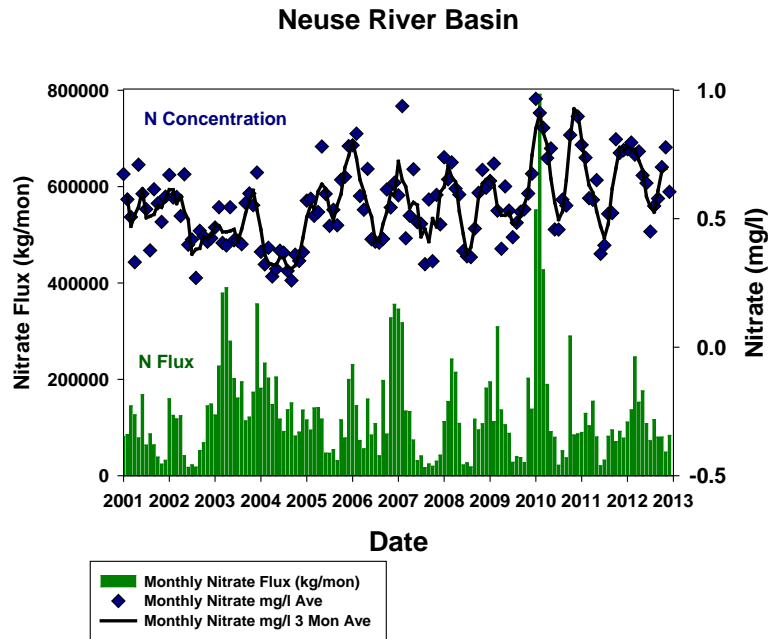


Figure 4. Monthly N flux at Fort Barnwell North Carolina versus nitrate concentration. Nitrate concentration is a poor predictor of water quality trends, but nitrate concentrations in the lower Neuse have increased over the past decade with the highest values observed after 2010.

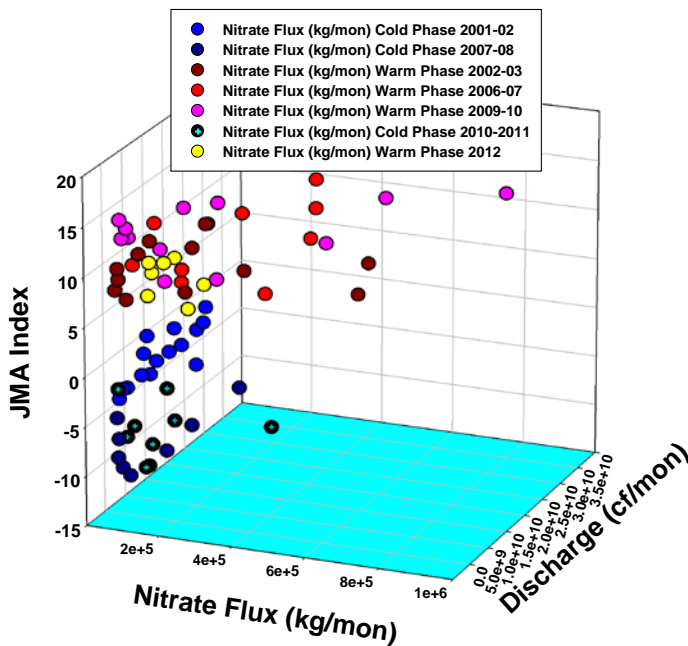


Figure 5. Monthly N flux at Fort Barnwell North Carolina versus Discharge and the El Nino climate index plotted versus warm, neutral and cold years. Highest fluxes are observed during the warm years.

MONITORING IN THE CAPE FEAR RIVER BASIN

River Nutrient Mapping

Four RiverNet Stations have been operated in the Cape Fear #19 sub-basin for the past 2 years in a predominately agricultural basin (Figure 5). Two stations were damaged by Hurricane Irene and one station (Great Cohaire) was vandalized in 2013. These stations have been discontinued in 2014, and a new station is being installed in a secure location at Bynum on the Haw River to support the Lake Jordan nutrient mapping efforts in 2014.

