Water Quality Trends and Conditions

The Continuing Saga of Chesapeake Bay Restoration

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(and many friends)

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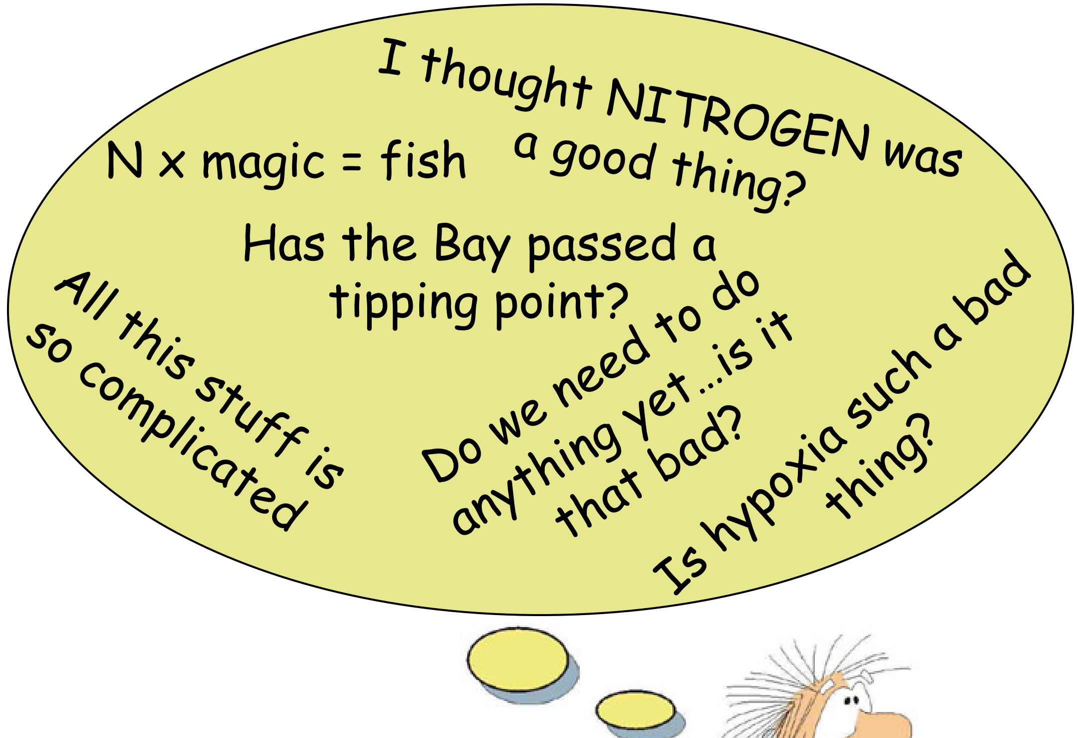


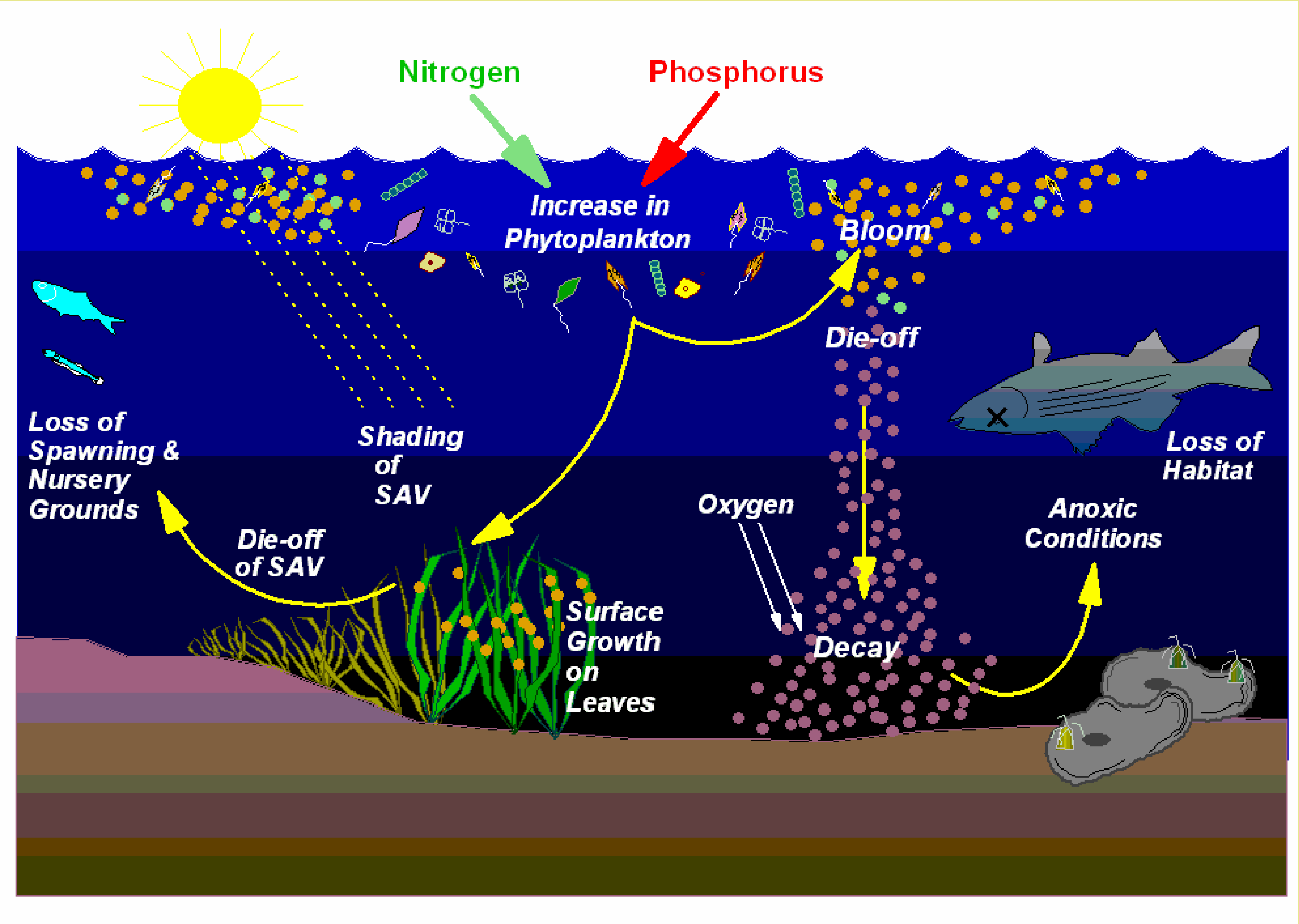
What to say about Water Quality and Restoration in the Potomac and Chesapeake Bay

in 35 minutes or less?

