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# LOADS OF NUTRIENTS IN SELECTED STREAMS OF THE ALBEMARLE–PAMLICO BASIN

*What they are. How do the Basin Loads Compare with other Areas? and Trends*

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# Overview

- Water Quality standards and Criteria are usually established as concentrations….not yields or loads…we'll look at why loads and yields are important, what are typical nutrient loads and yields worldwide, on the east coast of the US, and what's typical in North Carolina
- What have been trends in streams of the Albemarle-Pamlico Basin since the 1970s and more recently after 1997?
- What are some of the problems with interpreting loads, what kind of data do we need, and for how long?

# Data (all Neuse sites had monthly or more frequently)

- Flow and nutrient chemistry from USGS: http://nc.water.usgs.gov/infodata/surfacewater.html

Data collected primarily as cooperative effort between NCDENR and USGS

- Nutrient chemistry from NCDENR Division of Water Quality Web site (indirectly through EPA STORET): http://portal.ncdenr.org/web/wq/ess/eco/ams -- Samples collected through NCDENR's Ambient Monitoring System

# What nutrients are we talking about?

- Total nitrogen = NO3+NO2 (filtered) + Ammonia plus Organic Nitrogen (unfiltered)
- Total phosphorus = All forms (dissolved inorganic and organic P) (unfiltered)

# How are loads computed?

- USGS LOADEST Program

1. Compute instantaneous loads from concentration and flow on days when both data were available-usually one concentration value with one flow value (daily mean)—typically monthly-bimonthly frequency
2. Relate log of instantaneous loads to up to 9 flow and time variables to estimate loads on days where no concentration data were originally available
3. Sum all daily loads to get annual load

Details of the procedure at:
http://water.usgs.gov/software/loadest/doc/

# Loads and Yields

- **Load** Q (flow volume/unit time) X C (mass/ unit volume) = L (mass/unit time)

  ie. tons / day

  kilograms/ day

- **Yield** mass / unit area/ unit time

  usually tons per square mile per year

  kilograms per square kilometer per year

# What are some problems with load interpretation?

- Strongly ($r^2 > 0.90$) influenced by the flow parameter—it can mask effects from other important variables and thus largely reveals information on changes in flow—also very "noisy" because of flow variability: not easy to detect long-term trends
- Can bypass this problem by dividing total annual load by total annual flow-effectively leaving only the mass transported per unit volume of water (mg/L)
- WQ Standards are usually established as concentrations, not loads

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# Why is movement of nutrient loads to coastal waters important?

- Excess nutrients can exacerbate eutrophication processes
- Increase in species that are pollution tolerant and potentially toxic
- Increase in massive amounts of oxygen-depleting algal growths, can cause fish kills through hypoxia
- Worldwide increase in dead zones

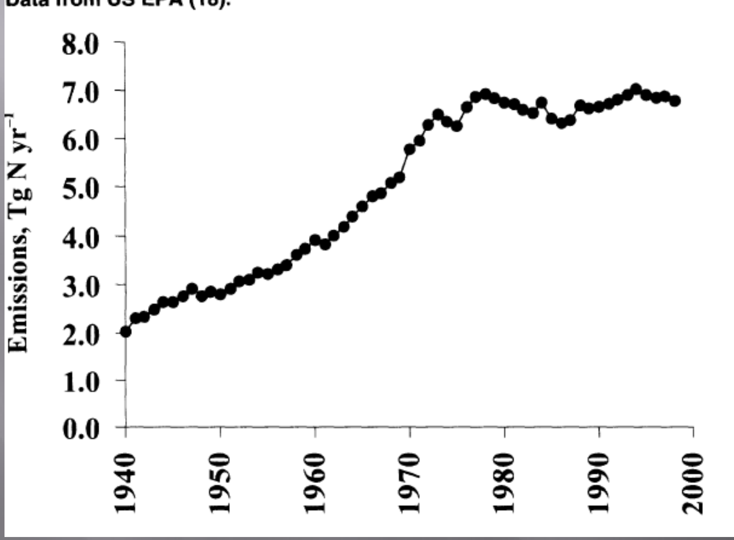
# Loads and Yields useful to characterize nutrient transport processes in different environments and land uses

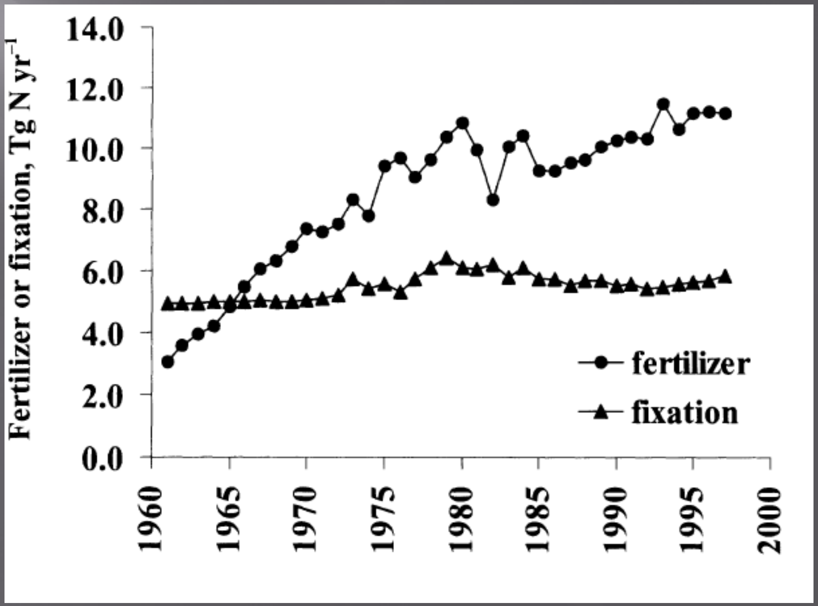
- Loads are useful primarily as indicators of change through time, but they indicate ALL transport processes taking place at all upstream areas-difficult to tease out specifics
- **Yields are potentially most useful as indicators of change and because they reflect regional environmental process variables, including land use, and are normalized by unit area**
- To eliminate the major effect of the flow variable, it is necessary to divide by flow to show concentration only-best to evaluate changes in point sources of nutrients

# Changes through time

- **Sources of nitrogen and phosphorus have gone up since the turn of the century and particularly since 1960 (Smil 1991; Schlesinger (1997); *Howarth et al. 2002); for NC, Don Stanley (1992) and Stow, Borsuk, and Stanley (2001)***

Figure 1. Atmospheric $NO_x$ emissions in the USA from 1940–2000. Data from US EPA (18).



