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. RiverNet expanded into the Cape Fear Basin in 2010 and $286,500 was allocated to the program for this period. The RiverNet Monitoring network has been operated over the past 10 years. During this past year we have employed novel river nutrient mapping techniques in other areas that was first used to measure groundwater fluxes and deep groundwater flow paths transporting biosolid nitrogen into the river at the Neuse River Wastewater Treatment Plant. This year we continue monitoring in the Neuse basin, and installed 4 stations in the Cape Fear River Basin to monitor water quality in a concentrated swine CAFO area. Six stations are operating in the basin from Raleigh to Fort Barnwell, with one station in the Contentnea watershed, and five are along the Neuse main stem (Figure 1). Four stations are operating in the Six Runs Creek, the Great and the Lesser Coharie watersheds in Sampson County (Figure 1). Physical water quality property measurements with nitrate concentrations are made every 15 minutes. The data is transferred to a server at the NCSU Raleigh 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 watershed mapping in the Neuse and Cape Fear Watersheds.

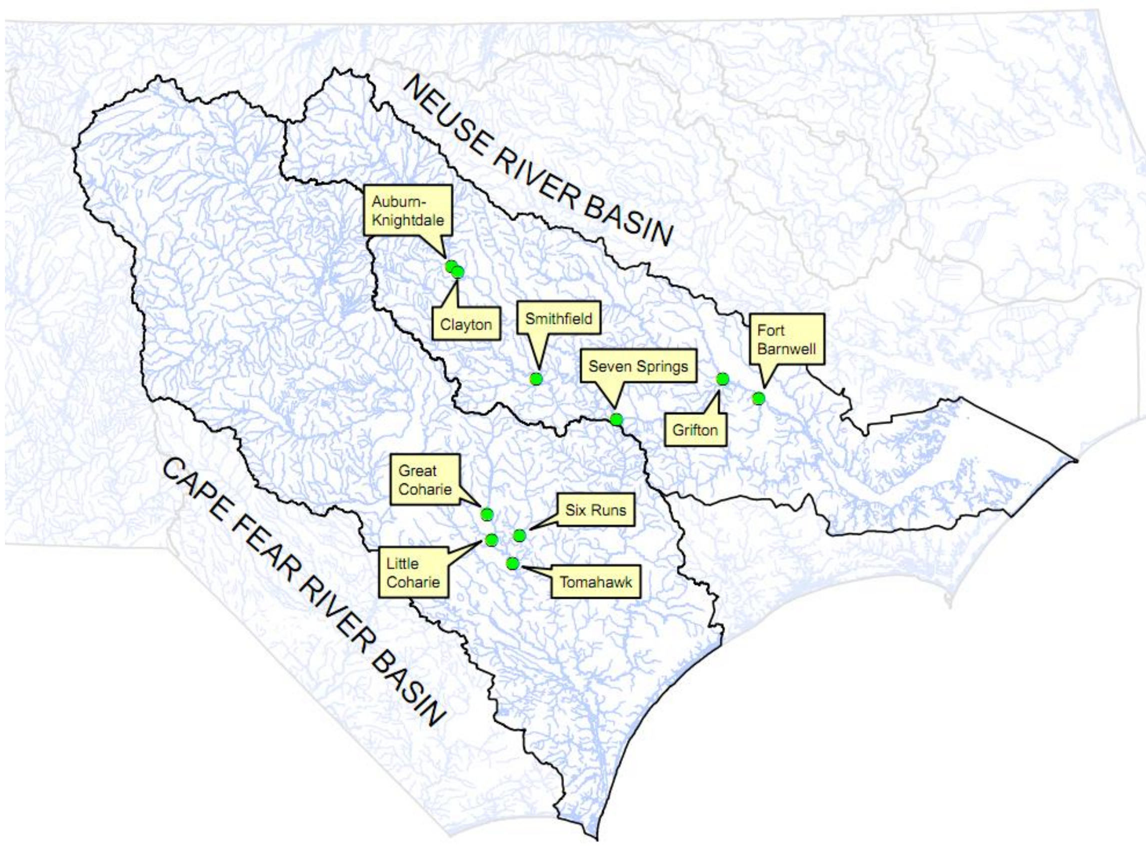

Figure 1. The RiverNet monitoring network with stations located in the Neuse and the Cape Fear River Basins. Stations will monitor water quality in the nutrient sensitive Neuse River Basin and on the major rivers in sub-basin #19 in the Cape Fear River Basin. There are 7 municipal waste water treatment facilities in the basin with a concentration of swine CAFO's at this location with a design capacity of 1.6 million animals.

RiverNet: Results 2010

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. In 2006 an El Nino began to build in the equatorial Pacific that peaked in fall 2006. The 2006 El Nino event and was slightly larger in magnitude than the 2003 El Nino event, and has been followed by the cold phase La Nina that continues to decrease temperatures in the equatorial Pacific. In 2007, the N flux in the Neuse Basin increased with discharge levels similar to the fluxes observed in 2003 (Figure 2). In 2007 the El Nino transitioned in late spring to the La Nina cold phase and fluxes dramatically decreased. There has not been a significant La Nina event since 1975, so the extent of the La Nina effects is not well known. The cold phase in the summer of 2007 resulted in a drought over the entire SE United States. Rainfall has decreased, and river discharge, groundwater levels, and N flux fell in the second half of 2007. In 2010 a significant La Nina cold phase developed with a low NAO index, and precipitation and river discharge has been very low with N flux (Figure 2). Over the past ten years there is an overall trend of increased N flux in the Neuse River basin, and the inter-annual N flux variations are significant and are related to large scale climate oscillations. Nitrate concentration in the river is a poor predictor of water quality trends (Figure 3). However, in 2010 both flux and concentration began to rise in the Neuse River basin Flux measurements are better indicators of potential eutrophication events in the NRE estuary and coastal waters, but flux/concentration relationships have changed since 2006 and again in 2010 (Figure 3).

