Relation of Watershed Setting & Stream Nutrient Yields At Selected Sites in Central & Eastern NC, 1987-2008

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US Geological Survey

Monitor Track
Berne Room
3:15-3:45pm

Albemarle-Pamlico Ecosystem Symposium
Embarking on a New Voyage

Relation of watershed setting and stream nutrient yields at selected sites in central and eastern North Carolina, 1997-2008

Cooperative study between NCDENR DWR and USGS

Final project report published online in May 2013

Acknowledgments

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Statement of Need

- In evaluating potential limitations to NSW management strategies for the Neuse and Tar-Pamlico River basins, DWR identified additional information needed to support further development and implementation of the strategies
  - Primary need to further document nutrient loads in basins in eastern NC, including smaller watersheds having dominant land uses (ie, urban and agriculture)
  - Development of approaches for identifying watersheds that are most likely to export nutrients
- Study initiated in 2009 to better understand the relations between various watershed settings and nutrient yields in streams throughout central and eastern North Carolina

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Study Objectives

- Primary purpose of report was to summarize and synthesize nutrient yield data compiled for 48 stream sites in central and eastern NC
- Focus of the data analyses was to identify important environmental variables in the watersheds that influence nutrient export within and among the study sites
- Study results intended to assist management efforts for developing NSW management strategies for nutrient impaired streams and identifying watersheds where increased nutrient reduction efforts may be needed

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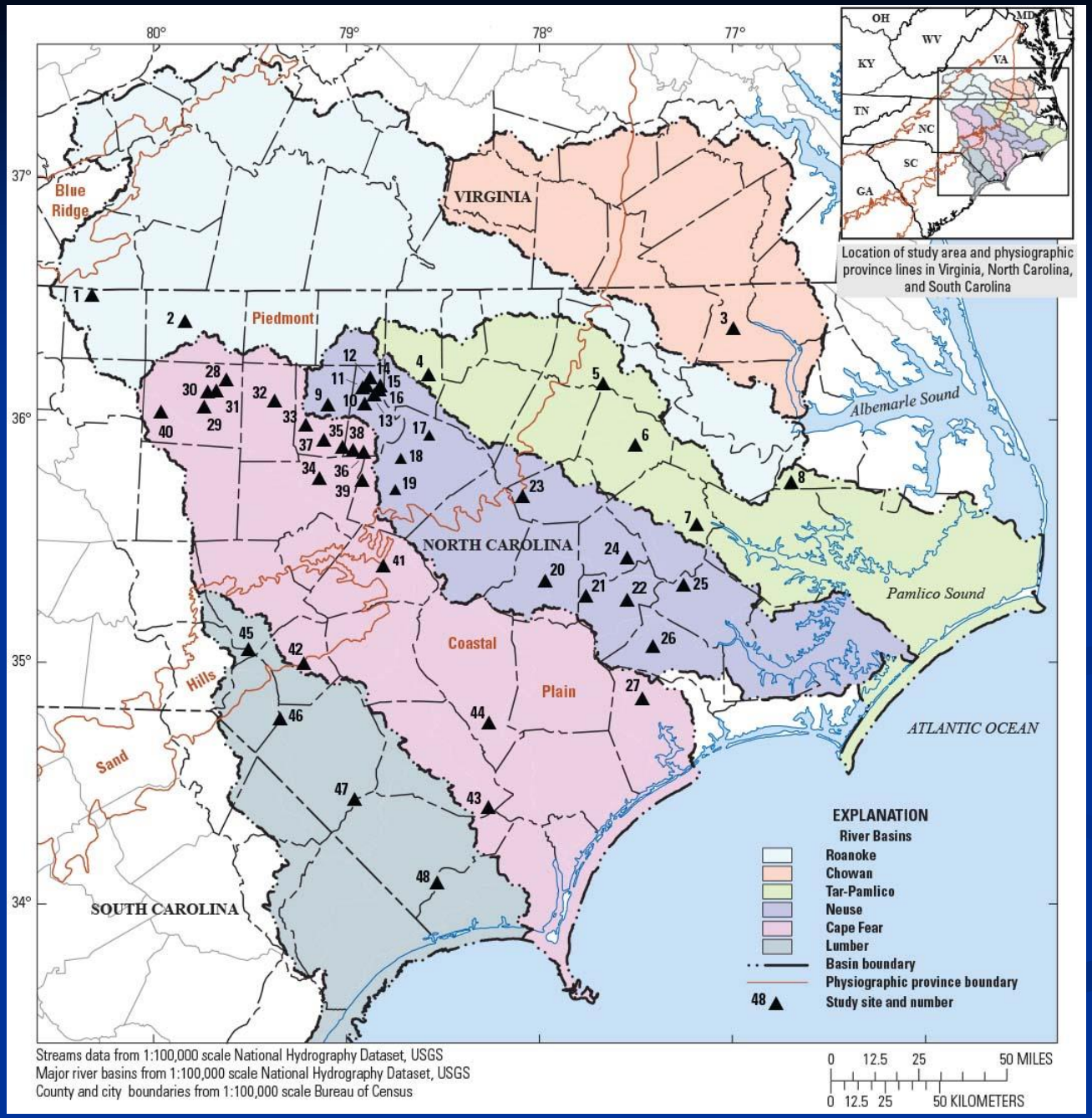
80°
79°
78°
77°
37°
36°
35°
34°
Blue Ridge
Piedmont
Coastal Plain
Hills
Sand
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
Albemarle Sound
Pamlico Sound
ATLANTIC OCEAN
OH
WV
MD
KY
VA
TN
NC
SC
GA
Location of study area and physiographic province lines in Virginia, North Carolina, and South Carolina
EXPLANATION
River Basins
Roanoke
Chowan
Tar-Pamlico
Neuse
Cape Fear
Lumber
Basin boundary
Physiographic province boundary
Study site and number
Streams data from 1:100,000 scale National Hydrography Dataset, USGS
Major river basins from 1:100,000 scale National Hydrography Dataset, USGS
County and city boundaries from 1:100,000 scale Bureau of Census
0 12.5 25 50 MILES
0 12.5 25 50 KILOMETERS