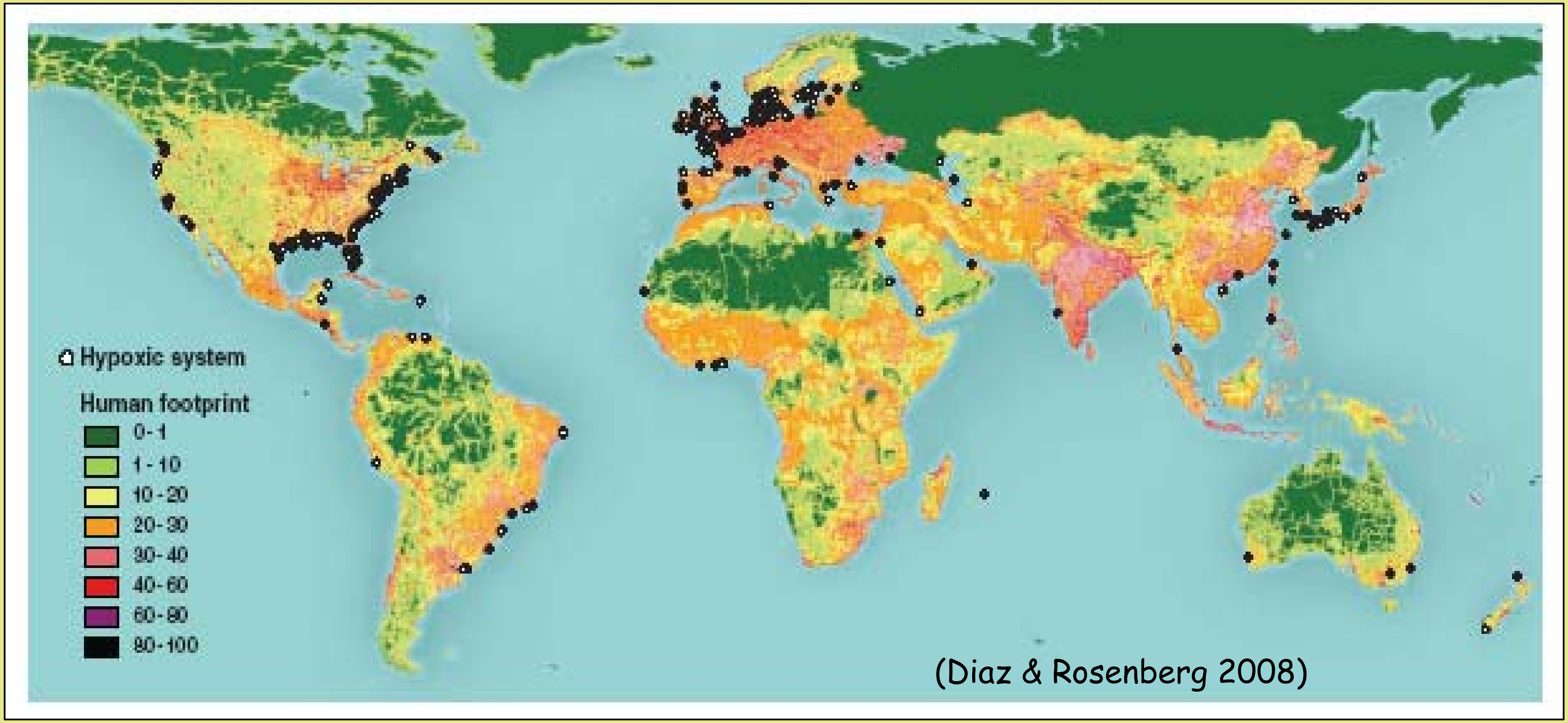
Topics for Today

- A Brief Eutrophication Primer
- WQ Trends in the Potomac (+ and -)
- A Natural "Hot Spot" for Nutrient Losses
- Restoration Activities
- Some Concluding Thoughts

Eutrophication Cartoon



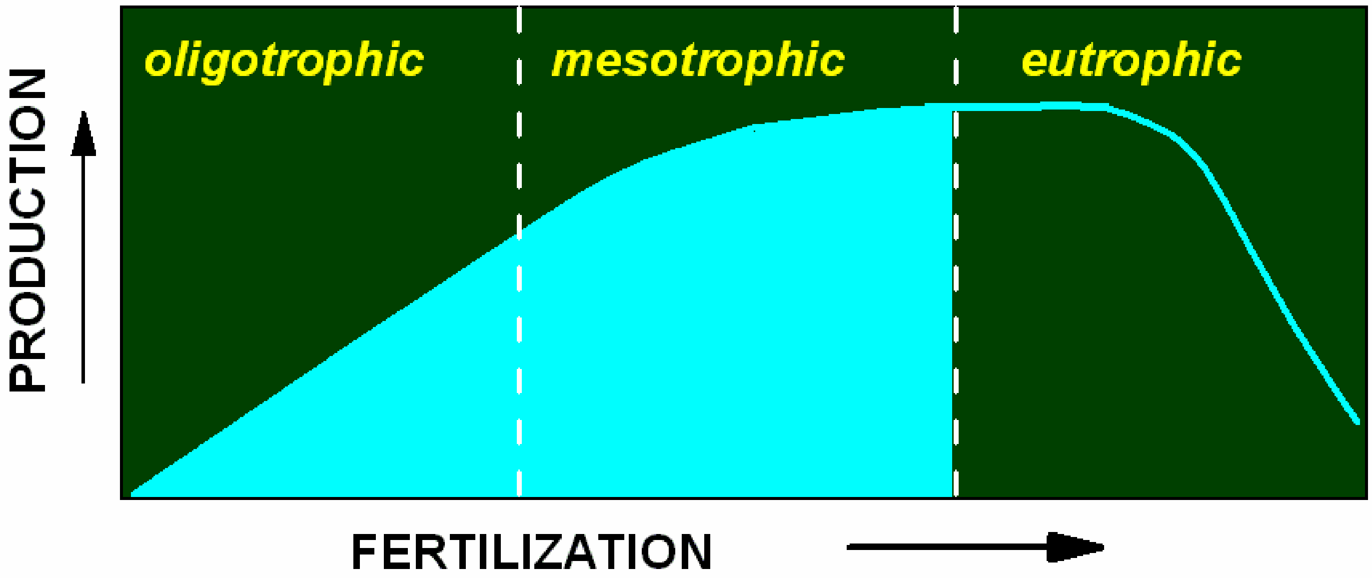
Global Distribution of Hypoxic Systems



• Recent (2008) survey identified > 400 reported systems with hypoxia due to eutrophication; expanded to more regions covering ~250,000 km^2.

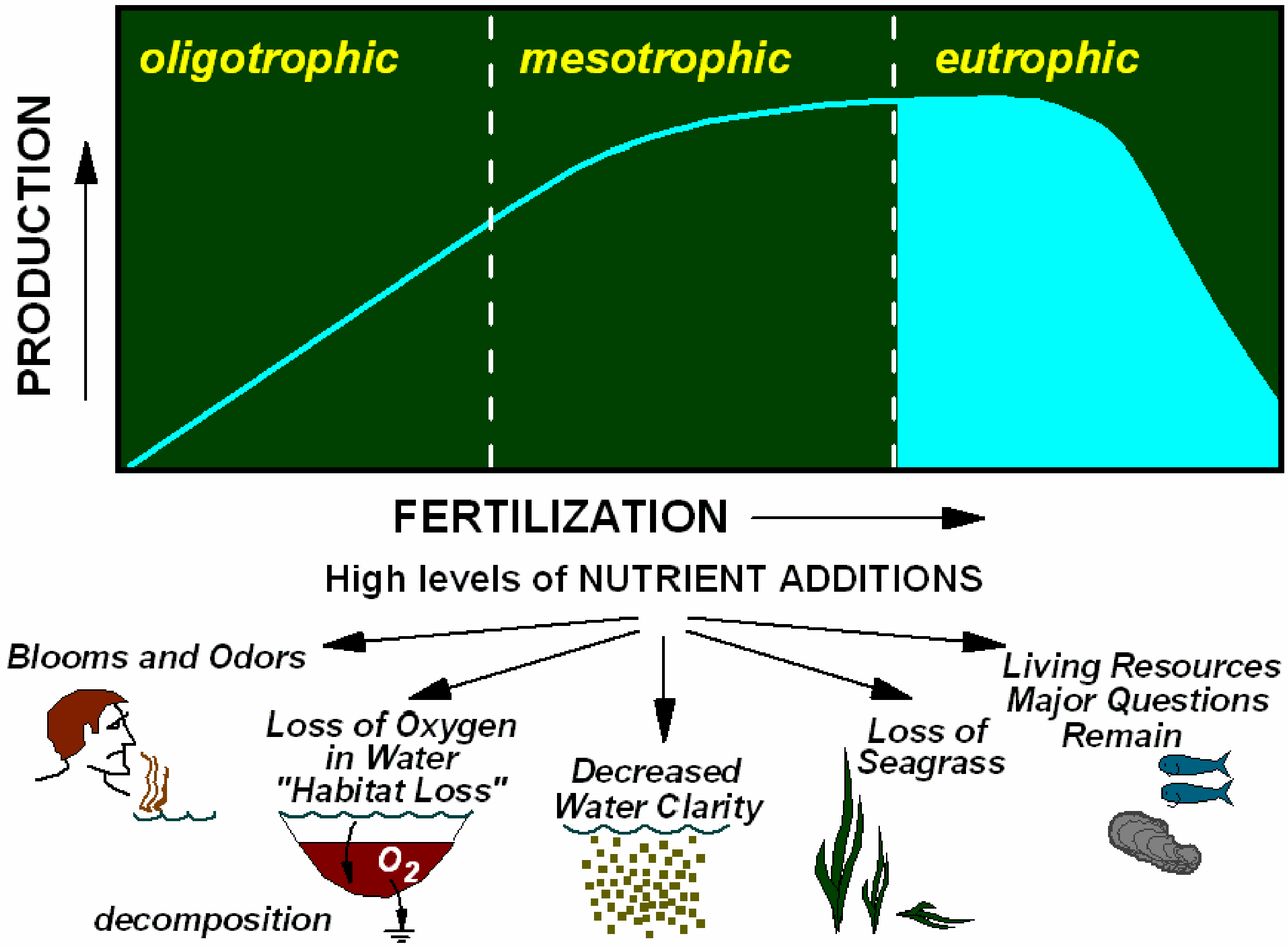
• Hypoxia distribution linked with watershed regions having large human "footprint" (i.e., intense human activity and influence).