The two large scale climate oscillations that affect North Carolina precipitation and hydrology are El Nino and the North Atlantic Oscillation. Nitrate flux increases with positive El Nino oscillations. 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 where conditions are controlled by the difference of sea-level pressure between the Icelandic Low and the Azores high. This difference controls the strength and direction of westerly

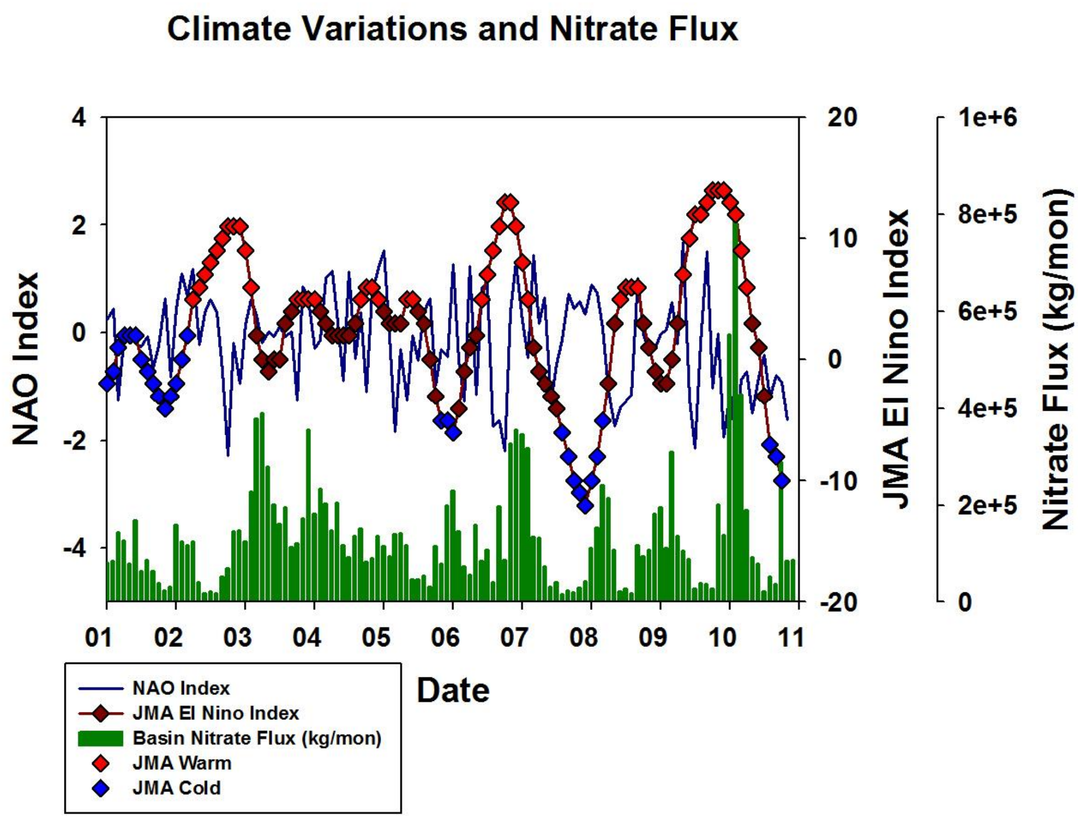

Figure 2. Daily discharge and Monthly N flux at Fort Barnwell North Carolina at the bottom of the Neuse River Basin. This graph represents over 178,000 individual measurements at this one station.