Scope of Work

- Compiled existing nutrient concentration data and streamflow data between 1997 and 2008 for the 48 stream sites
- The USGS LOADEST program was used to develop model estimates of nitrate, total N, and total P loads for each site
  - Compiled annual, seasonal, monthly, and daily loads
  - Annual loads were focus of report data evaluations
- Nutrient yield data were used in the final analysis to explore relations between watershed attributes and stream nutrient export

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Watershed Attribute Data

- Land-cover data
  - Watershed
  - 50-ft stream buffer within watershed
- Streamflow data
  - Annual streamflows and yields
- NPDES wastewater discharge facilities
  - Estimated annual point-source flows (wastewater discharged) from NPDES facilities within the study sites
- CAFOs (# permits, animals, and density)

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Land-Cover Data

- Compiled data for 15 individual land-cover classes
- 12 of the 15 classes were aggregated into 4 primary classes
  - Developed
  - Forested
  - Agriculture
  - Wetlands
- Sites assigned to 1 of 7 land-use categories based on relative % of developed and agricultural lands within the watersheds and the % of point-source flow contributions to the streams

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Criteria used for assigning land-use categories to the study sites				
Land-use category	Land-use code	% developed in watershed	% agriculture in watershed	% point-source flow to streamflow
Undeveloped	UN	≤ 10	≤ 15	0
Low agricultural	LAG	≤ 10	> 15 and ≤ 30	≤ 10
High agricultural	HAG	≤ 10	> 30	≤ 10
Low urban	LUR	> 10 and ≤ 30	≤ 15	≤ 10
High urban	HUR	> 30	≤ 15	≤ 10
Mixed	MIX	> 10	> 15	≤ 10
High point-source flow	HPS	na	na	> 10

Relation of streamflow and nutrient loads

- Variability in the estimated nutrient loads reflect variability in both the nutrient concentrations and streamflows used to compute the loads
- Streamflow is one of the dominant factors that influence stream nutrient concentrations and loads
- Streamflows strongly related to watershed drainage areas
  - Larger watersheds have higher streamflows, and consequently, higher nutrient loads