In the Cape Fear, watershed nutrient mapping completed in rivers and in lakes (Figure 5, 6) indicates that wetlands control river nitrate levels, not proximity to swine CAFO's or other agribusinesses. Increases in river nitrate in the Little and Great Coharie Creeks are found near artificial tile drain systems and near cattle facilities that do not have riparian buffers. Swine operations in this watershed have hydric buffers and do not appear to affect the river nitrate levels except near tile drains. High spatial resolution mapping shows the importance of hydric soils, and suggests that engineered hydric buffers could protect water quality when natural hydric buffers are absent, or have been modified by deforestation or other land use changes.

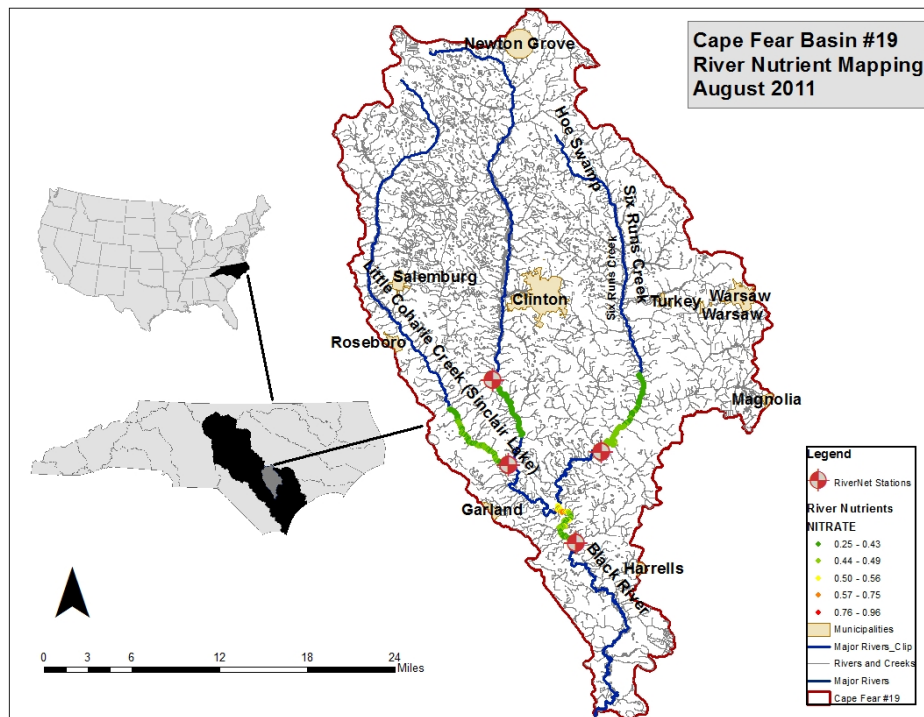


Figure 5. Nutrient watershed mapping sites in the Cape Fear sub-basin #19 during low flow conditions.



Figure 6. Nutrient mapping in rivers (kayak) and drinking water reservoirs (boat in Falls Lake).

Lake/Reservoir Nutrient Mapping

We had adapted the nutrient mapping technology to a small boat to efficiently map nutrients in lakes that serve as drinking water reservoirs for North Carolina (Figure 6). Over the past year we have upgraded to optical instruments so that Temperature, conductivity, pH, Chl a, Phaeophytin, DO, and CDOM (dissolved organic carbon) can be measured with high spatial resolution (10 meters, or measurements every 5 seconds). The advantage of making multiple measurements with high spatial resolution is that biological and chemical data can be spatially associated and differentiated on a large scale.