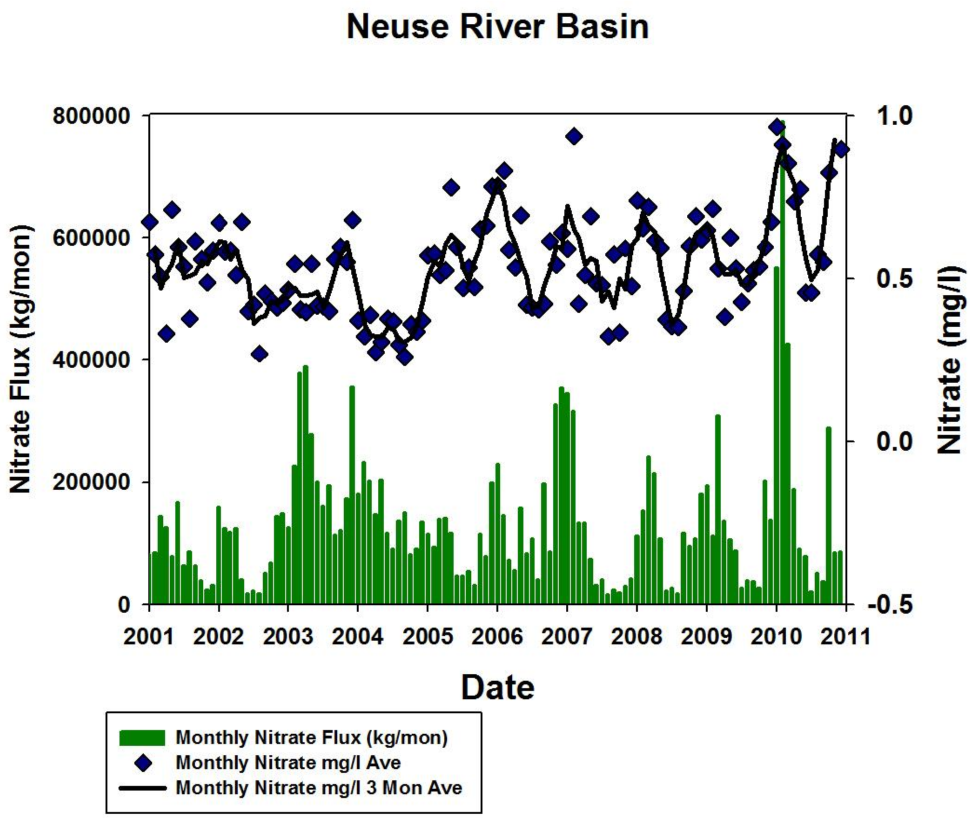

Figure 3. Monthly N flux at Fort Barnwell North Carolina versus nitrate concentration. Nitrate concentration is a poor predictor of water quality trends, during high flux periods concentrations tend to be lower that during low flux intervals.

winds and storm tracks across the North Atlantic. When the North Atlantic Oscillation Index is positive, the westerly flow across the North Atlantic and western Europe is enhanced. In this NAO 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 climate oscillation effects are well illustrated by comparing the discharge, nitrate flux, and JMA El Nino Index (Figures 4). When nitrate flux per year is plotted, there is no apparent

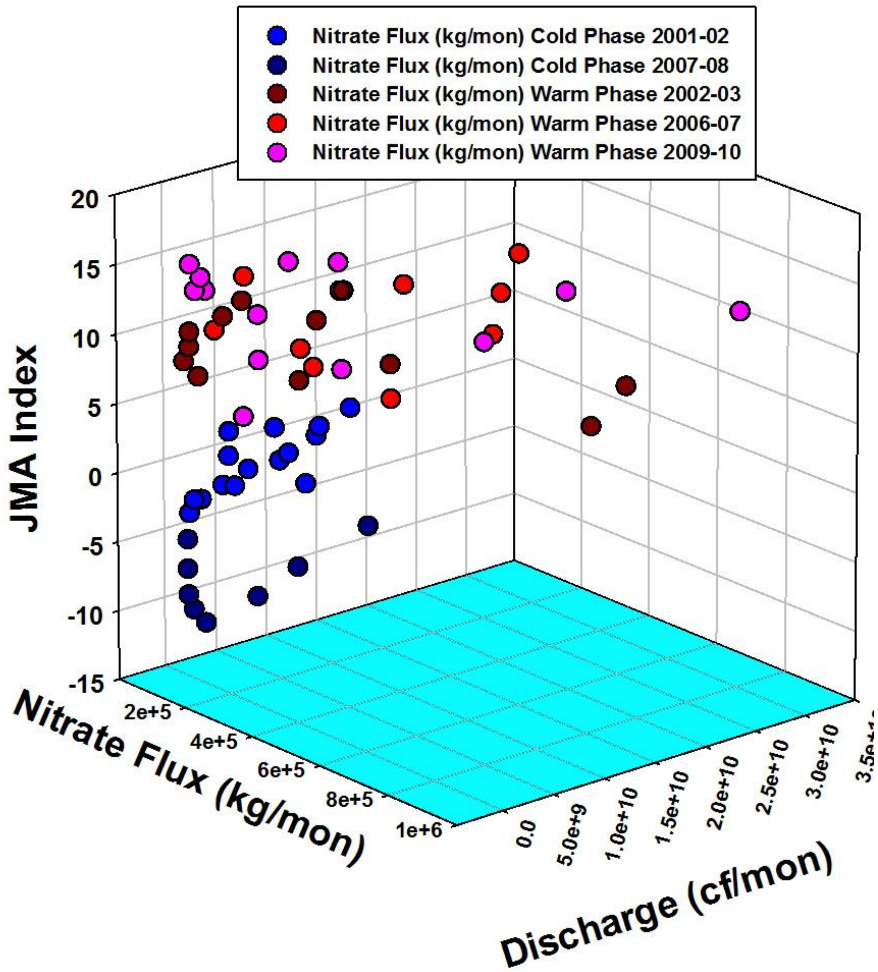

Figure 4. Monthly N flux at Fort Barnwell North Carolina versus Discharge and the El Nino climate index plotted versus warm, neutral and cold years. Highest fluxes are observed during the warm years. N Fluxes for the 2009-10 El Nino events is greater than the 2006 event.

trend, but when the nitrate flux is plotted for the warm, neutral and cold phases, the differences are apparent (Figure 4). There is also a difference in the warm high nitrate fluxes over the last decade. The 2010 warm period had highest basin-wide N Fluxes observed since 2001 similar to the 2003 warm period (Figure 5). This change in warm phase fluxes coincides with the change in concentration and flux relationship (Figure 3).