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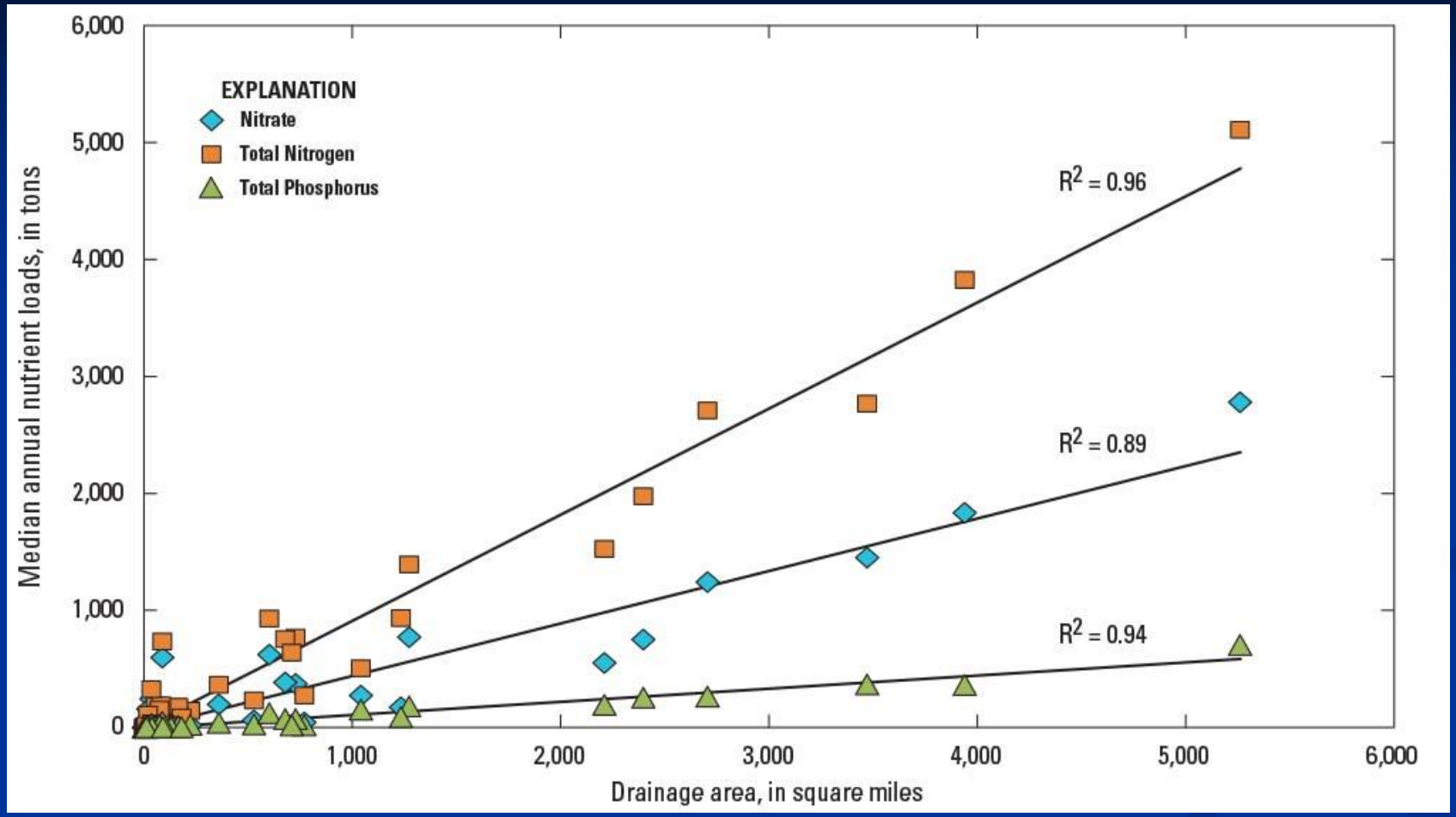

Median annual loads strongly related to watershed drainage area

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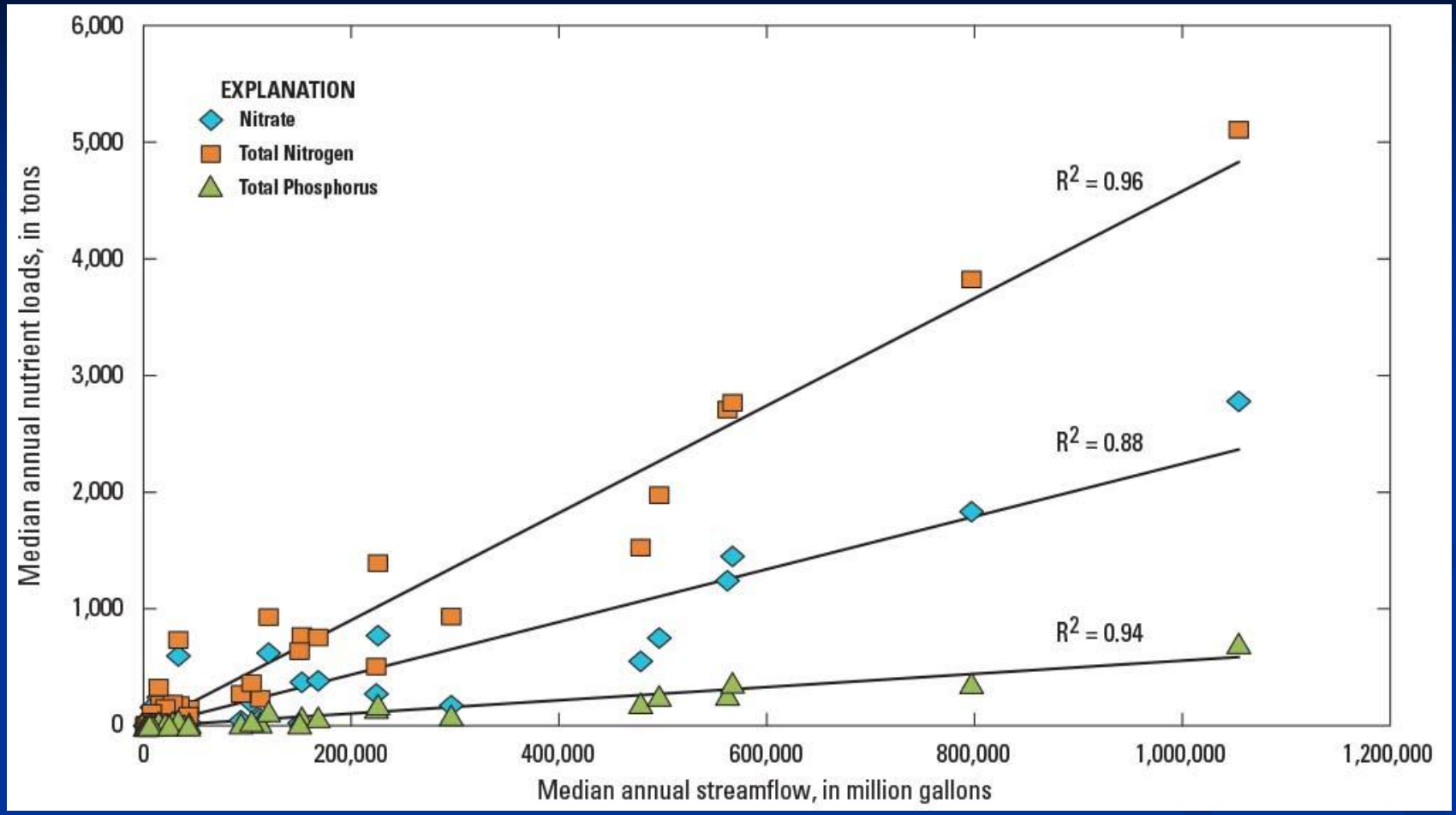