POSITIVE EFFECTS



- Essential for plant growth. In most estuaries and the open ocean microscopic plants provide the basic food supply.
- Within limits, increased fertilization increases food supply and production of other organisms.

Negative Effects...Nutrient Obesity



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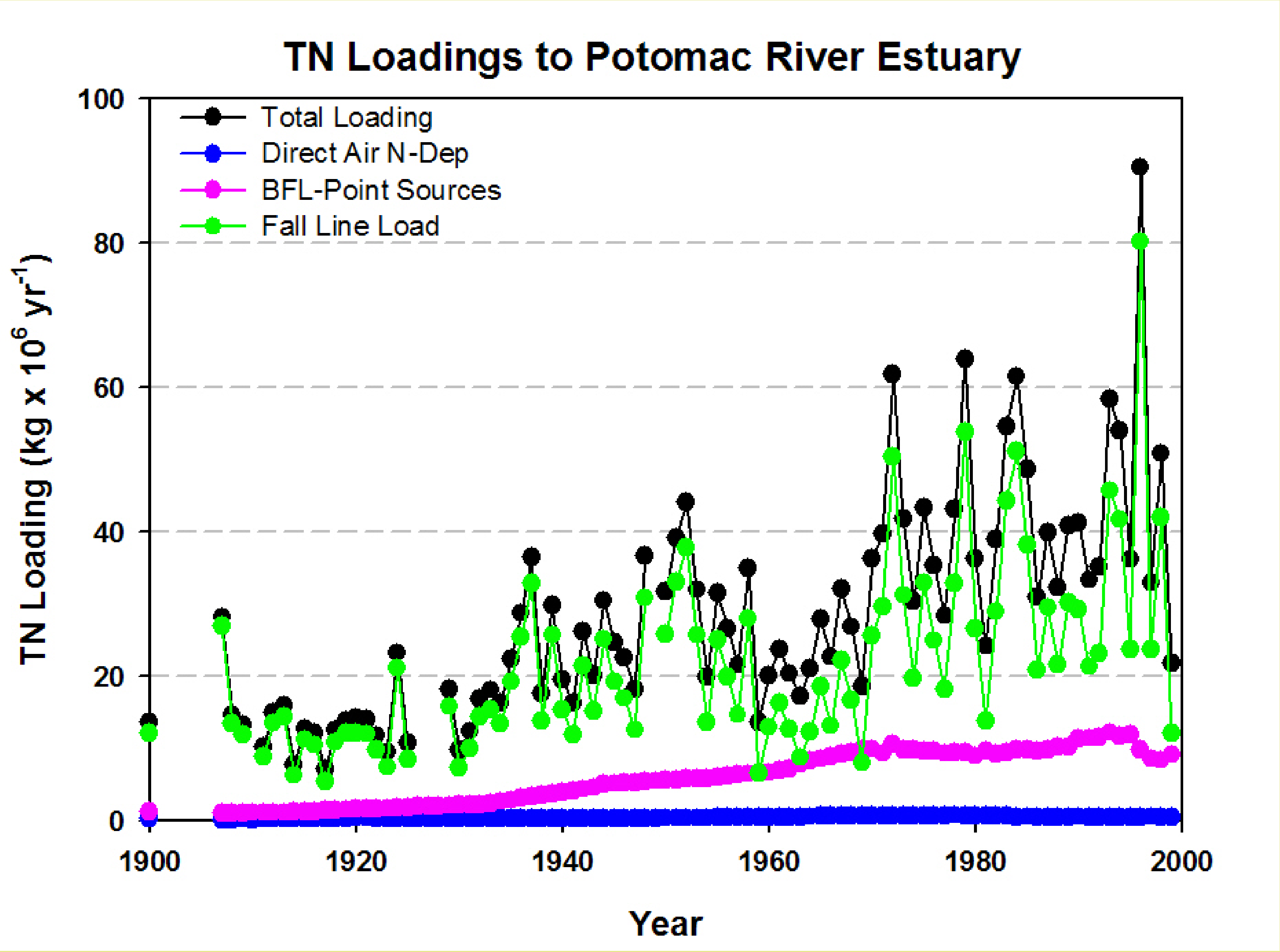
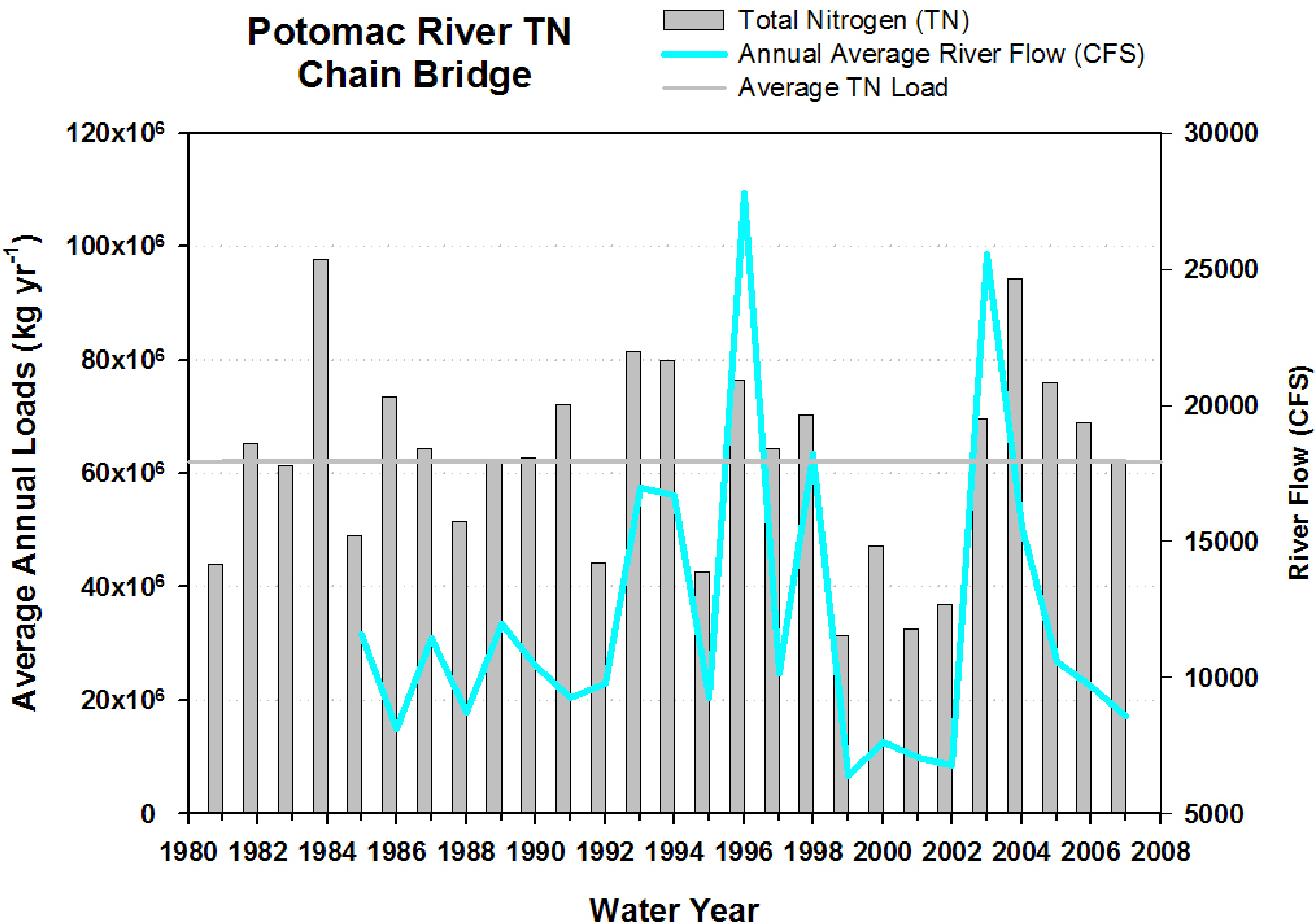