Nitrate is elevated in the lower portion of Lake Jordan at the Haw River inlet during the spring and summer months, but Chl a blooms are prevalent in the upper portion of the lake (Figure 7). Dissolved organic matter is also high in the upper portion of the lake's surface waters (which we measure as CDOM, the optically active portion of dissolved organic matter - DOM). DOM accumulates in the deeper portion of the lower lakes and is a problem for treatment of lake waters for drinking in the fall when the lake overturns and deep waters that accumulate CDOM rise to the surface of the lake. But the spatial relationships are not well understood, and high resolution mapping needs to be completed on a seasonal basis to understand nutrient cycling in these lakes. Preliminary data from Falls Lake indicates nutrient inputs from bottom sediment exceeds nutrient inputs from surface waters.

During the next year, Rivernet will collaborate with the USGS Raleigh office to investigate nutrient sources in the Haw River Basin. Nutrient sources in the Haw River will be identified with stable nitrogen isotopes, and critical portions of the Haw will have nutrient mapping completed during high and low flow conditions.

This will ensure that the wrong parties are not blamed for water quality problems, and the solutions employed will be cost effective in protecting our water resources.

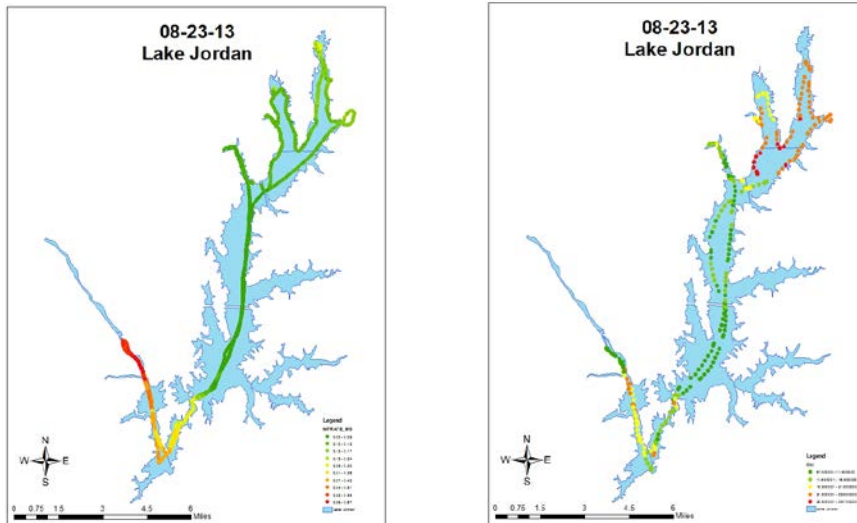


Figure 7. Nutrient maps of Jordan Lake August 2013 for nitrate (left), Chl a (right) Nutrient inputs are highest from the Haw River, but Chl a concentrations are elevated in the shallow northern portions of the lake. Nutrient recycling from bottom sediments may be important in the upper portions of Jordan Lake.

Summary:

RiverNet is a river water quality monitoring system that has significantly evolved and given researchers, policy makers, and water quality regulators a new understanding of fundamental processes affecting water quality on a watershed scale. RiverNet data is used by government policy makers, regulators, scientists, environmentalists, and the general public, especially fishermen and communities that live along the river. At the present time we are combining RiverNet monitoring efforts with the USGS to look at nutrient inputs in Jordan Lake and the Haw River. These nutrient mapping efforts in drinking water reservoirs will support efforts to treat nutrient loads in the lake (*in situ*). The newly redesigned web pages makes this data available to university and government researchers, students, the general public, and policy makers in real time (Figure 8). These efforts have so far proven to be very successful in understanding nitrogen transport across landscapes and will aid in efforts to design treatment wetlands and flood buffers to remediate contaminated surface and groundwater nitrate entering our river basins in order to better protect our water resources and water quality.



RiverNet is designed to bring you the latest information on the water quality in select rivers of North Carolina.