Median annual loads strongly related to median annual streamflows

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- Annual loads of nitrate, total N, and total P increase as both drainage areas and streamflows increase

- Difficult to examine relations between the loads and other watershed attributes (ie, land cover and nutrient sources) because variations in loads are largely controlled by variations in streamflow

- Used nutrient yields to explore relations between watershed attributes and nutrient export. Nutrient yields normalize the effects of basin size and streamflow differences among the sites.

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Comparison of nutrient yields by land-use category

- Evaluated whether differences in yields of nitrate, total N, and total P were discernible among the land-use categories assigned to the study sites

- Sites were grouped on the basis of their designated land-use category (UN, LAG, HAG, LUR, HUR, MIX, and HPS) and tested for statistical differences in annual nutrient yields

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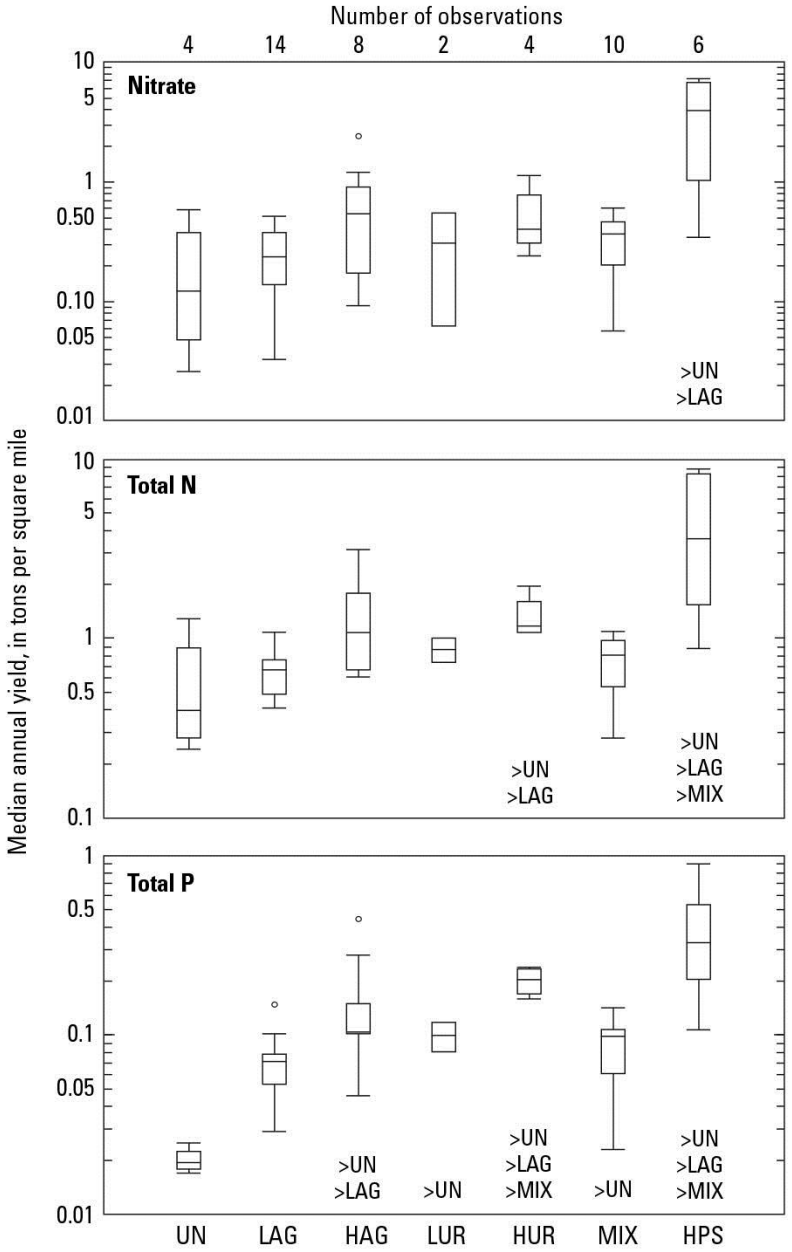
Number of observations
4
14
8
2
4
10
6
Nitrate
Total N
Total P
Median annual yield, in tons per square mile
10
5
1
0.50
0.10
0.05
0.01
0.5
0.1
>UN
>LAG
>MIX
UN
LAG
HAG
LUR
HUR
MIX
HPS

Multiple Comparison Test Summary

The results for nitrate, total N, and total P were similar in that the HUR and (or) HPS sites had statistically higher yields relative to the UN and LAG sites.