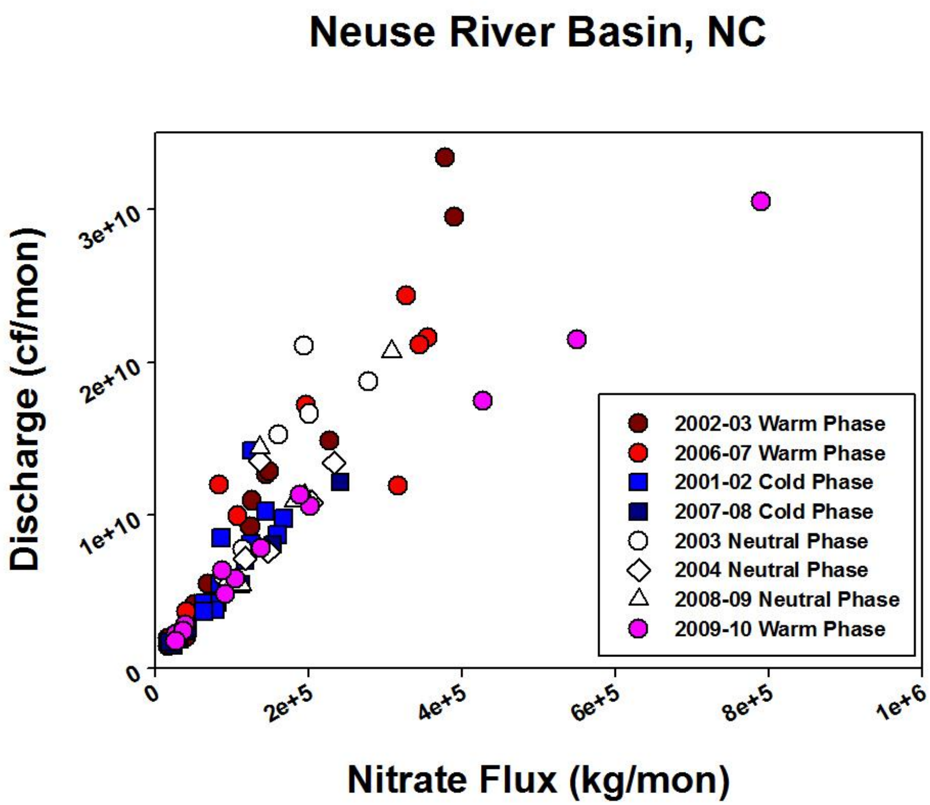

Figure 5. Monthly N flux at Fort Barnwell North Carolina versus Discharge plotted against warm, neutral and cold years with the pre- and post-2006 warm phases separated. Highest fluxes occur in the 2010 El Nino event indicating that when like climate phase fluxes are examined, water quality is changing in the Neuse River Basin.

MONITORING IN THE CAPE FEAR RIVER BASIN

Four RiverNet Stations have been operated in the Cape Fear #19 sub-basin for the past 6 months (Figure 1). Watershed nutrient mapping has also been completed in the Little Coharie Creek, Great Coharie Creek, Six Runs Creek, and the Black River near Tomahawk (Figure 6). Increases in river nitrate in the Great Coharie Creek have the highest concentrations during low flow conditions (Figure 7). These increases in nitrate concentration are associated with cattle operations that do not have hydric buffers. Swine operations in this watershed have hydric buffers and do not appear to affect the river at low flow conditions. Monitoring during high flow conditions must be completed before any definitive conclusions can be reached on the importance of the presence or absence of hydric buffers to protect river water quality in this region.

Stable isotope results of riverine nitrate indicate that waste nitrogen dominate the sources of nutrients to the Cape Fear sub-basin #19 (Figure 8). Fecal Coliform bacteria are found in all samples, sources include municipal waste treatment plants, farm CAFO’s (cattle, poultry, and swine), and wildlife/waterfowl. Concentrations are not high enough for MDNA source identifications. We are currently looking at organic content of the dissolved CDOM to differentiate sources (Figure 9). These data compared to the isotopic composition of river nitrate and the other water quality parameters are unique for different reaches of the river reflecting sources of pollution to the river. Different types of dissolved organic matter fluoresce at different wavelengths (Figures 9 & 10), but results from the Cape Fear #19 sub-basin during low flow conditions show terrestrial

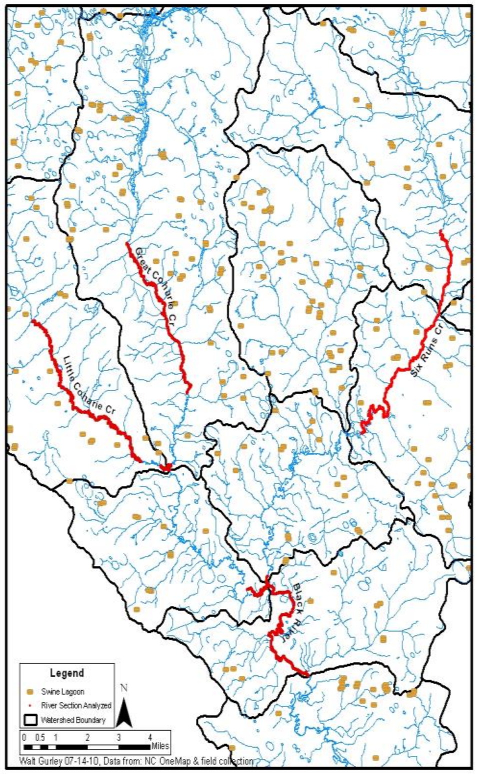

Figure 6. Nutrient watershed mapping sites in the Cape Fear sub-basin #19 during low flow conditions.