Led by Dr. William J. Showers at North Carolina State University's Department of Marine, Earth and Atmospheric Sciences, RiverNet is a program that is designed to understand nitrogen fluxes in watersheds with different land uses. This is achieved through the continual collection of different types of water quality data in an effort to provide the information needed to promote the long-term sustainability of natural and managed watersheds and to develop successful remediation strategies.

Most Recent Data

Neuse River

CLAYTON
FORT BARNWELL
GRIFTON
SEVEN SPRINGS
SMITHFIELD
AUBURN-KNIGHTDALE

date	time	depth (ft)	pH	Nitrate (mg/L)		
January	26	05:00:00	1.846	6.280	1.382	graphs / archive
January	26	05:15:00	4.451	6.190	0.758	graphs / archive
January	26	05:00:00	12.460	5.850	0.808	graphs / archive
January	26	05:15:00	1.967	6.340	0.840	graphs / archive
January	26	05:15:00	3.121	6.560	0.675	graphs / archive
January	26	05:00:00	2.701	6.290	0.531	graphs / archive

Cape Fear River

GREAT COHARIE
LITTLE COHARIE
SIX RUNS
TOMAHAWK

date	time	depth (ft)	pH	Nitrate (mg/L)		
January	26	05:45:00	5.25	6.3	0.676	graphs / archive
January	26	05:45:00	2.32	6.17	0.832	graphs / archive
January	26	05:30:00	5.05	5.84	1.308	graphs / archive
January	26	05:30:00	5.105	7.09	1.002	graphs / archive

NCSU RiverNet Program | North Carolina State University | 1125 Jordan Hall, NC State University, Raleigh, NC 27695 | Director: [Dr. William J. Showers](#)

Figure 8. The redesigned web page allows easy access to the data generated by this project.

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 large scale climate cycles. These climate cycles are the El Nino/La Nina oscillation, which has a 5-7 years time period, modulated by the NAO (North Atlantic Oscillation) which has a 1-2 year cycle. These climate cycles must be considered when planning for water quality and water availability. Nitrate concentrations are increasing in the Neuse River Basin over the past decade and fluxes during the comparable different warm and cold phases are getting larger.
- 15 minute RiverNet flux measurements are significantly more accurate than flux estimates made from daily concentration measurements because they take into account the natural nitrate concentration and discharge variations of hydrographic storm events and wastewater treatment plant conditions. Daily flux estimates have a 10 to 40% error depending upon the location in the river basin.
- Watershed nutrient fluxes in the Neuse River basin are slowly increasing in

periods with similar climate index oscillations. Average nitrate concentrations are also increasing over time.

- River nutrient mapping can identify watershed areas that would benefit from constructed wetlands to protect water quality. This technology is now being employed by Smithfield Foods to reduce the nutrient footprint of swine CAFO's by treating tile drain discharges in Waverly, VA. If successful this technology can be employed at low cost in North Carolina.
- Nutrient mapping on a watershed scale can identify where contaminated surface and groundwater enters the river. The groundwater quality in these groundwater discharge zones has a direct effect upon surface water quality downstream from these regions.
- Nutrient mapping in lakes and drinking water reservoirs can identify sources and location of nutrient inputs and lake dynamics as the "biological cascade" stimulates biological productivity and biomass production. Identification of the nutrient inputs and subsequent impact on lake chemistry is crucial to remediation of contamination sources.
- 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.
- New optical technology can make Chl a and CDOM mapping possible with nitrate concentrations to define reach and reservoir characteristics that can be related to pollution source. These sources are dynamic and change with space and time, so high resolution data is required to identify and remediate these problems.

The progress towards watershed N flux and N mapping that the RiverNet program made this past year will be employed over the next year in two Triangle area drinking water reservoirs. 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 and grow our state's economy without environmental impairment. By combining research efforts with industry and with educational outreach programs, we can train the scientists, regulators and policy makers of the future. In the end we will protect the environment and business development, and 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.