# So….have yields increased since the 1970s?

1. Worldwide, loads (and therefore yields) DIN and DIP increased ~3 X between the 1970s and 1990s (Smith et al. 2003).

2. Total N from about 1 tpsm to 3 tpsm (NE US) and 2 tpsm (SE US) (Howarth et al. 2000); 2.1 tpsm (calculated from DIN reported in Smith et al. (2003)

3. Total P from 0. 07 tpsm to **0.2 tpsm (east Coast U.S. calculated from DIP reported in Smith et al. (2003))**

# Typical World, SE US, and North Carolina (A-P) N and P Yields in tpsm

| Nutrient | Europe and eastern US (late 1990s) | SE US (late 1990s) | A-P (early 1980s-mid90s) |
|---|---|---|---|
| Total Nitrogen | 2.1 (using 0.7 tpsm for DIN) (S); 3 (H) | 2 (H)<br>1-2 tpsm (HM) | TN=0.53-1.6 (Hnd) |
| Total Phosphorus | 0.2 (using 0.08 for DIP) (S) | NI (0.2 from Smith) | TP=0.03-0.21(Hnd) |
| | | | |

H=Howarth et al., 1996 Biogeochemistry 35 75-139
S= Smith et al., 2003, Bioscience 53 No. 3, 235-245
Hnd=Harned et al., 1995 USGS WRI 95-191
HM=Hoos/McMahon 2009 Hydrologic Processes DOI: 10.1002/hyp.7323

# Nutrient short-term trends: 1997-2008

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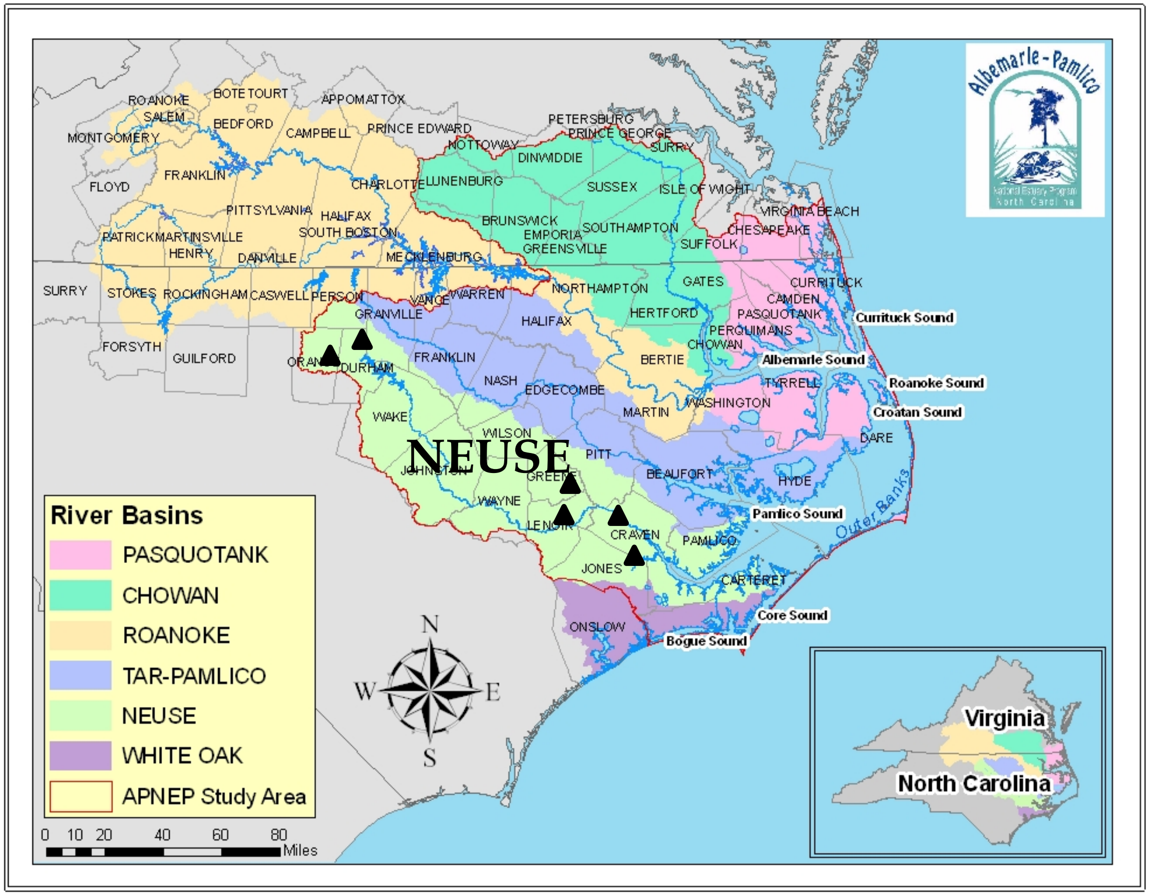
# Neuse Monitoring Stations NCDENR DWQ Ambient Monitoring System



# Nitrogen Trends in Neuse River Basin 1997–2008

| | | Total Nitrogen | | |
|---|---|---|---|---|
| Station | Basin | TNTrend? | TNLoad (tons) | TNYield (tpsm) |
| Eno River Hillsborough | Neuse | D | 50 (28-72) | .77 (.43-1.1) |
| Little River Orange Fctory | Neuse | D | 69 (38-100) | 0.86 (0.48-1.26) |
| Contentnea Cr Hookerton | Neuse | N | 894 (669-1118) | 1.22 (0.91-1.52) |
| Neuse River at Ft. Barnwe | Neuse | N | 3942 (3063-4820) | 1.01 (0.78-1.23) |
| Bear Creek Mays Store | Neuse | N | 232 (147-317) | 3.94 (2.50-5.38) |
| Trent River near Trenton | Neuse | N | 208 (130-286) | 1.25 (0.78-1.72) |
| | | | | |
| | | Signficant at 5% | | |
| | | Significant at less than 1% | | |

# Phosphorus Trends in Neuse River Basin 1997-2008

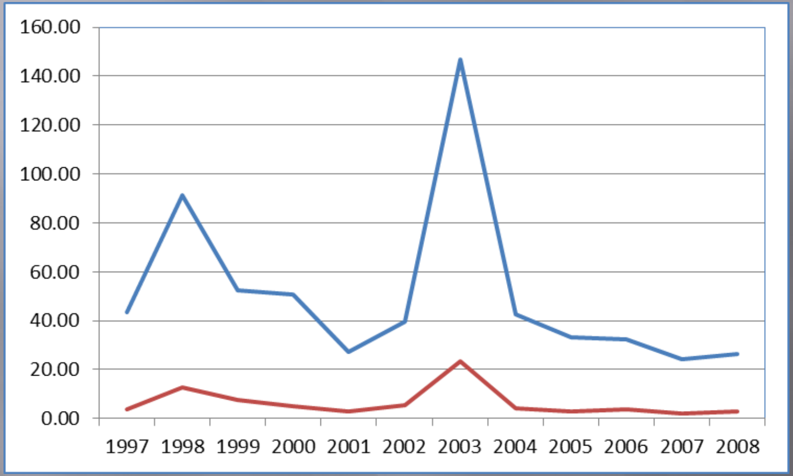
| | Total Phosphorus | | |
|---|---|---|---|
| Station | TPTrend? | TPLoad (tons) | TPYield (tpsm) |
| Eno River Hillsborough | N | 6.4(2.5-10.3) | 0.10(0.04-0.19) |
| Little River Orange Fctory | N | 8.18(4.34-12.02) | 0.10(0.05-0.15) |
| Contentnea Cr Hookerton | D | 110(66.7-154.36) | 0.15(0.09-0.21) |
| Neuse River at Ft. Barnwell | N | 430 (323-537) | 0.11(0.08-0.14) |
| Bear Creek Mays Store | N | 24.21(1.11-47.33) | 0.41(0.02-0.80) |
| Trent River near Trenton | N | 21.9 (12.0-31.8) | 0.13 (0.07-0.19) |
| | | | |
| Signficant at 5% | | | |
| Significant at less than 1% | | | |