Primary difference in results is that total P yields also were higher for the HAG sites compared to the UN and LAG sites, and for the LUR sites compared to the UN sites.

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Although based on a limited dataset, the results suggest that evaluating stream nutrient yields using the land-use classification scheme devised in this study may be a useful approach for characterizing differences in watershed setting and nutrient yields.

Site Examples of Point-Source Influences

Based on the data analyses, urban sites having high point-source flow contributions to receiving streams were found to have notable influences on nutrient yields.

A couple of examples are presented in the report to illustrate how point-source flow contributions influenced stream nutrient yields in urban watersheds

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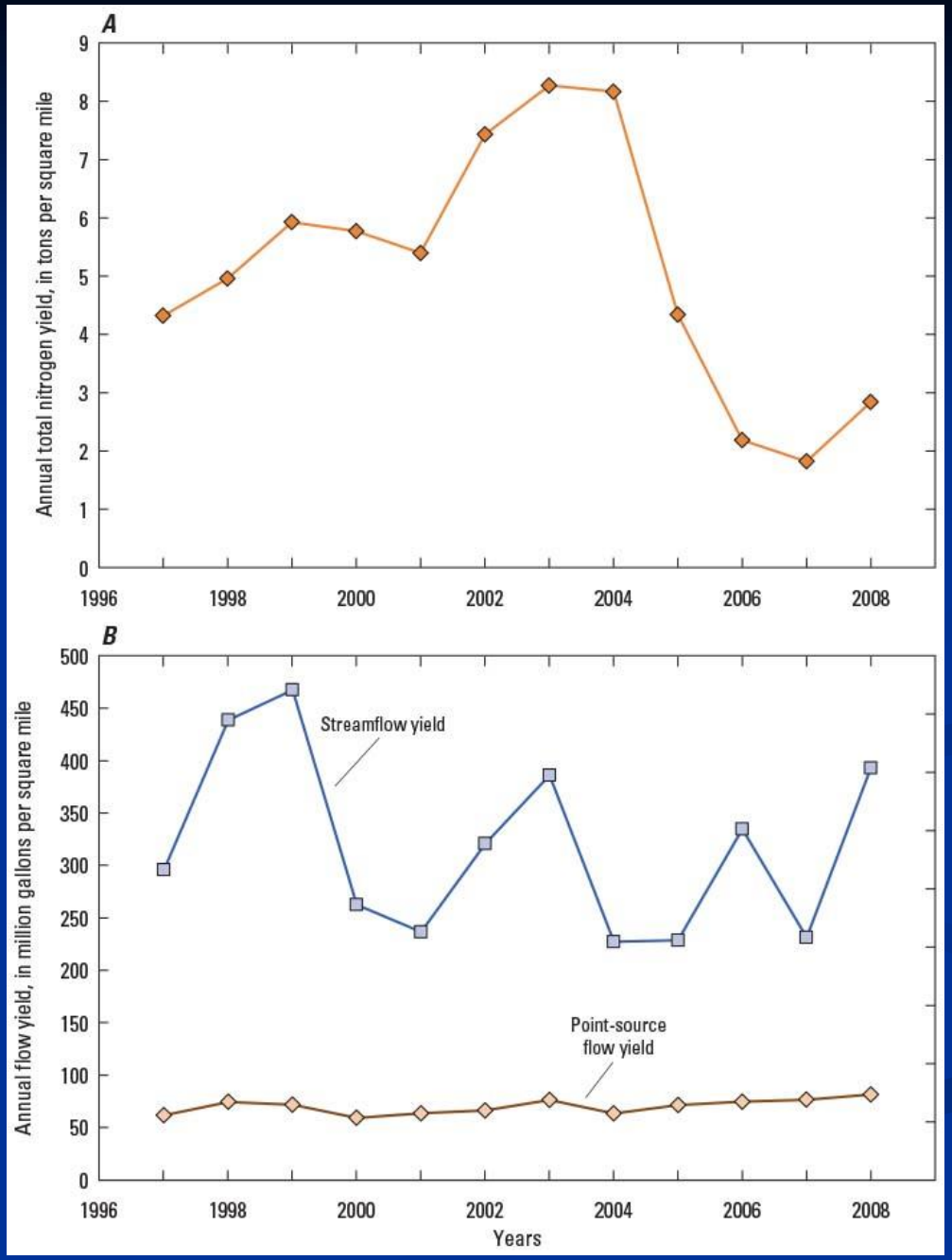
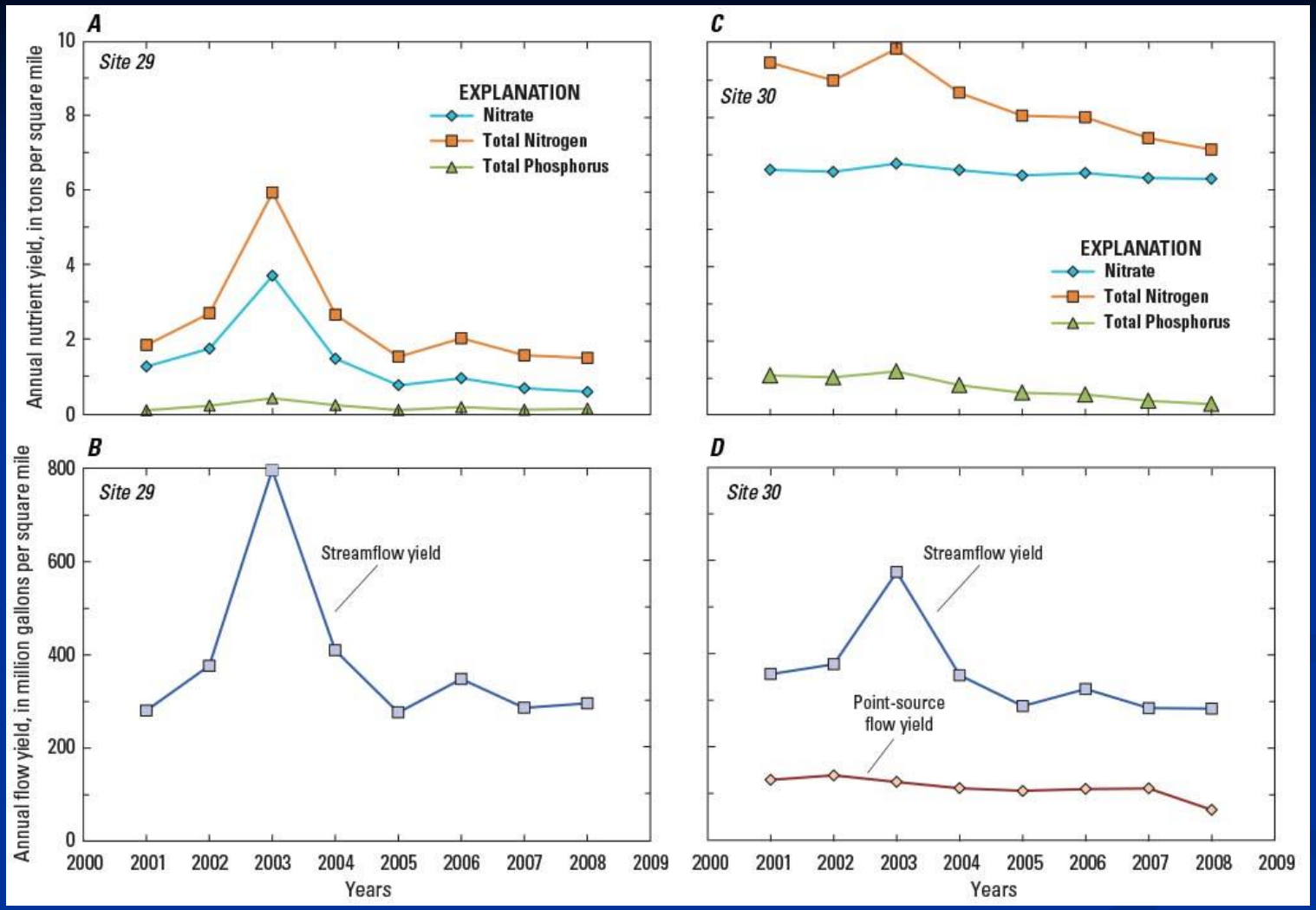
- NE Creek Genlee: Upgrade to Triangle WWTP had beneficial effect on total N
- PS flows: 15-33%
- 1997-2004: avg yield 6.3 ton/mi^2
- 2006-2008: avg yield 2.3 ton/mi^2
- 64% reduction in total N yield following upgrade





- Sites have similar size (34-37 mi^2) and land cover (> 80% dev). Site 30: PS flow about 33%; inc nutrient yields about 74-83% relative to Site 29

Influence of Watershed Variables on Nutrient Yields

- Used regression tree models to examine relations between watershed setting and stream yields of nitrate, total N, and total P.
  - Watershed environmental variables serve as “predictor variables”
  - Annual nutrient yields represent the “response variables”

- The models identify those predictor variables that best partition, or split, the nutrient yield data into increasingly homogenous subsets.

- Models developed for each nutrient individually to determine which characteristics are associated with basins that are likely to have high or low nutrient yields.