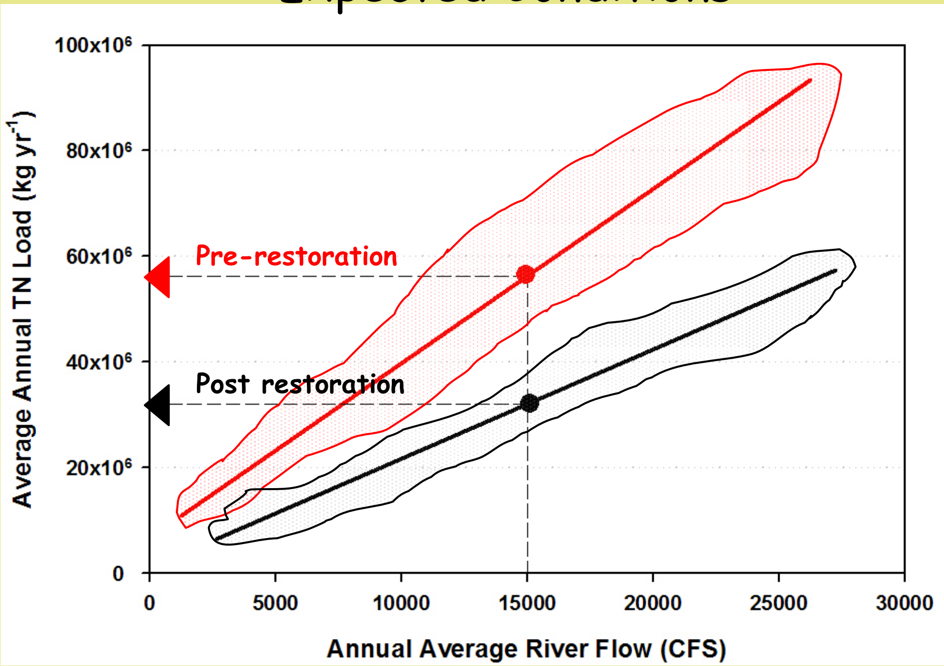
N. Jaworski 2007



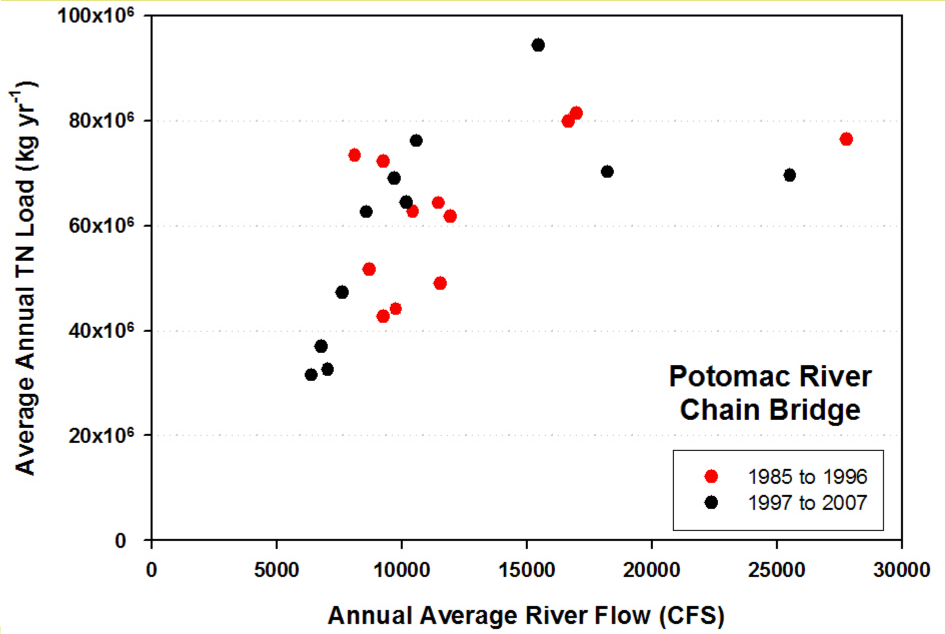
Potomac River TN
Chain Bridge
Total Nitrogen (TN)
Annual Average River Flow (CFS)
Average TN Load
Average Annual Loads (kg yr-1)
0
20x10^6
40x10^6
60x10^6
80x10^6
100x10^6
120x10^6
River Flow (CFS)
5000
10000
15000
20000
25000
30000
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008
Water Year