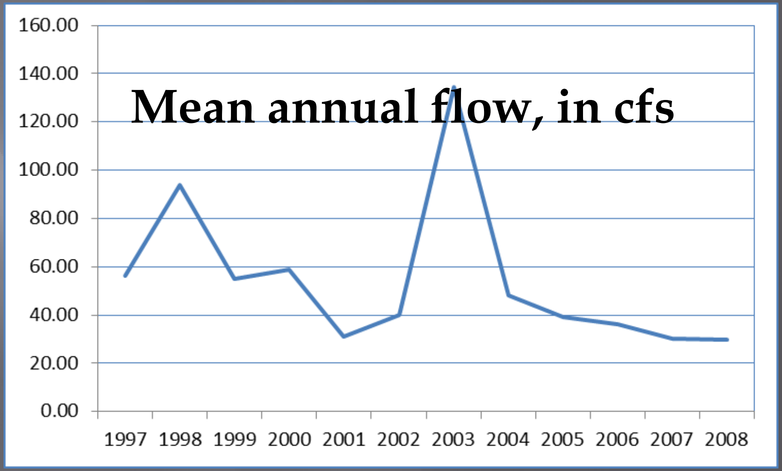
# Trends in Flow Neuse River Watershed 1997–2008

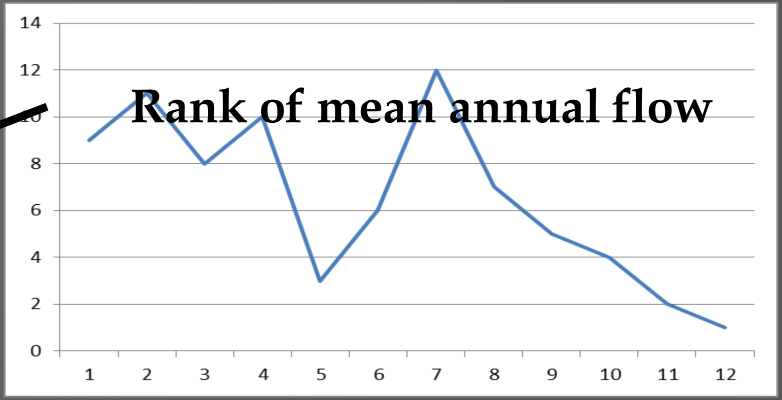
| | | | |
|---|---|---|---|
| Table 1. Mean annual flow and 95 percent confidence interval (in parentheses) | | | |
| for annual flow at 6 selected stations in the Albemarle-Pamlico Basin, 1997-2008 | | | |
| Spearman Rho Trend tested on 12 years of annual flow data. D=decreasing(alpha=0.05) | | | |
| | | | |
| | | | |
| Station | Watershed | Flowtrend? | Flow(cfs) |
| Eno River Hillsborough | Neuse | D | 31(35-75) |
| Little River Orange Fctory | Neuse | D | 67.4(44.5-90.3) |
| Contentnea Cr Hookerton | Neuse | No | 798 (537-1059) |
| Neuse River at Ft. Barnwell | Neuse | No | 3879 (2845-4912) |
| Bear Creek Mays Store | Neuse | No | 79.9 (50.7-109) |
| Trent River near Trenton | Neuse | No | 191 (121-261) |

# Total Nitrogen and Phosphorus Load and Mean Annual Flow, Eno River near Hillsborough, NC, 1997-2008

Total Nitrogen and Phosphorus Load, in tons




Spearman ρ = 0.70
$p < 0.05$ (0.59 required for Significance)

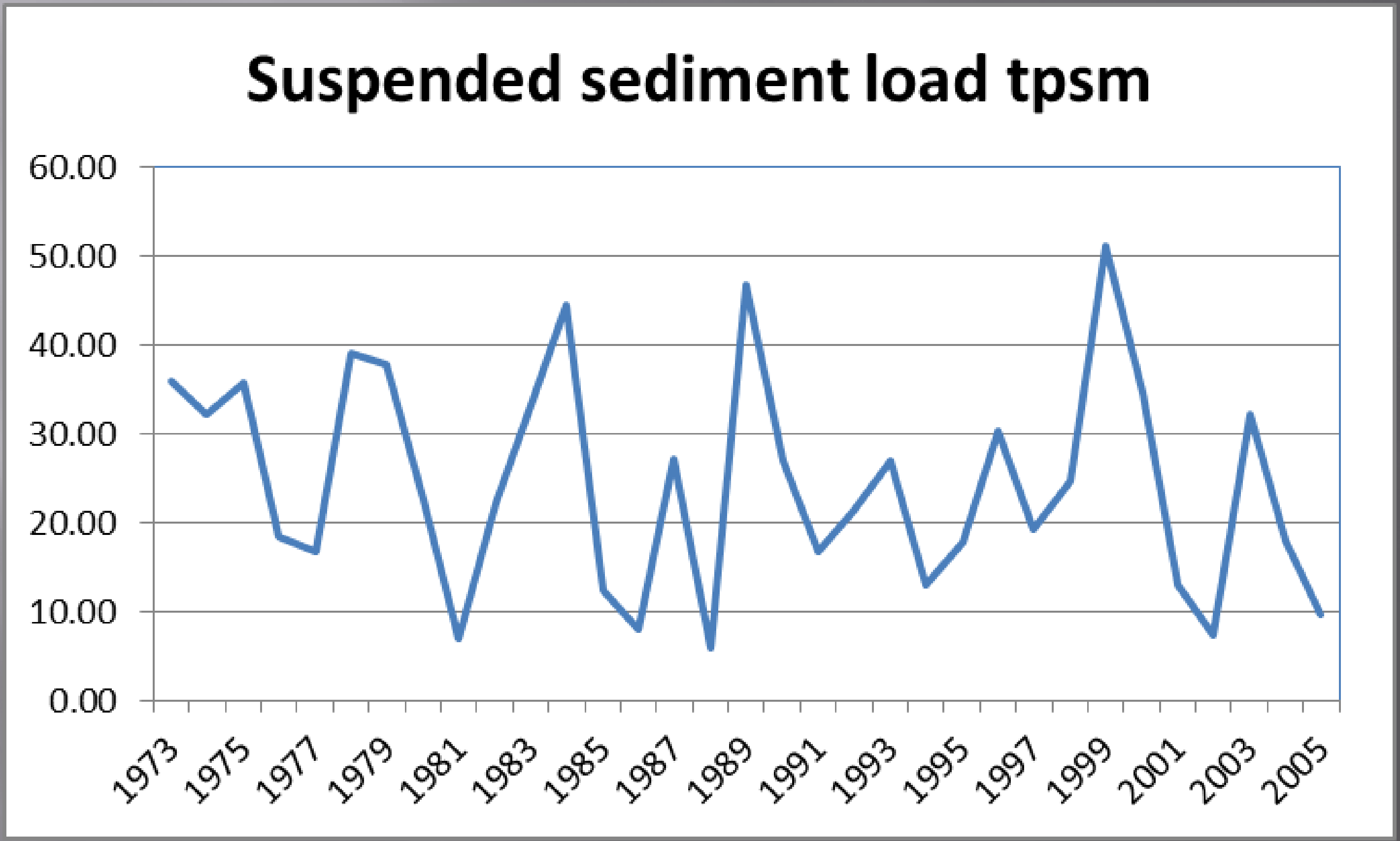
# Short term trends-generally not much has changed since 1997