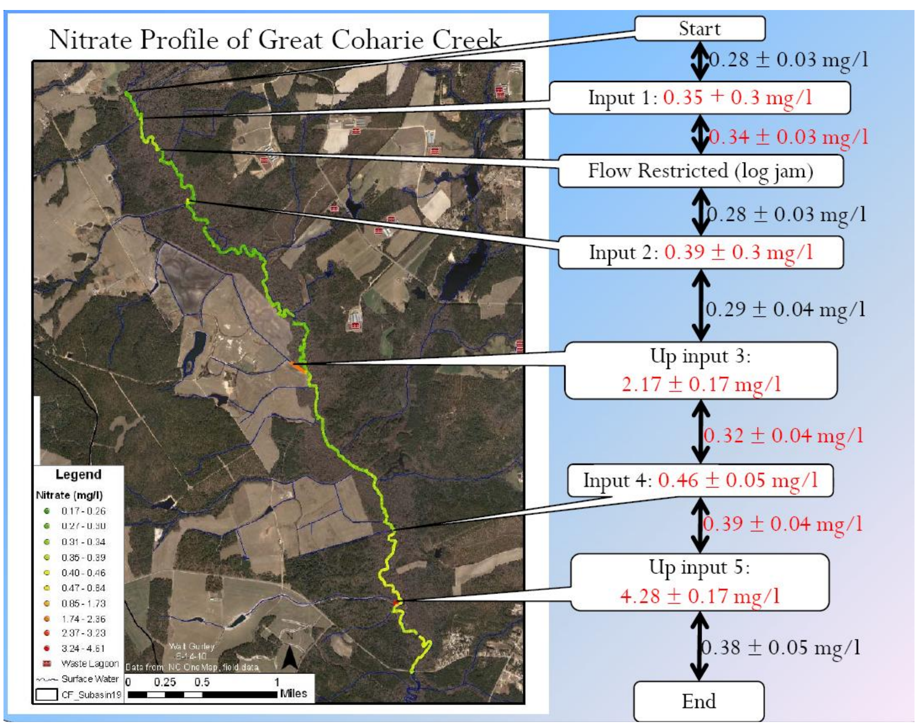

Figure 7. Nitrate concentrations in the Great Coharie Creek during low flow conditions. Increases in river nitrate are associated with cattle operations that do not have hydric buffers. Swine operations that have hydric buffers do not increase nitrate concentrations during low flow conditions.

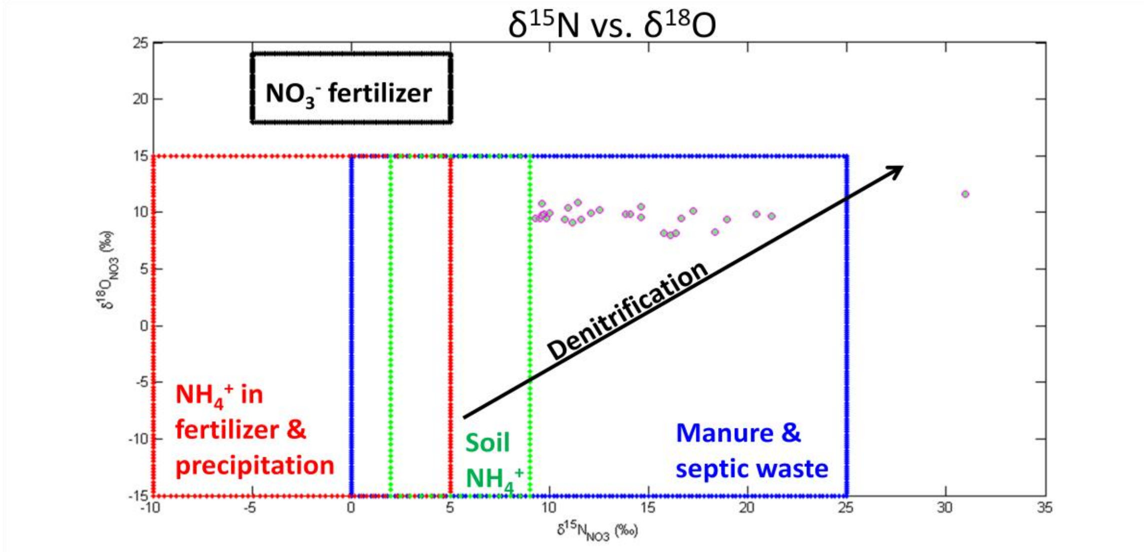

Figure 8. Nitrate isotopic composition of the river water in the Cape Fear #19 river basin, this data indicates waste sources dominates riverine nitrate.