Potomac River Load-Flow Patterns

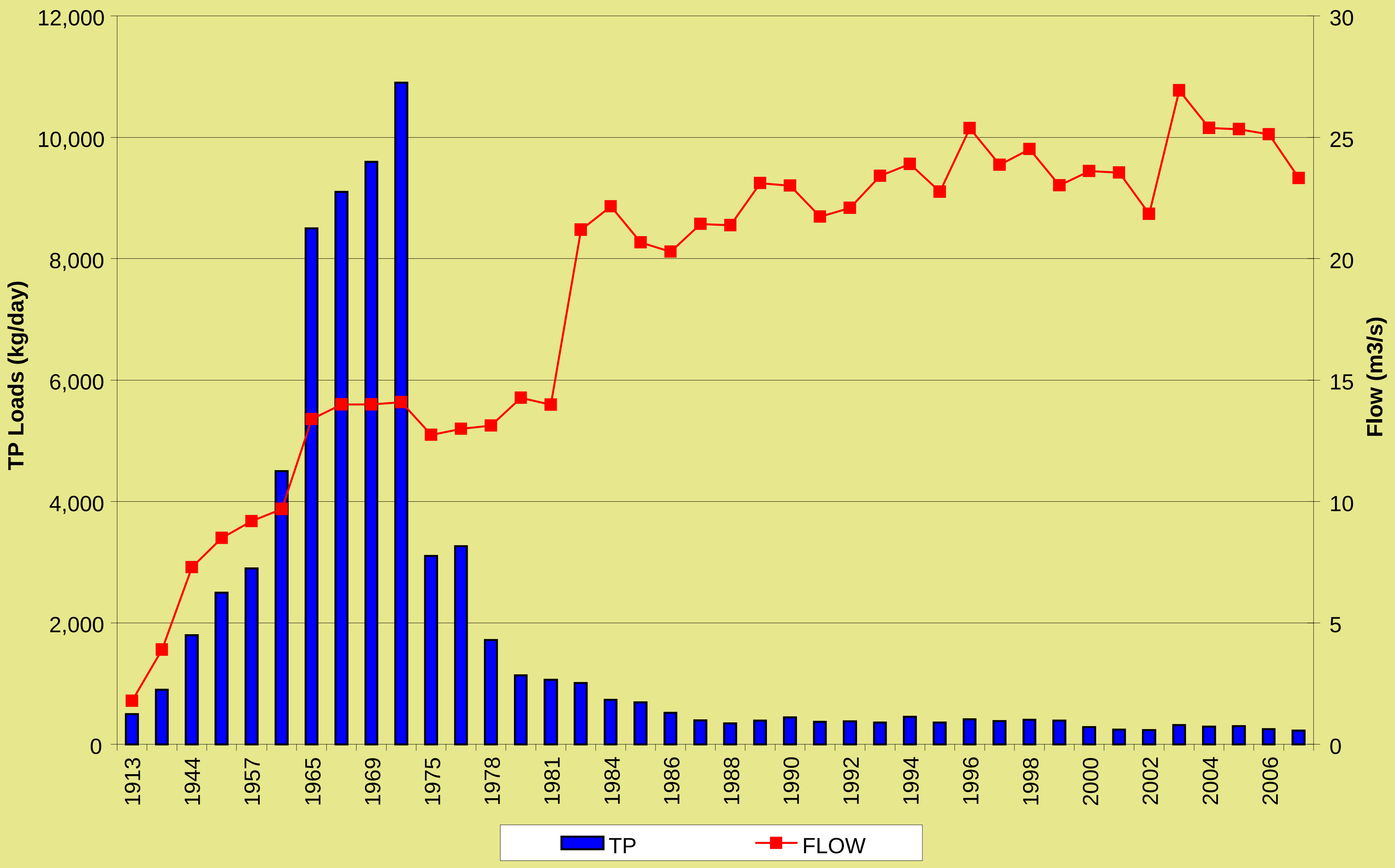
Expected Conditions

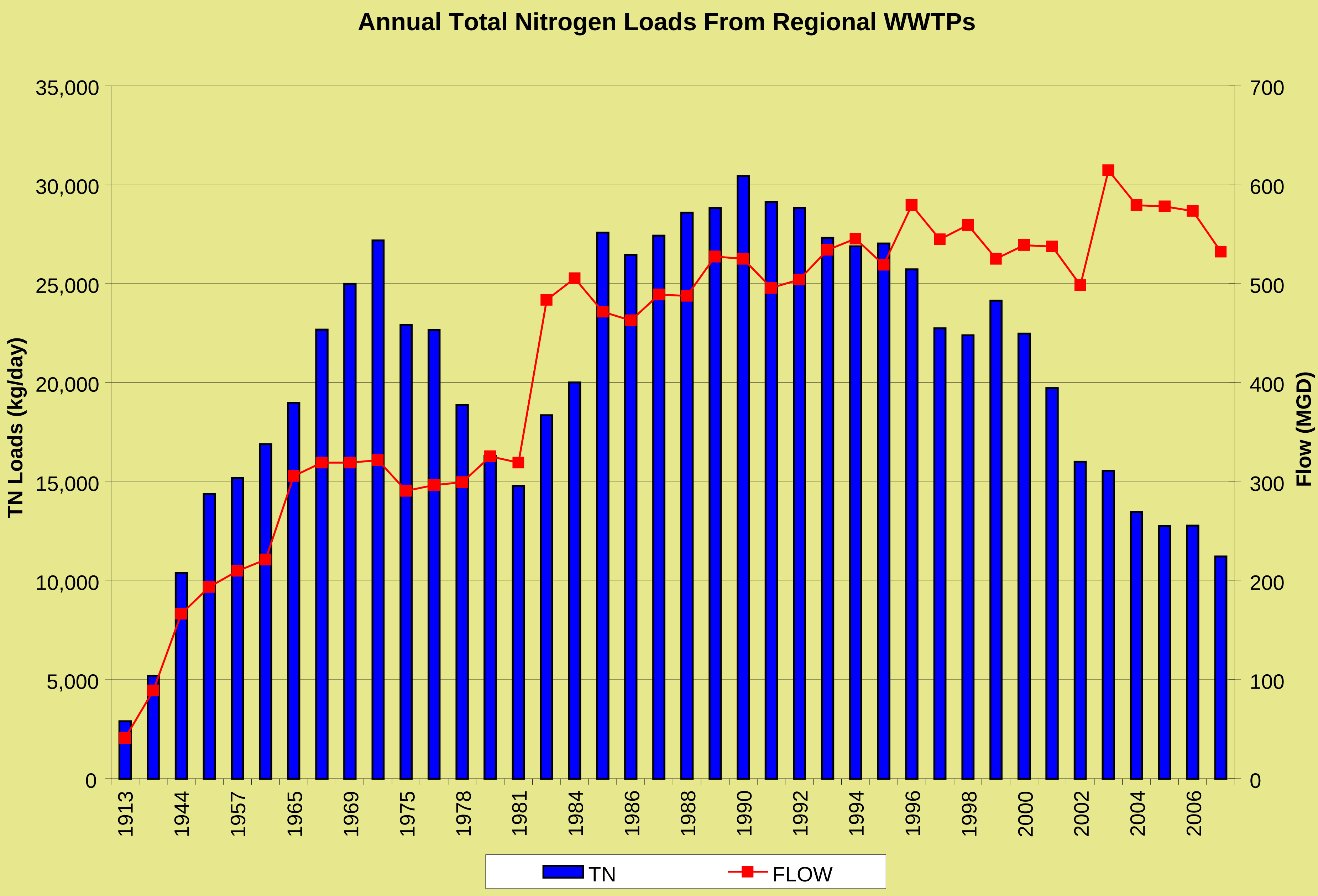


Actual Conditions



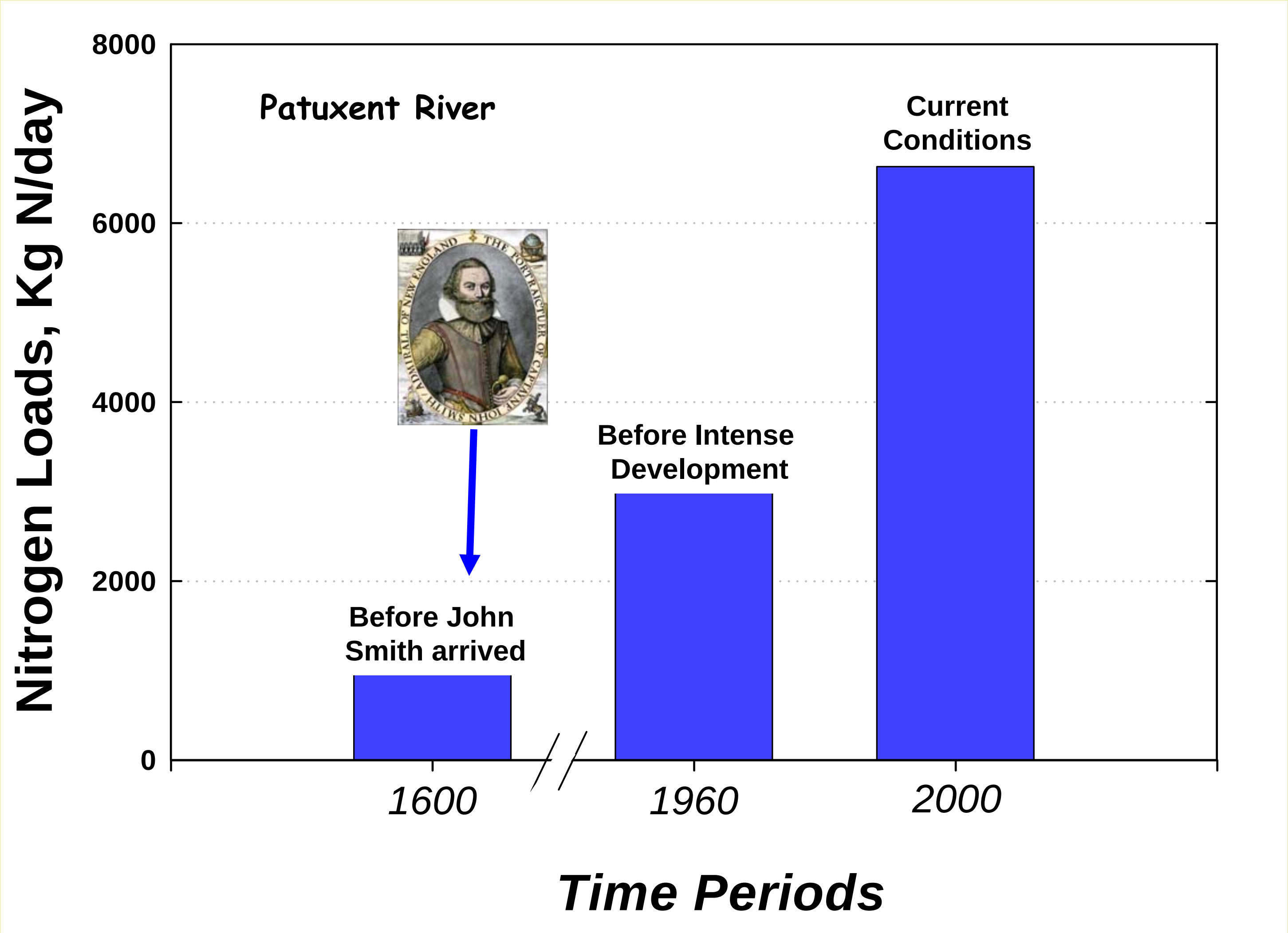
Annual Total Phosphorus Loads From Regional WWTPs