- In the Neuse Basin,  there have been no statistically discernible trends in loads/yields of nitrogen at four of the six sites analyzed
- Where decreasing total nitrogen trends were found in the Eno and Little River, they followed the decreasing flow trend
- No trends in P except at Contentnea Creek at Hookerton, where a decrease in phosphorus was detected

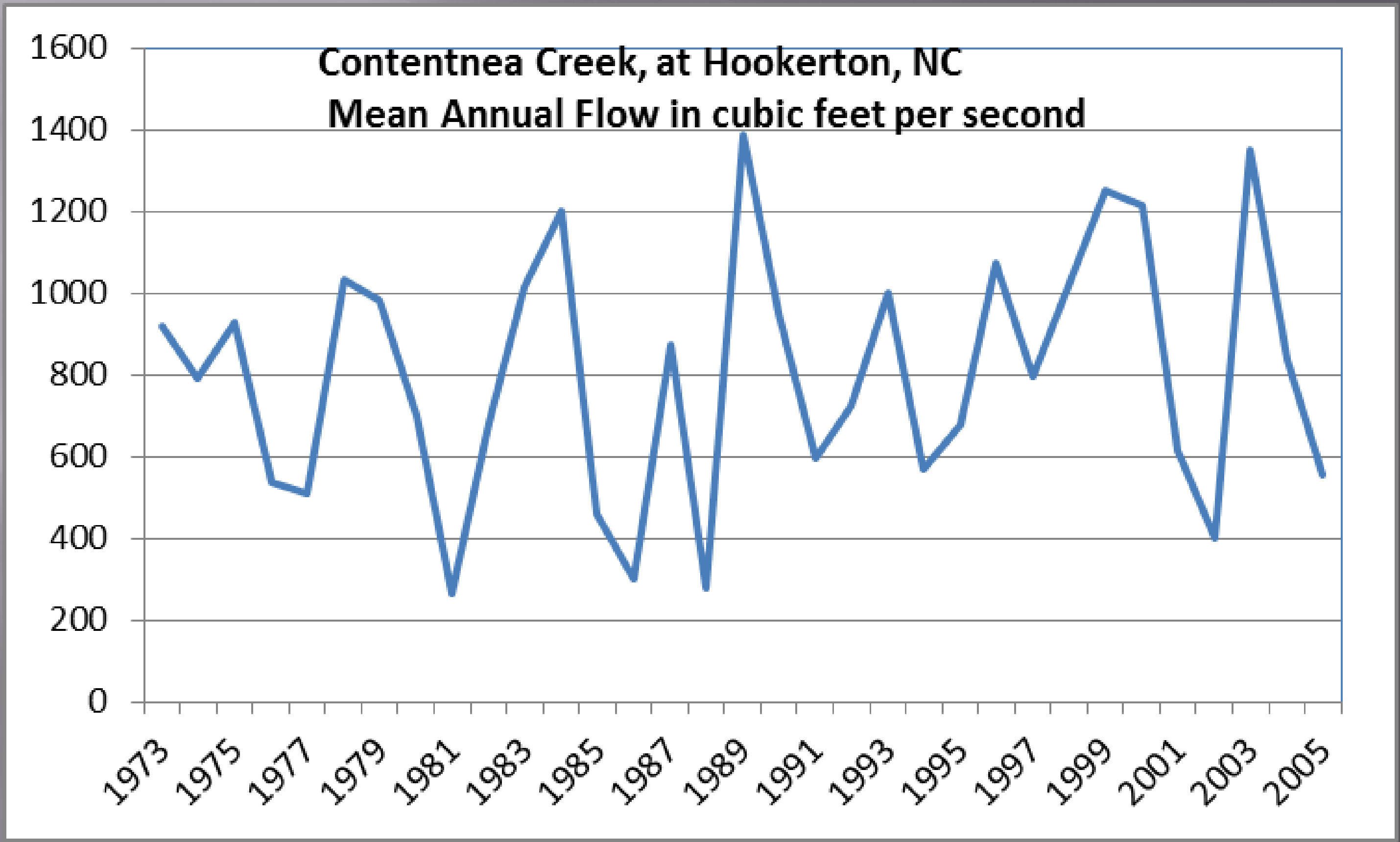
# Nutrient long-term trends in loads and concentrations: 1973-2008

1. Suspended sediment (ok..so it's not a nutrient, but it *is* interesting and shows how concentration can be helpful in discerning trends)
2. Total Nitrogen
3. Total Phosphorus

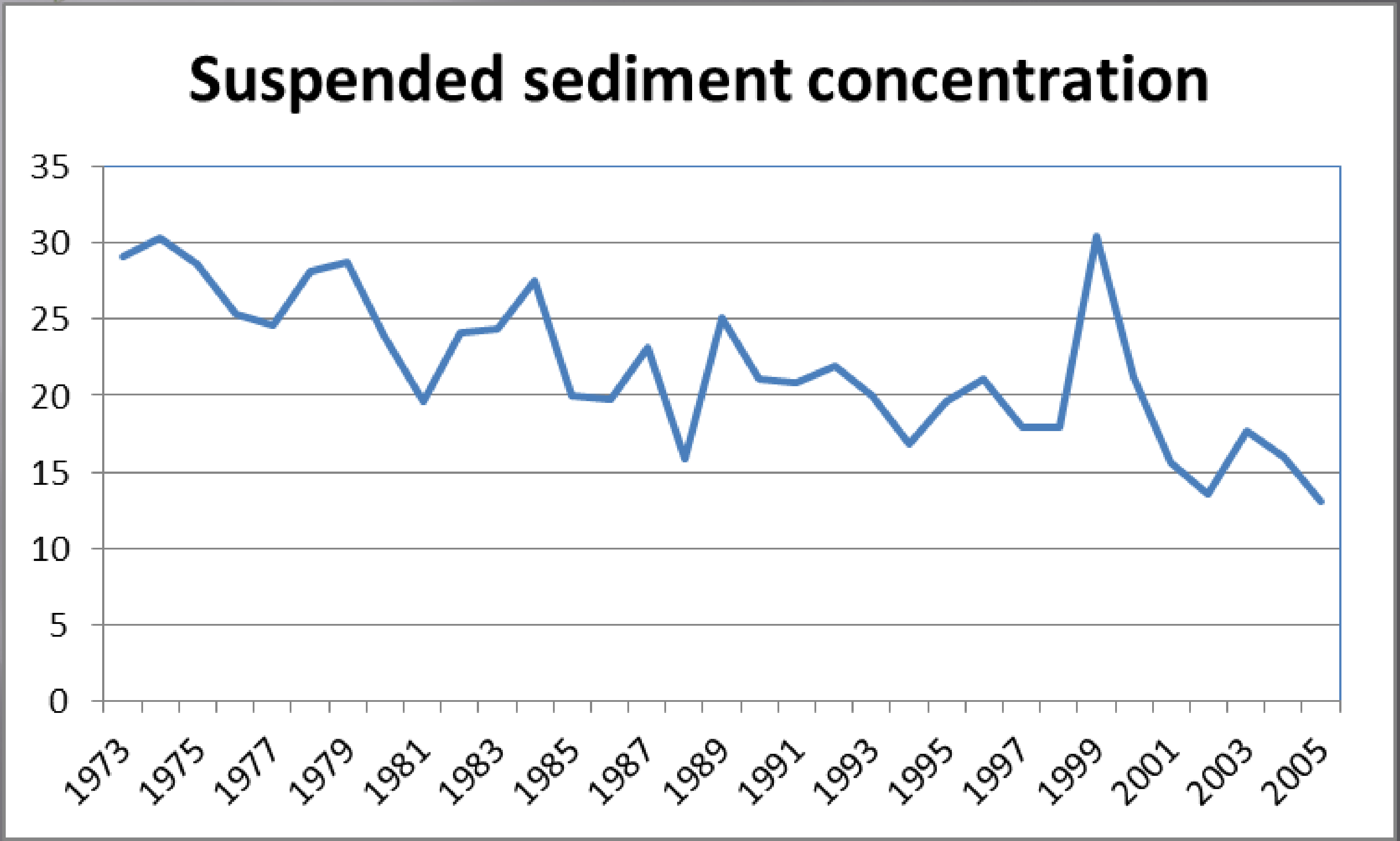
# Suspended sediment Contentnea Creek at Hookerton, 1973-2005