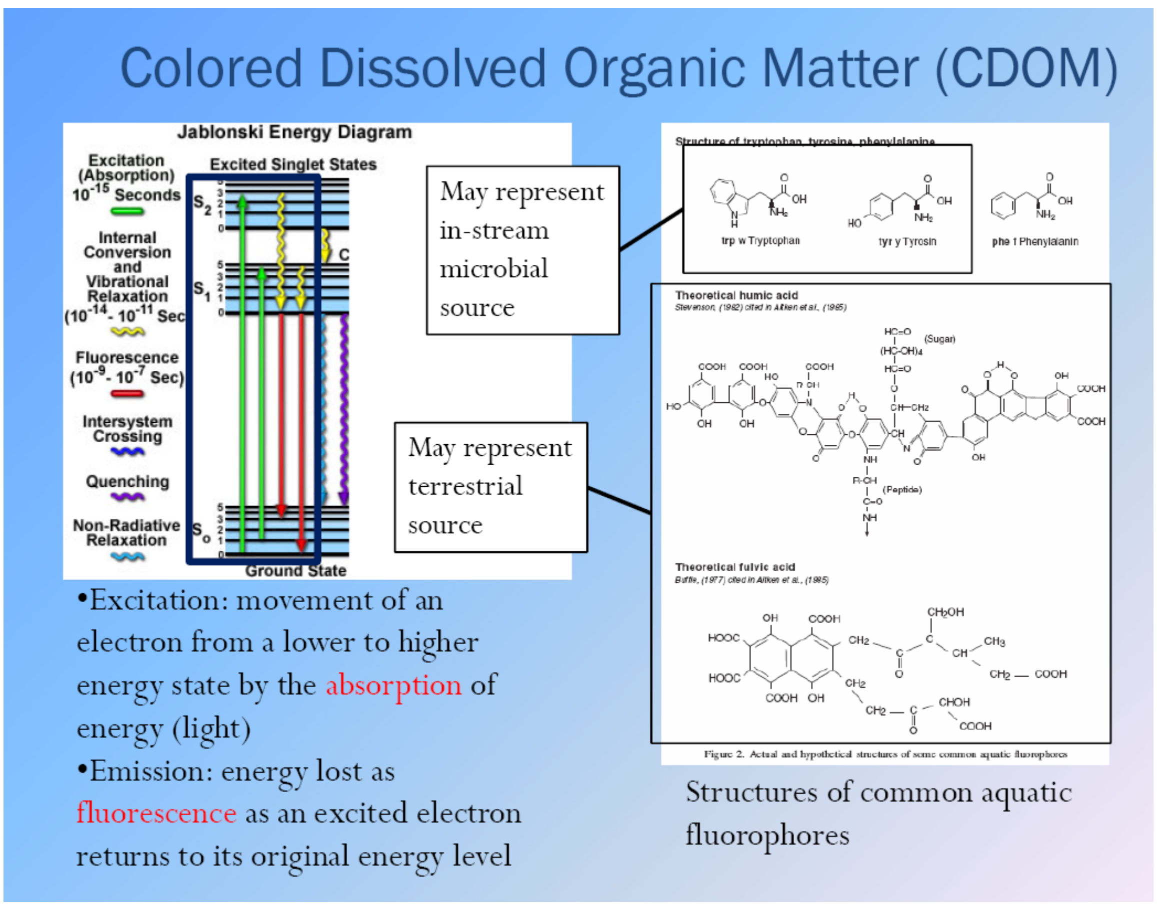

Figure 9. Fluorescence of CDOM can differentiate between difference materials

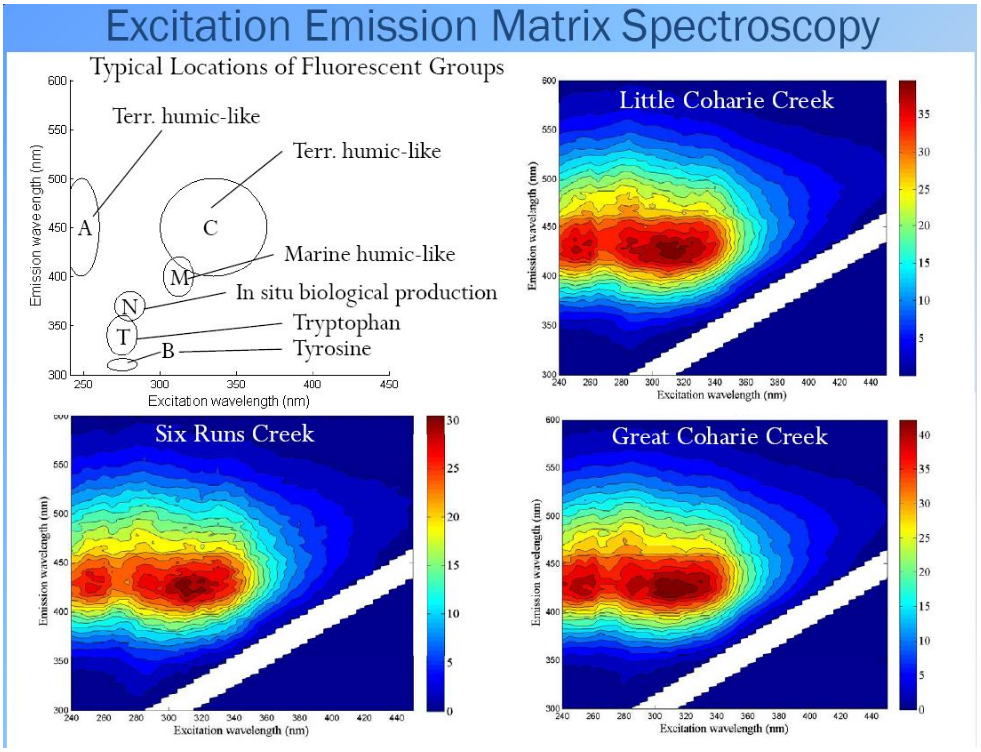

Figure 10. Fluorescence results from Cape Fear #19 sub-basin. The T & B peaks that would indicate animal waste flowing into the river are not prevalent during low flow conditions.