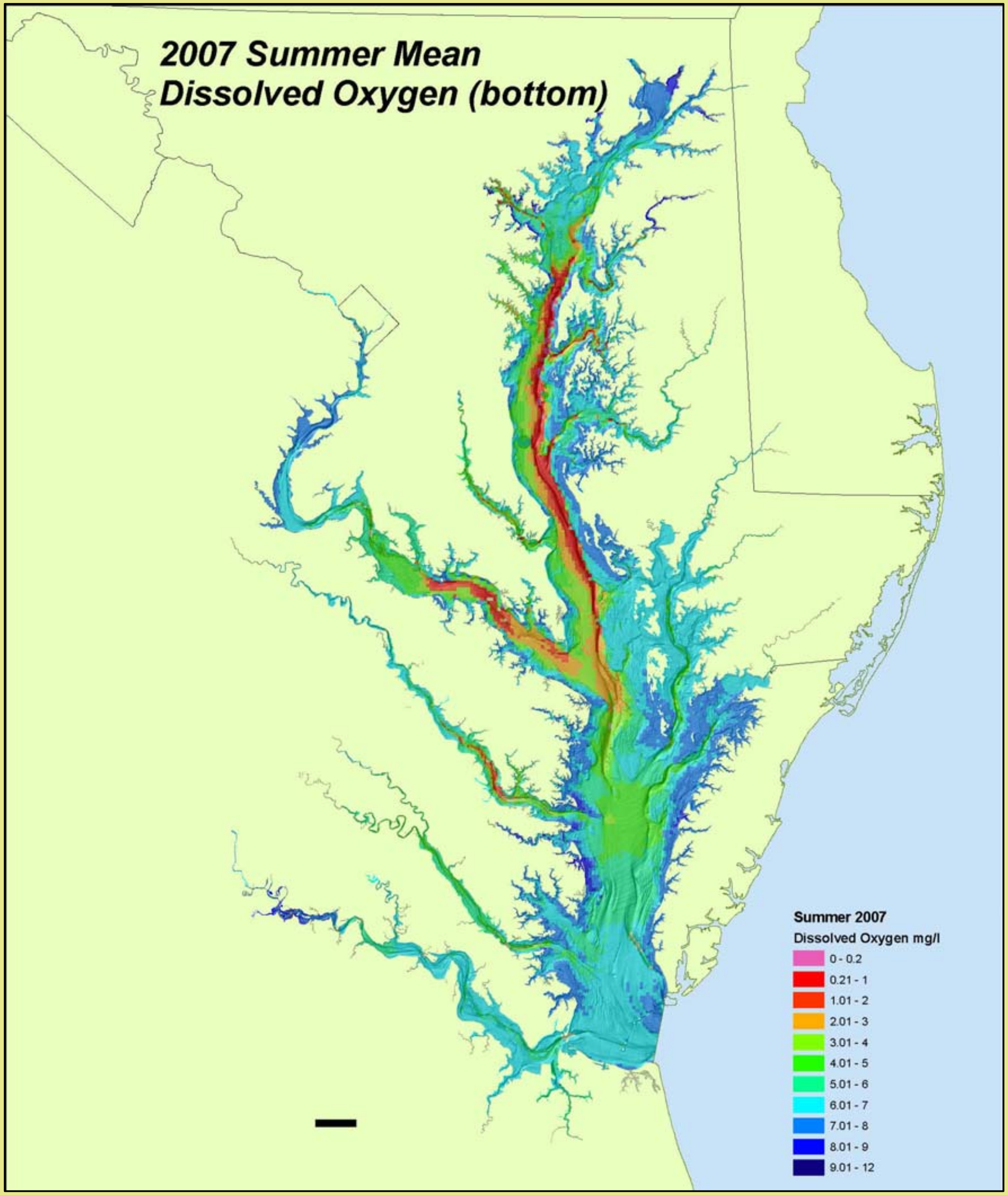


Annual Total Nitrogen Loads From Regional WWTPs
TN Loads (kg/day)
Flow (MGD)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
700
600
500
400
300
200
100
0
1913
1944
1957
1965
1969
1975
1978
1981
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
TN
FLOW

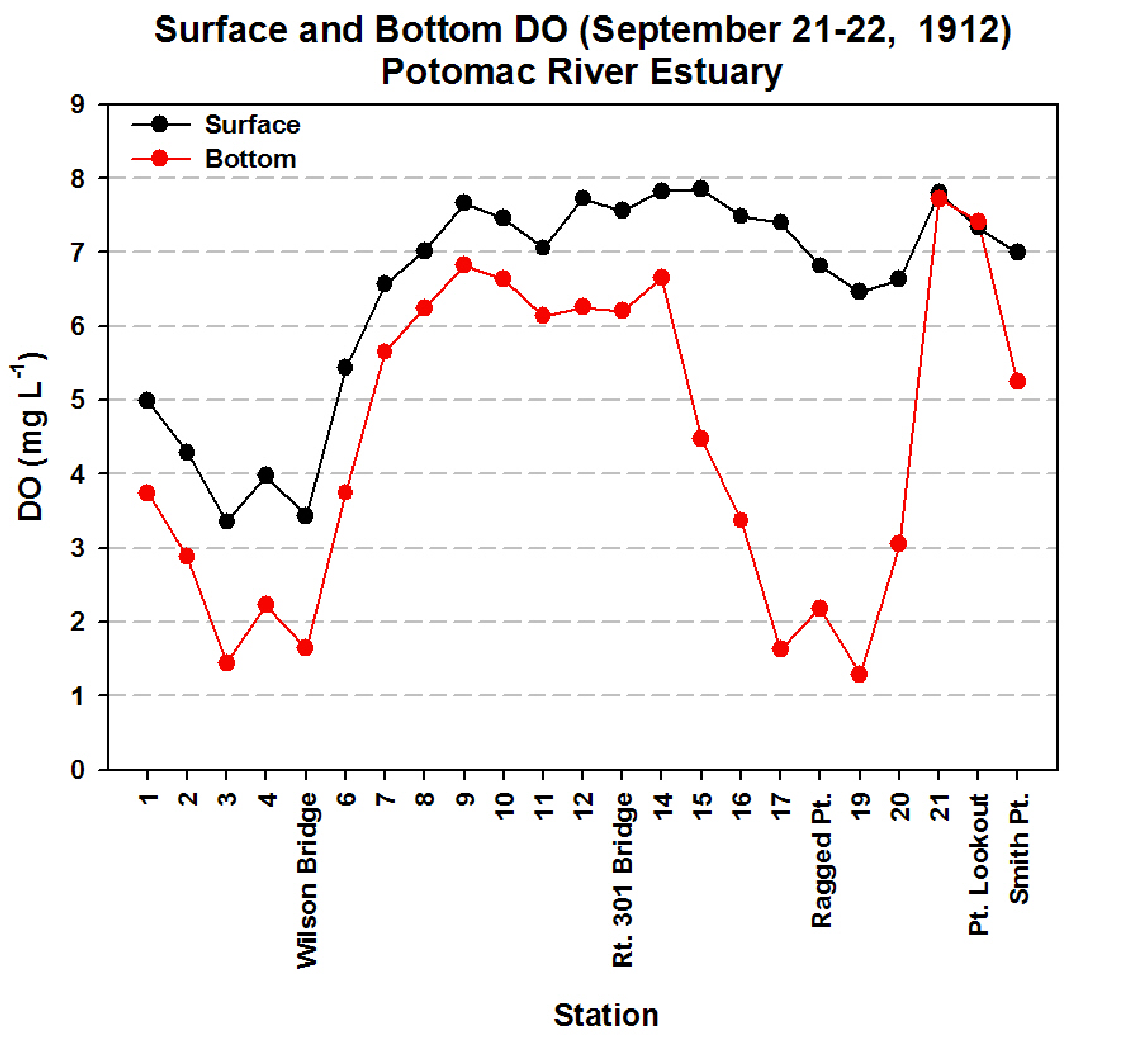
Historical Increases in Bay Nitrogen Loading