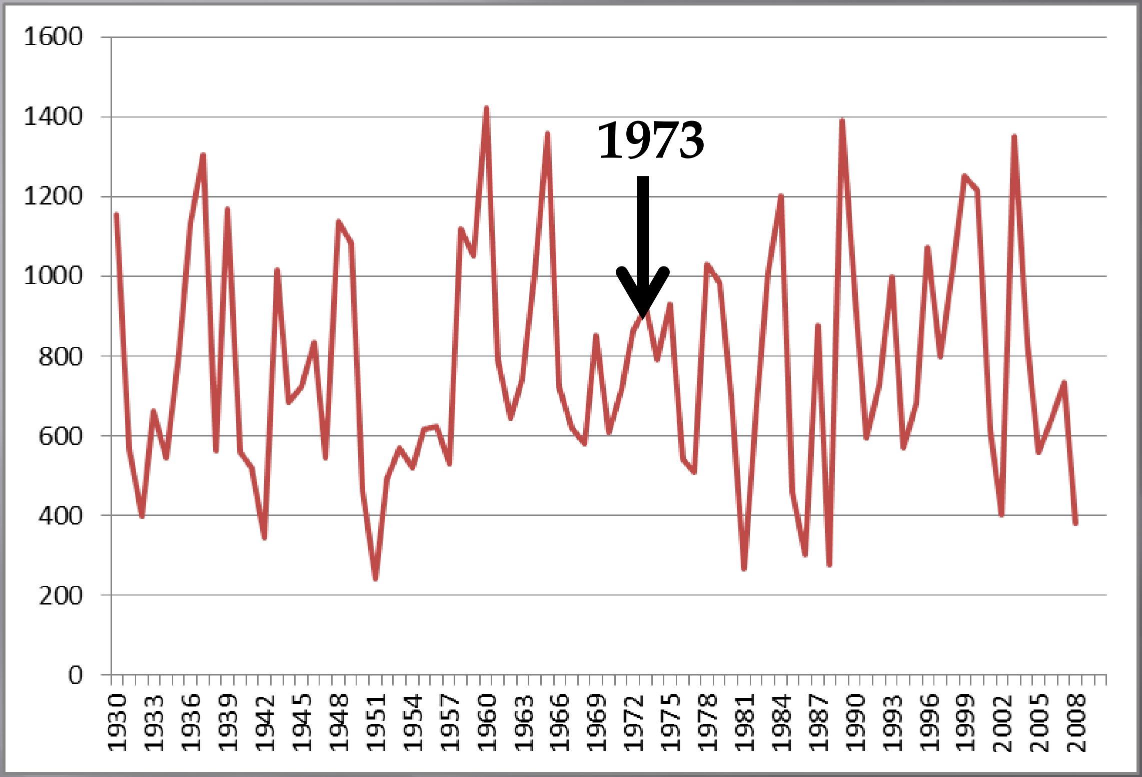
# Mean annual flow, cfs, Contentnea Creek at Hookerton, 1973–2005