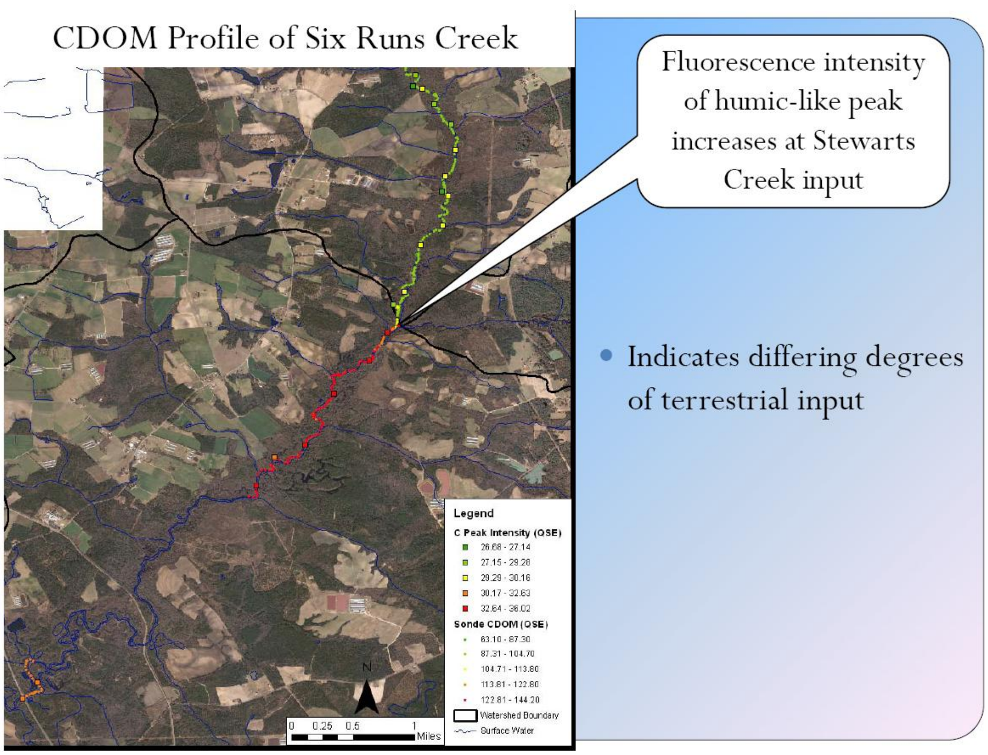

Figure 11. Fluorescence mapping in 6 Runs Creek during low flow conditions.

and microbial sources, but not protein sources associated with animal waste (Figure 10). When CDOM concentrations are mapped in the river, different reaches have different characteristic and water quality parameter associations which are related to river flow and groundwater inputs (Figure 11). Mapping at high flow conditions must be completed when the river flow increases as the La Nina climate oscillation ends during the Spring/Summer of 2011.

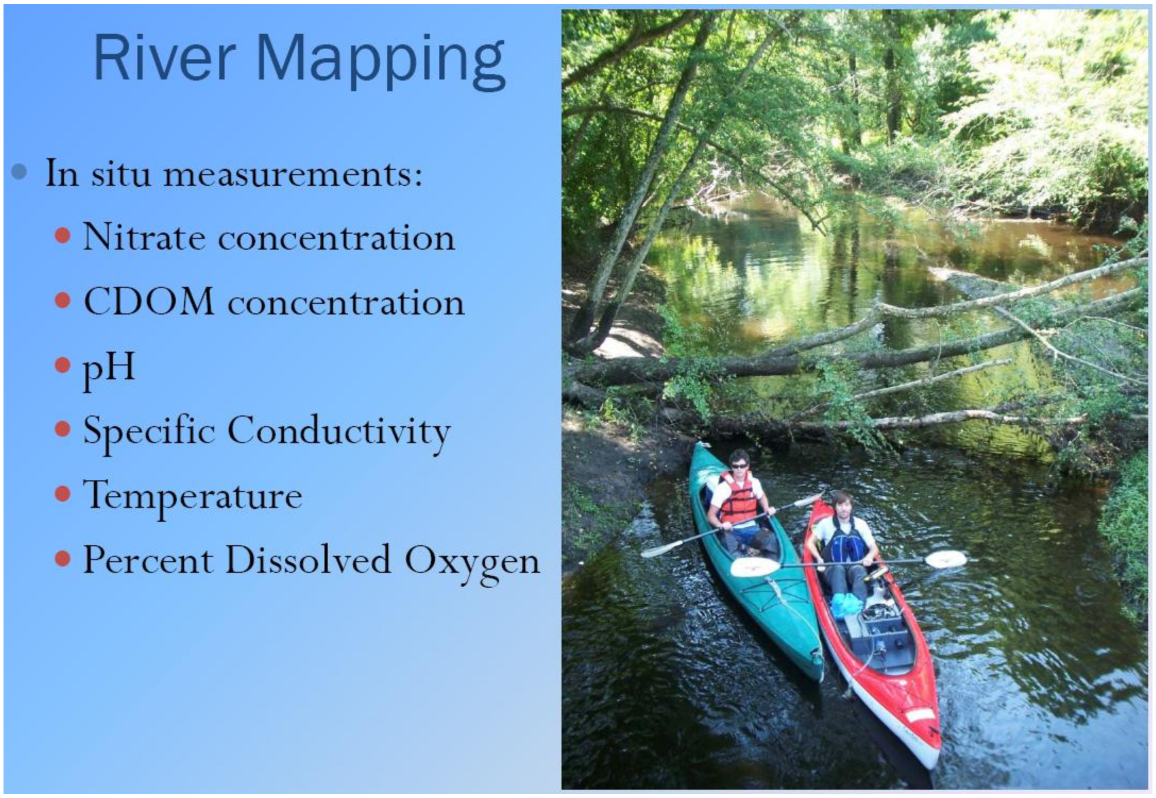

Figure 12. Students and RiverNet staff getting ready to make a mapping run down the Little Coharie Creek during the summer of 2010.

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. At the present time we are combining RiverNet monitoring efforts with the USGS/NC DENR Piedmont Groundwater Observatory at the Neuse River Waste Water Treatment Plant near Clayton NC to understand groundwater nitrate fluxes into the Neuse River. We are also mapping where contaminated groundwater enters the river with a new optical sensors that can measure a variety of water quality parameters such as nitrate, CDOM, and different chemical species. 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 13). 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.