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Developed 4 models to analyze relations between watershed variables and observed nutrient yields for the study sites

1) Examined all 48 sites, regardless of basin size and %PS flow

2) Examined sites (42) where PS flow $\leq$ 10%

3) Examined sites (33) where PS flow $\leq$ 10% and size $\leq$ 1,000 mi^2

4) Examined sites (17) where PS flow $\leq$ 10% and size $\leq$ 100 mi^2

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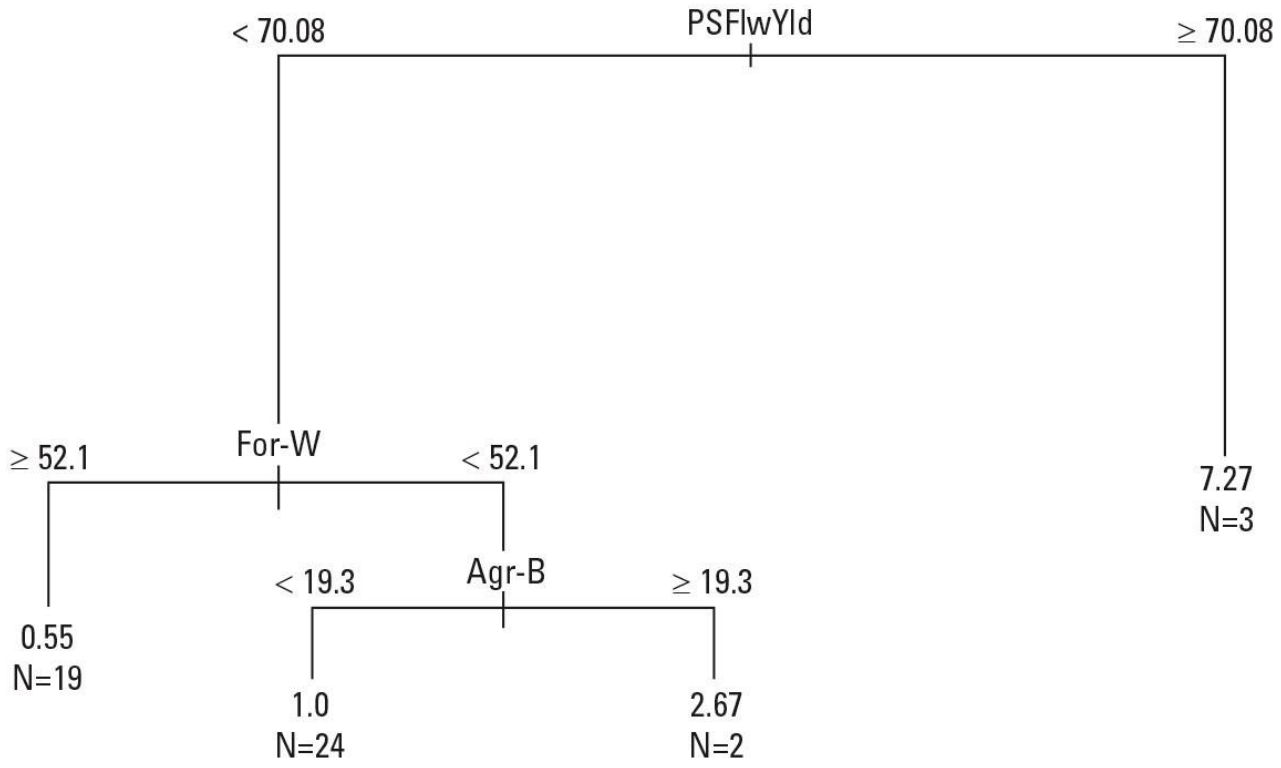
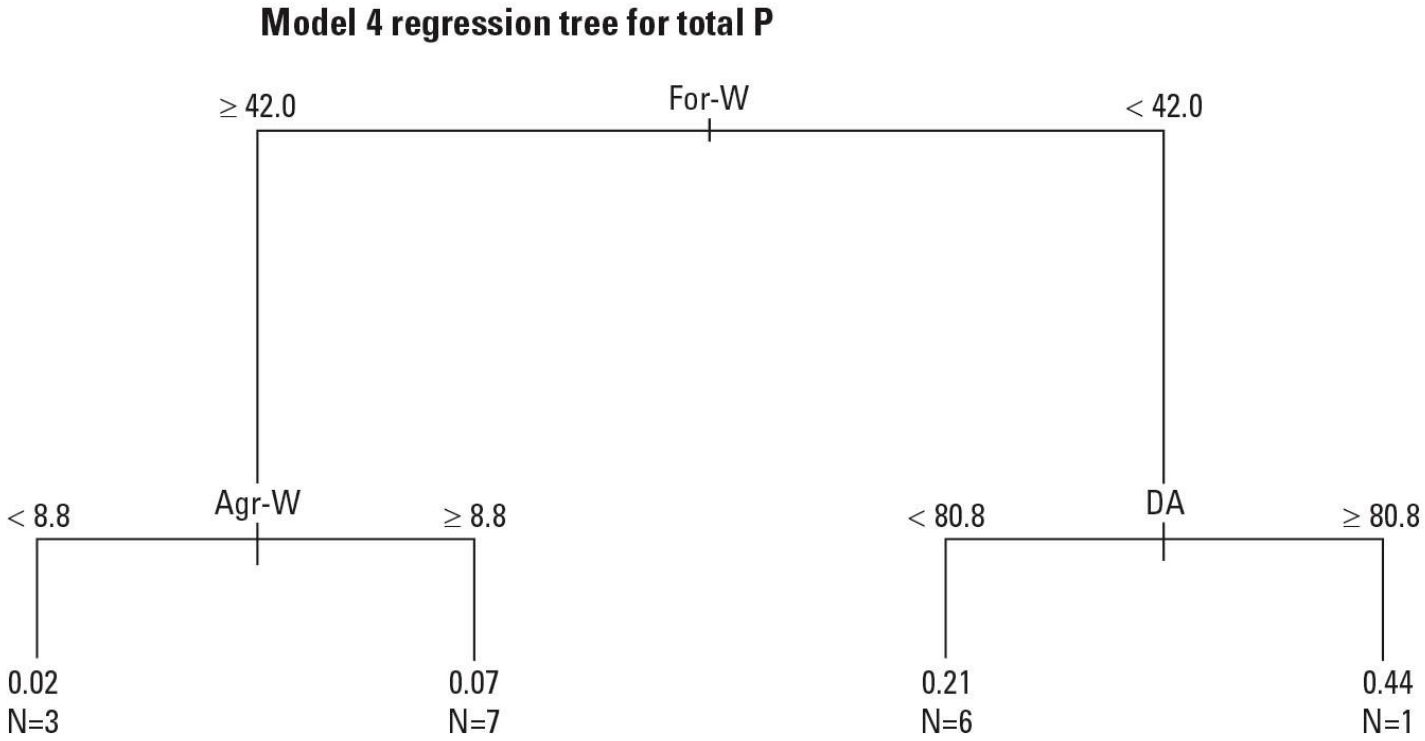
Model results summarized in tabular and graphical form