# Annual SS Concentration, Contentnea Creek nr. Hookerton, 1973-2005



# Flow, in cfs, Contentnea Creek, 1930–2008

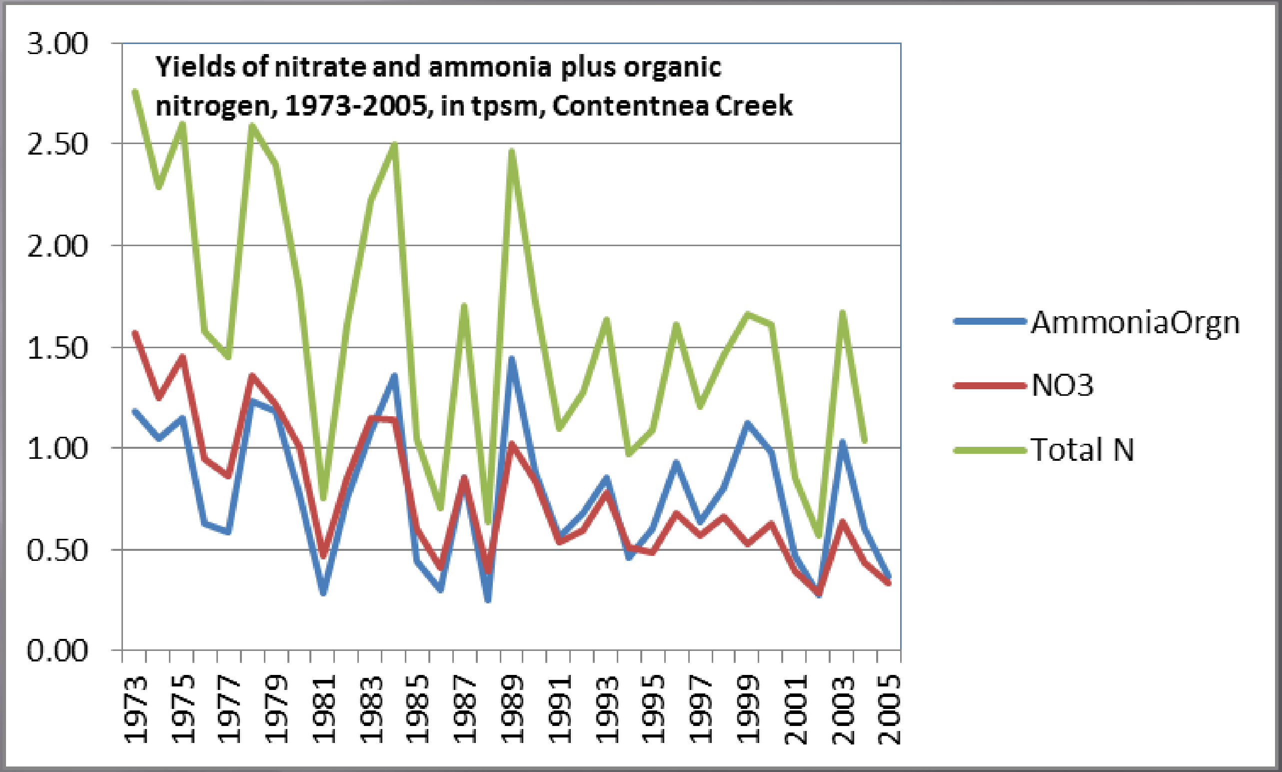



Trend ?

**1930-2008** NO
r=0.0516
P > 0.05 (0.183 to be significant

**1973-2008** NO
r=0.019
P > 0.05 (0.275)

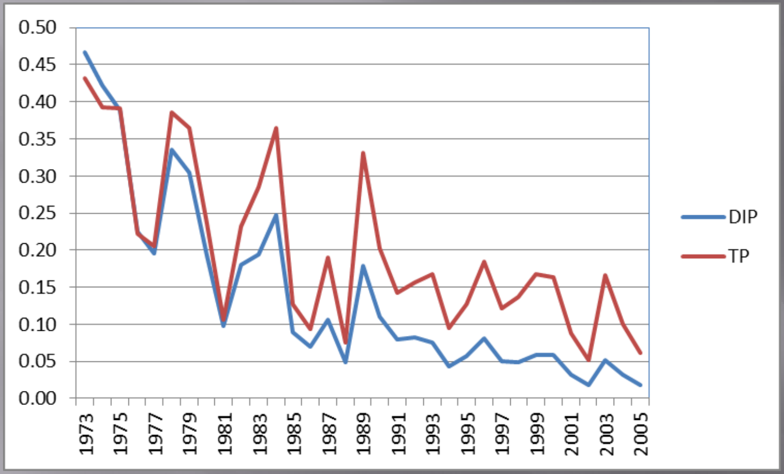
# Nitrogen Yield, in tpsm, Contentnea Creek near Hookerton 1973–2005

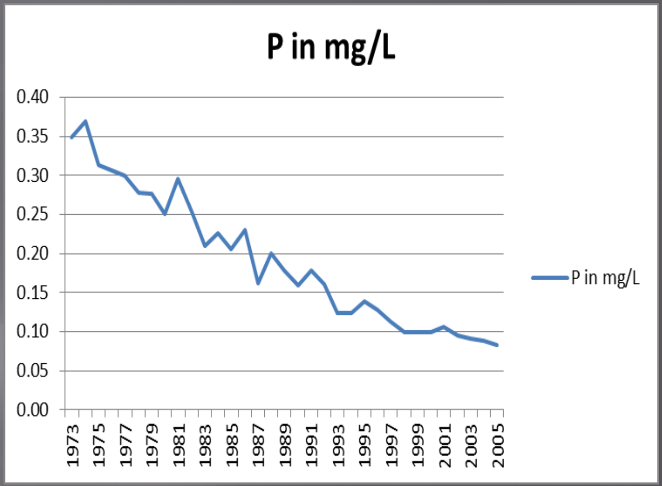


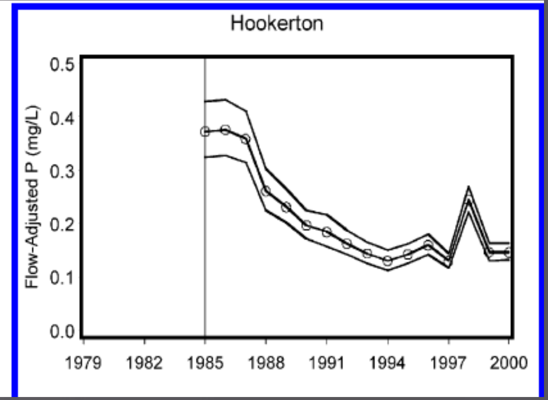
# Phosphorus Yield, in tpsm, and Concentration Contentnea Creek near Hookerton 1973–2005