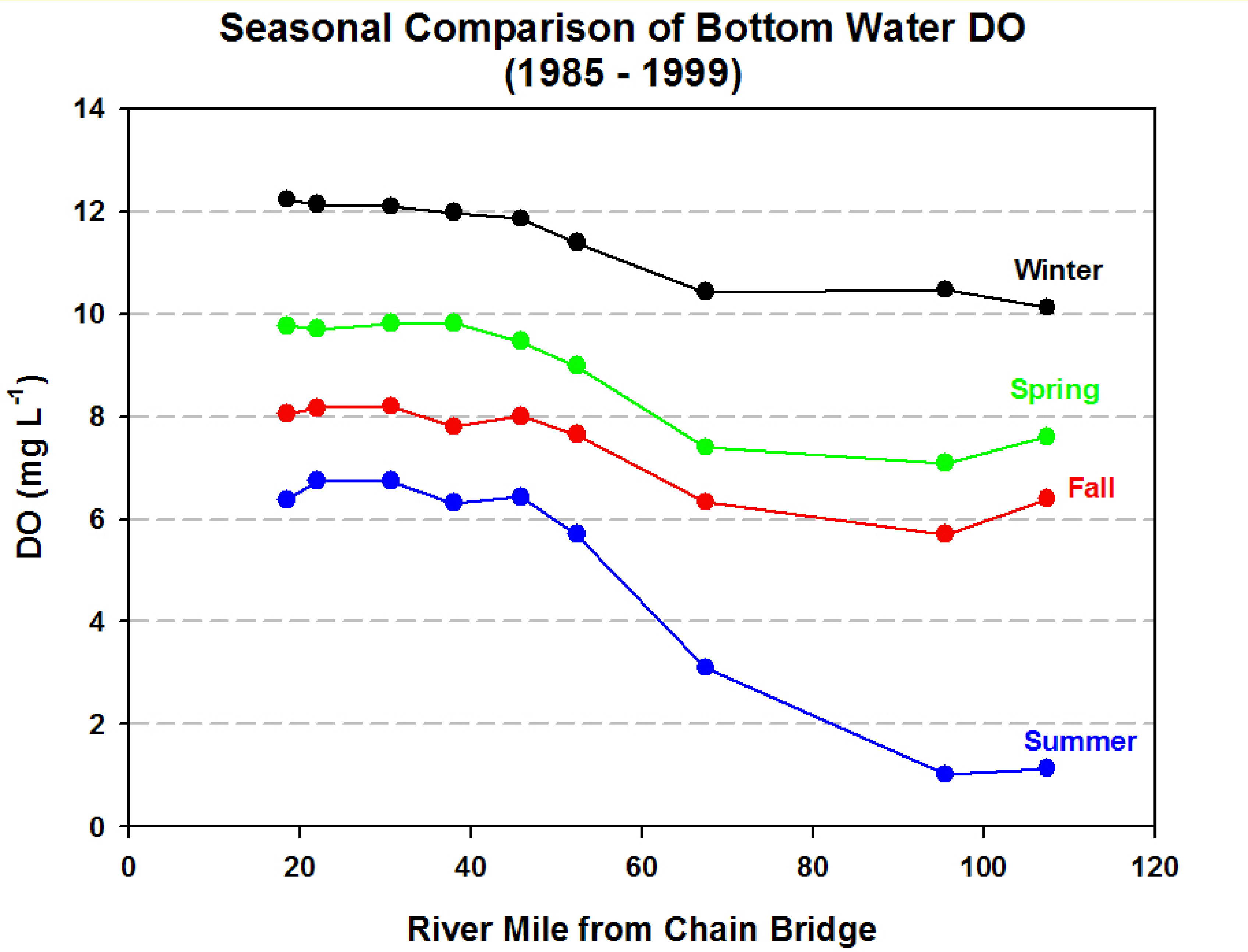


- 7-Fold Increase since John Smith's arrival to Bay Area
- 50% Increase during first 360 yrs & 50% increase in last 40 yrs



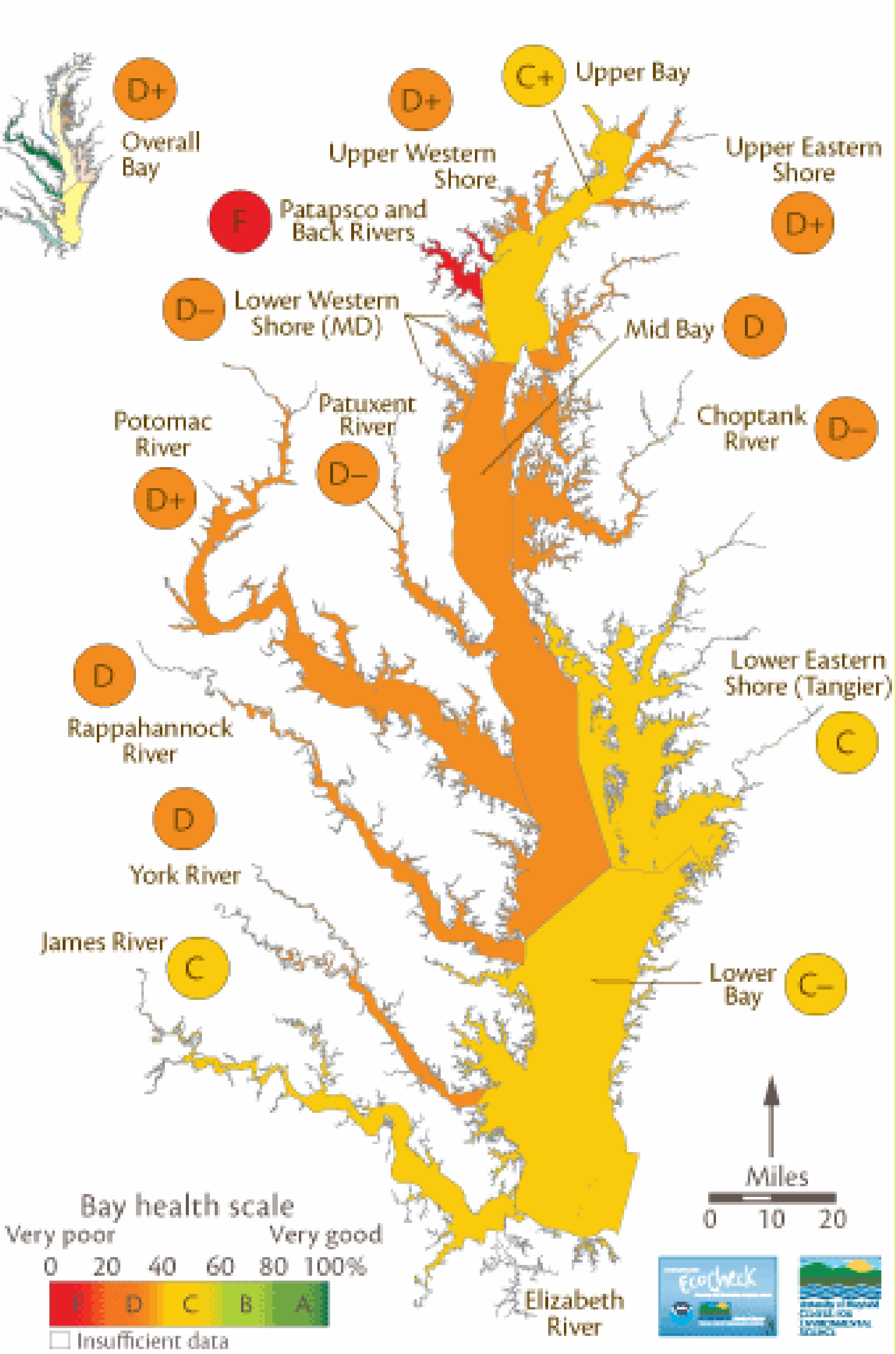
- Hypoxia in 2007 was not particularly severe…but not good
- Potomac one of the large hypoxic zones of the Bay system
- Note the disconnect between the Bay and Potomac low DO waters…suggesting that the Potomac generates its own hypoxia


Surface and Bottom DO (September 21-22, 1912)
Potomac River Estuary
Surface
Bottom
DO (mg L-1)
0
1
2
3
4
5
6
7
8
9
1
2
3
4
Wilson Bridge
6
7
8
9
10
11
12
Rt. 301 Bridge
14
15
16
17
Ragged Pt.
19
20
21
Pt. Lookout
Smith Pt.
Station