RIVER NET

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

	date		time	depth (ft)	pH	Nitrate (mg/L)	
CLAYTON	January	26	05:00:00	1.846	6.260	1.382	graphs / archive
FORT BARNWELL	January	26	05:15:00	4.451	6.190	0.758	graphs / archive
GRIFTON	January	26	05:00:00	12.480	5.850	0.808	graphs / archive
SEVEN SPRINGS	January	26	05:15:00	1.967	6.340	0.840	graphs / archive
SMITHFIELD	January	26	05:15:00	3.121	6.560	0.675	graphs / archive
AUBURN-KNIGHTDALE	January	26	05:00:00	2.701	6.290	0.531	graphs / archive

Cape Fear River

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

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Figure 13. 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 flux during warm phases is increasing in the Neuse River Basin over the past decade.
- 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.

- Measurement of surface and groundwater nitrate fluxes with the RiverNet technology has shown that groundwater N additions are episodic with time and space and cannot be understood or mapped without high resolution spatial and temporal data.
- Because of this project, remediation wetlands have been installed at the City of Raleigh Neuse River Waste Water Treatment plant, and can reduce about one half of the flux to the Neuse River via surface streams. On-going monitoring will assess the full effect of this engineering step to fix a problem that was unknown before the RiverNet Program.
- New optical measurement techniques are less expensive than the chemical measurement techniques and will allow the RiverNet program to map nitrate, Chl a and CDOM on a basin or reservoir scale. This next year we will map the Neuse Basin, sub-basin #19 in the Cape Fear, and Falls and Jordan Lakes (Figure 15).
- 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.
- 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 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.

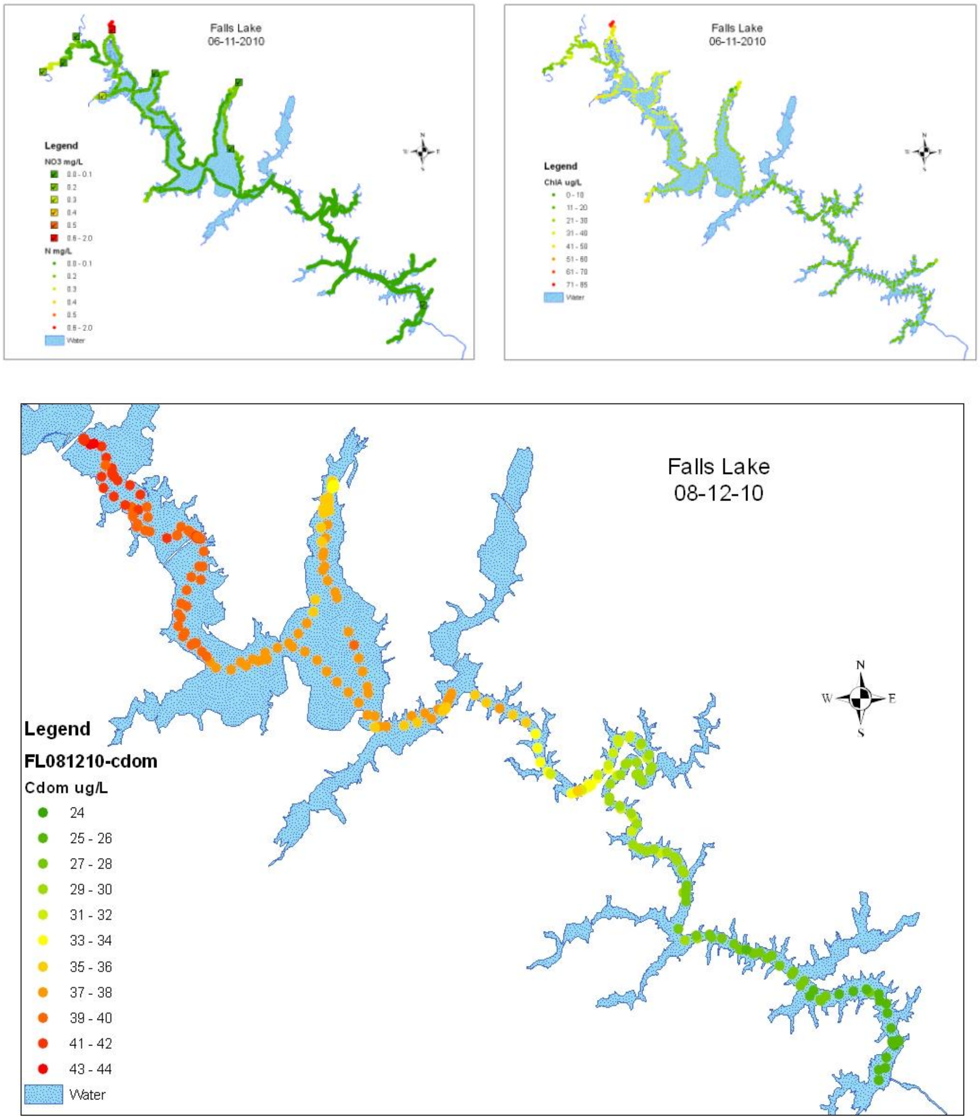

Figure 14. Falls Lake Nitrate and Chl a concentrations. During the spring and summer months, nitrate and Chl a are high in the upper portion of the lake, but in the winter months nitrate is high in some tributaries in the lower portion of the lake. With the new optical mapping technology, dissolved organic matter can also be mapped in surface and bottom waters to understand how the "biological cascade" affects drinking water at the Raleigh water intake at the bottom of the lake.