Concentration

Yield

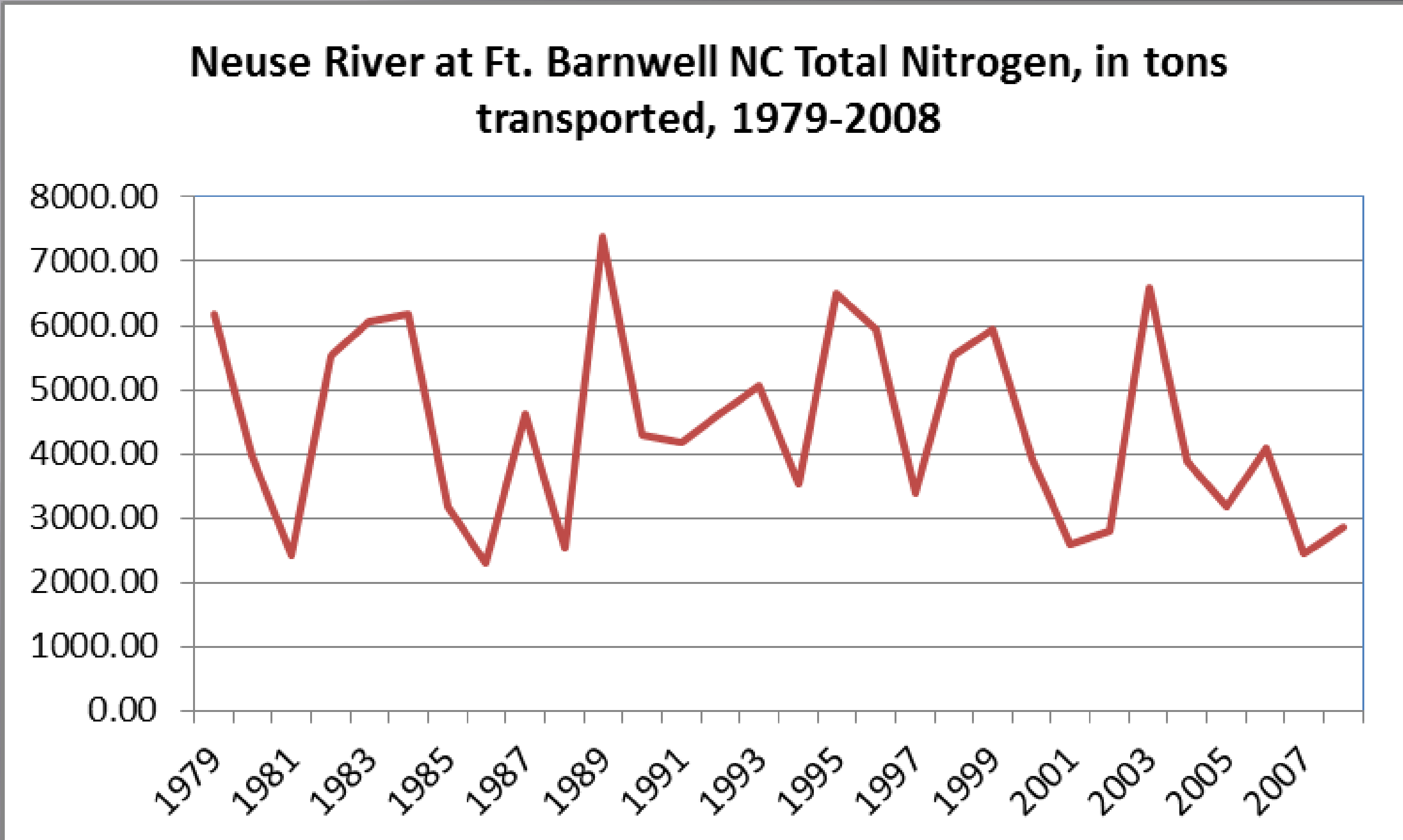


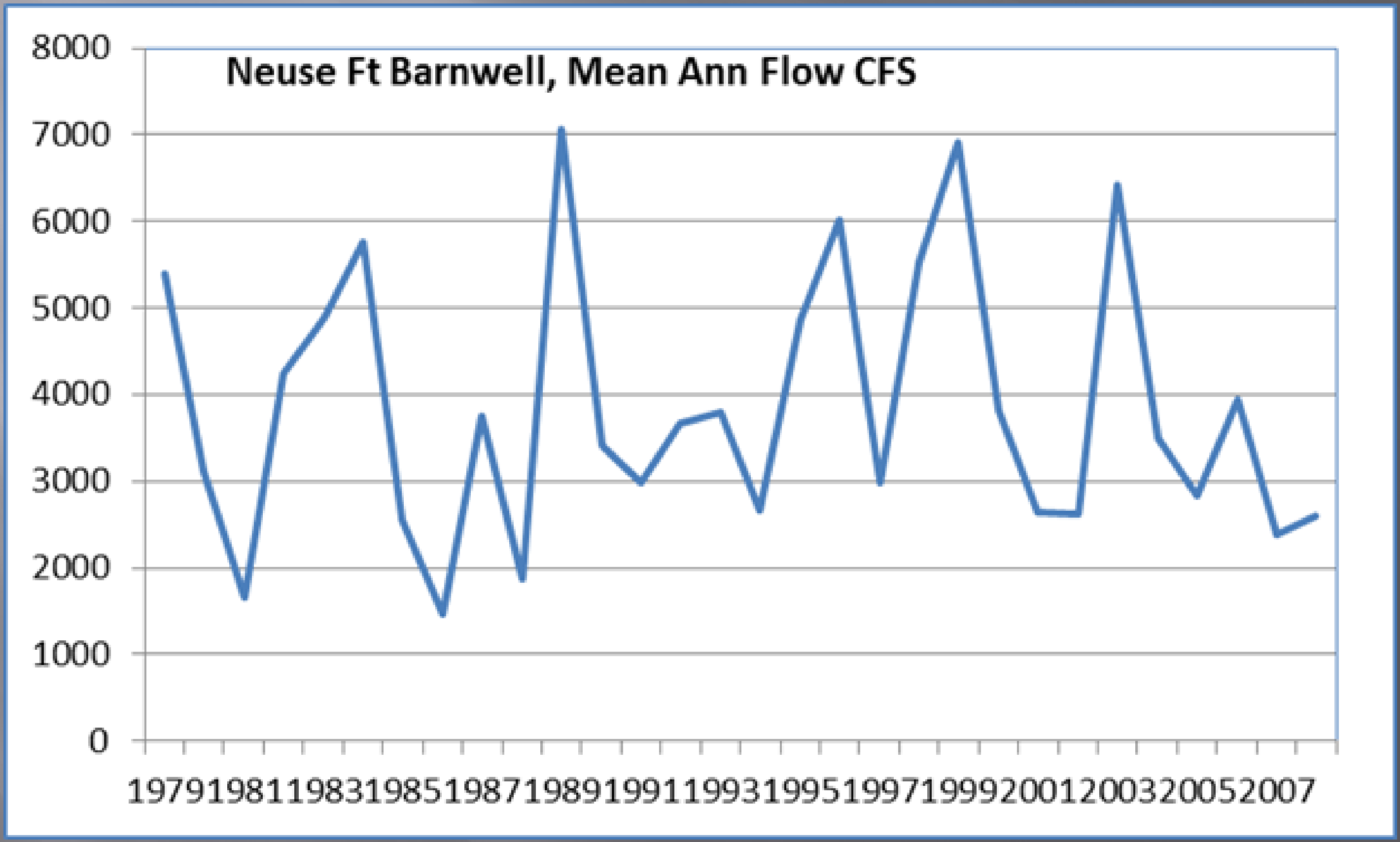




Stow and Borsuk, ES & T 2003

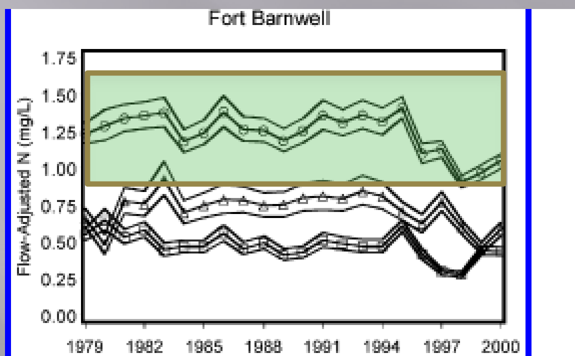
# Annual Total Nitrogen Load, Neuse at Fort Barnwell, 1979–2008



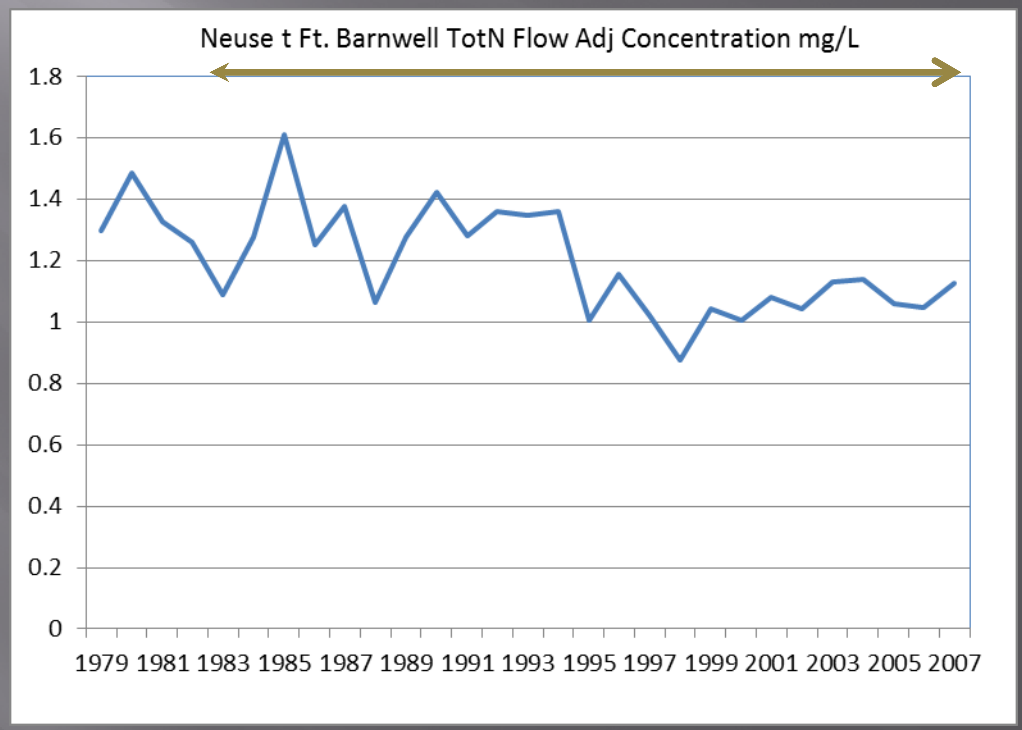
# Neuse River at Fort Barnwell Mean Annual Flow 1979–2008