Model 1 results for all 48 study sites for Total N			
Split	Predictor variable	Split value	% total deviance in Total N yield data explained by predictor variable
1	Median annual PS flow yield	< 70.1 Mgal/mi^2	63.2
2	Forested in watershed	$\geq$ 52.1 %	13.1
3	Agriculture in buffer	< 19.3 %	6.8

- The first split in the regression tree identifies the predictor variable that best explains the highest percentage of the total deviance in yield data
- Subsequent splits identify variables that explain successively lower percentages of the total deviance in the yield dataset
- Splits that do not contribute to a reduction in model error are removed, or pruned, from the regression tree.


Model 1 regression tree for total N
< 70.08
PSFlwYld
≥ 70.08
≥ 52.1
For-W
< 52.1
7.27
N=3
< 19.3
Agr-B
≥ 19.3
0.55
N=19
1.0
N=24
2.67
N=2


Model 4 regression tree for total P
For-W
≥ 42.0
< 42.0
Agr-W
< 8.8
≥ 8.8
DA
< 80.8
≥ 80.8
0.02
N=3
0.07
N=7
0.21
N=6
0.44
N=1

Regression Tree Summary

- Regression tree analyses indicated that some of the environmental variables examined in this study were useful for predicting observed yields of nitrate, total N and total P.

- Models 2, 3 and 4 did not identify any watershed variables that could adequately explain the observed variability in the nitrate yields.

- All 4 models successfully identified particular watershed variables that influenced the total N and total P yields among the study sites.

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Regression Tree Summary

- Primary watershed variables found to influence stream nutrient yields
  - Point-source flow yields
  - Streamflow yields
  - % forested land in watershed
- Additional influential variables included
  - % agricultural land in watershed or in 50-ft stream buffer
  - % forested land + wetlands in watershed
  - % point-source flow contribution to stream
  - Drainage area

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Regression Tree Summary

- Some of the compiled watershed variables (ie, HSGs, CAFOs, and precip) were not identified by the models as influential predictor variables for explaining variations in the observed yields.

- This does not imply that these environmental variables do not influence nutrient yields among the study sites.

- It is likely that the influential predictor variables selected by the models (ie, % forest land in the watershed) also serve as surrogates that reflect the integrated effects of additional environmental influences on the stream nutrient yields.

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Conclusions

- The land-use classification scheme devised in this study may be a useful approach for exploring differences between watershed setting and nutrient yields.

- The regression tree models provide a tool for relating differences in select watershed attributes to differences in stream nutrient yields, which can provide beneficial information for improving nutrient management in NC streams.

- Use of the models will be contingent on having the necessary data for characterizing those watershed environmental variables that influence stream nutrient yields.

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Conclusions

- The models (based on data from 1997 - 2008 at 48 sites) can be refined as more recent information on streamflows, PS flows, and nutrient loads become available for the existing monitoring sites.

- Can also include streamflow and nutrient load data for additional watersheds with varying degrees of land use and anthropogenic inputs (ie, AG watersheds with CAFOs) to allow further evaluation of factors that influence stream nutrient yields in North Carolina.

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Questions and Discussion

Link to online report and data appendixes:

http://pubs.usgs.gov/sir/2013/5007/

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