# Neuse River at Fort Barnwell annual concentration, 1979–2008

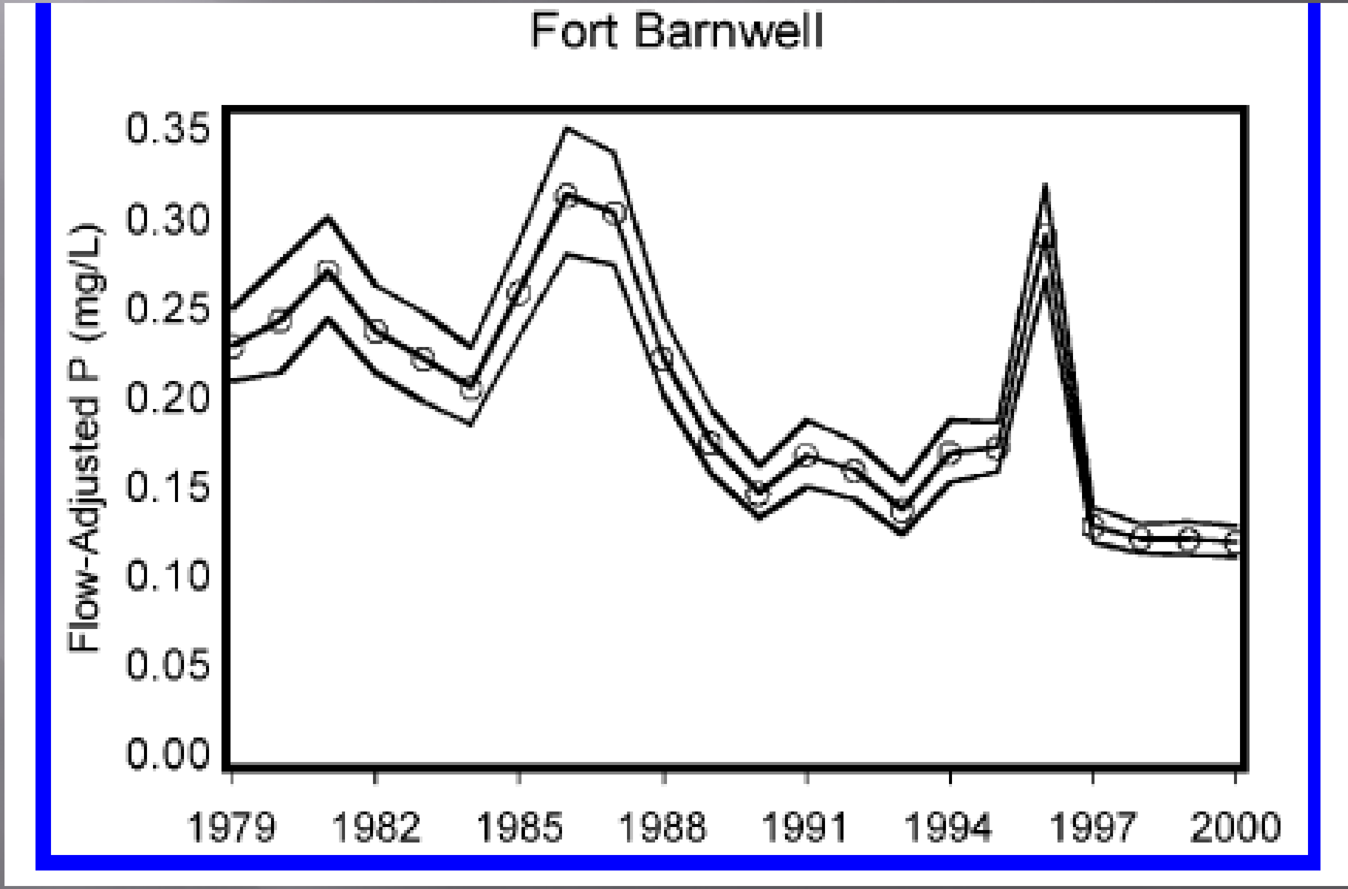



TMDL Phase II Neuse Basin (2001)-included analysis by Stow and Borsuk (ES&T, 2003)



# Flow weighted total P in mg/L, 1979-2000

Stow and Borsuk, ES & T 2003



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# Long-term Trends-Summary

- Decrease in nitrogen and phosphorus loads/yields have been demonstrated in Contentnea Creek-decrease in nitrate mostly responsible for decrease from ‘73 to ‘95-stable after that for N; continued decrease for P
- Decrease in loads not evident at Neuse at Fort Barnwell-but annual concentrations decreased 30% in ‘94-’95 from about 1.5 to 1 mg/L – stable since then

# Parting Observations:

- In general, nutrient (total N and P) yields in the A-P Basin appear relatively low compared to other areas of the East Coast of the US
- Most dramatic decreases in nutrient loads/yields in the Neuse Basin occurred between 1973 and 1995
- Very few statistically significant changes in nutrient loads since mid 1990s

# Observations (contd)

- Where no decreases observed in loads, annual flow adjusted concentrations can be effective indicators for changes due to something other than flow (i.e., land-use change, management actions)-also they correspond better with regulations established as concentrations
- The purpose of environmental management is to help guide appropriate actions in response to environmental damaging trends-monitoring flow and water quality are essential to do this-longer is *way* better
- If carefully collected, checked, and publicly available, the data are a safeguard against inappropriate action or inaction- can be used by anyone to verify claims of change

# Further reading

- Harned et al., 2009. Trends in Water Quality in the Southeastern United States, 1973-2005. USGS Scientific Investigations Report 2009-5268
- Harned et al., 1995. Water Quality Assessment of the Albemarle-Pamlico Open-File Report 95-191
- Also upcoming (summer 2012?)-- USGS report outlining results of NO3, Total N, and Total P loading in ~ 40 watersheds in North Carolina and relationships to land-use characteristics using DWQ data from AMS