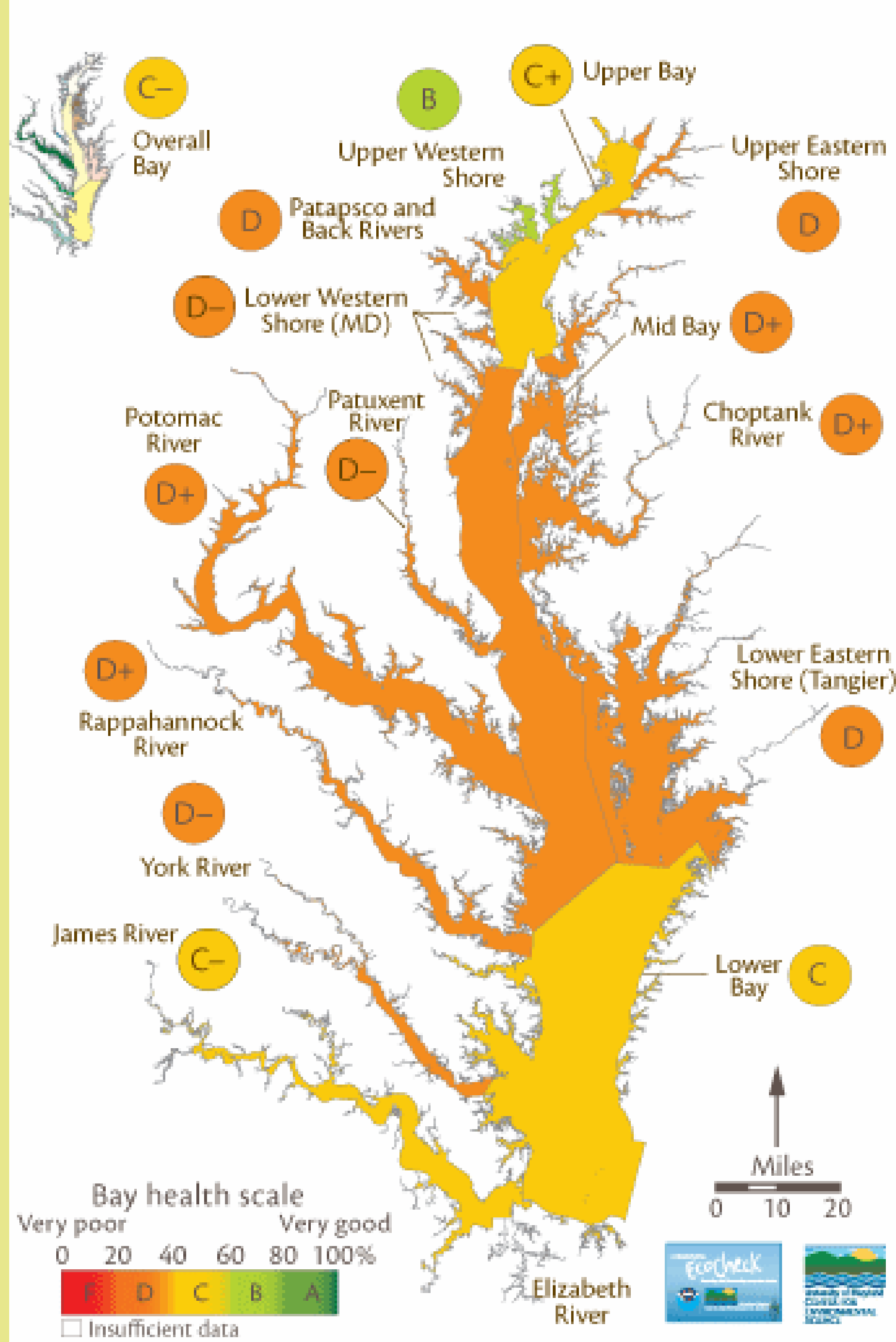


Seasonal Comparison of Bottom Water DO
(1985 - 1999)
DO (mg L-1)
River Mile from Chain Bridge
Winter
Spring
Fall
Summer
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120

Bay Health Index 2006



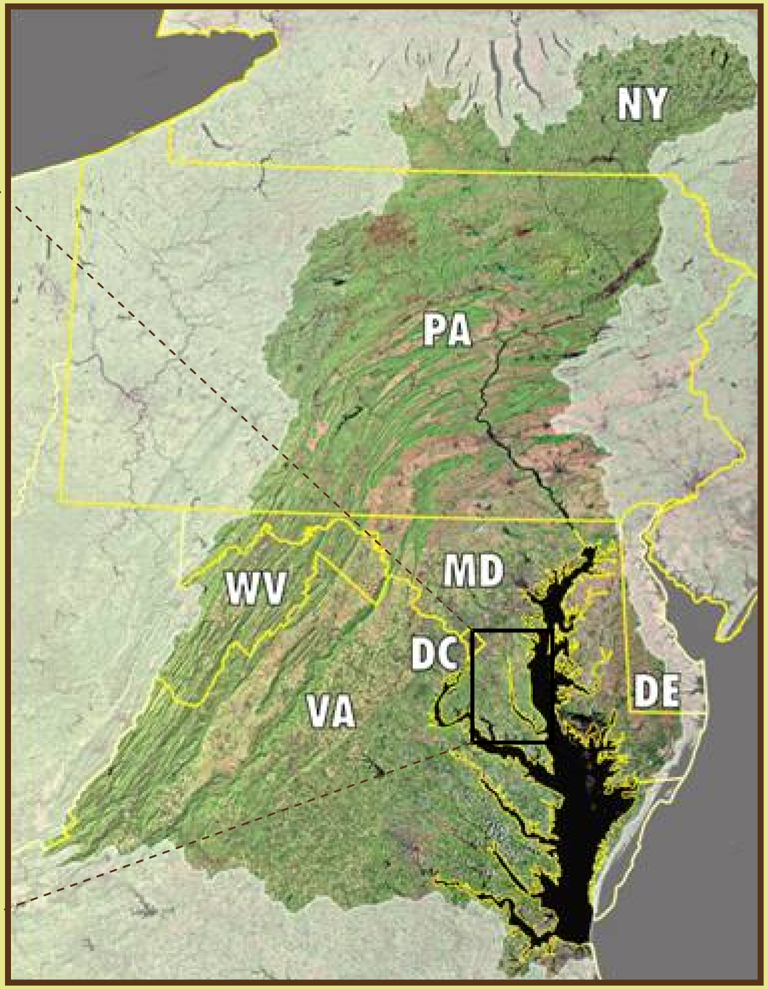
Bay Health Index 2007



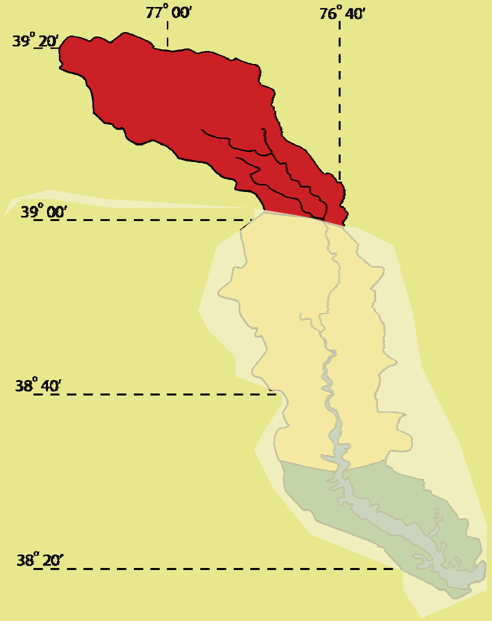
Topics for Today

- A Brief Eutrophication Primer and WQ Trends in the Patuxent
- **A Natural "Hot Spot" for Nutrient Losses**
- Major Restoration Activities
- Some Concluding Thoughts

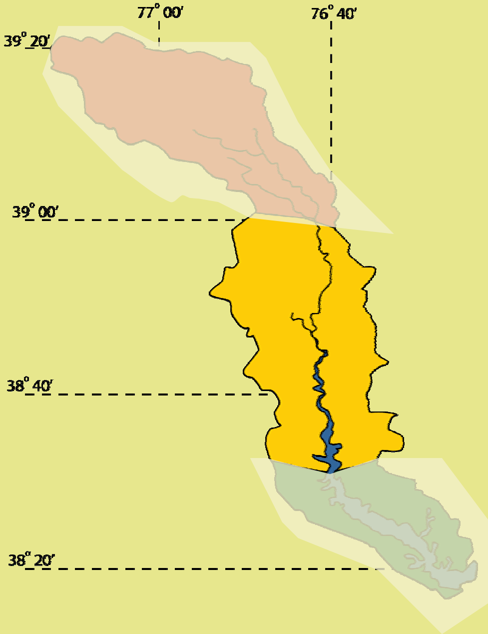
Patuxent River in the context of Chesapeake Basin and Bay



The upper Patuxent River has multiple tributaries, is narrow, has "flashy flow", is a water supply source and is rapidly developing.

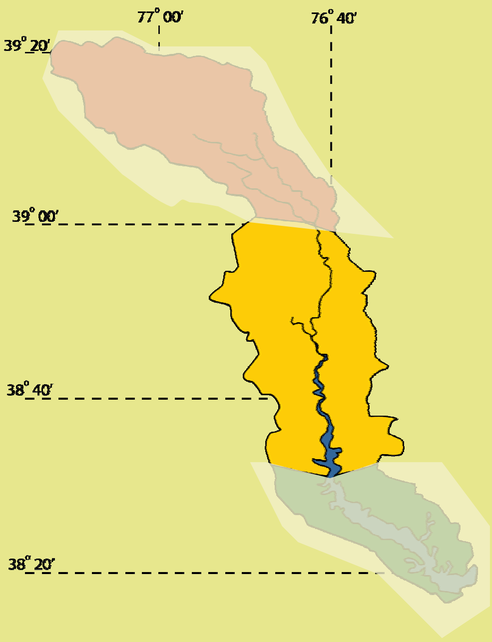


The mid-Patuxent is tidal and has more marsh than open water…a key element in the nutrient economy of this estuary



Jug Bay - University of Maryland

The tidal marshes of the mid-Patuxent are productive and keeping pace with sea level rise



Nutrient Budget Conceptual Model

- Basic components include inputs, internal losses and exports
- Internal storages and selected recycle processes also included
- Data averaged for multiple years
- Large number of data sources including:

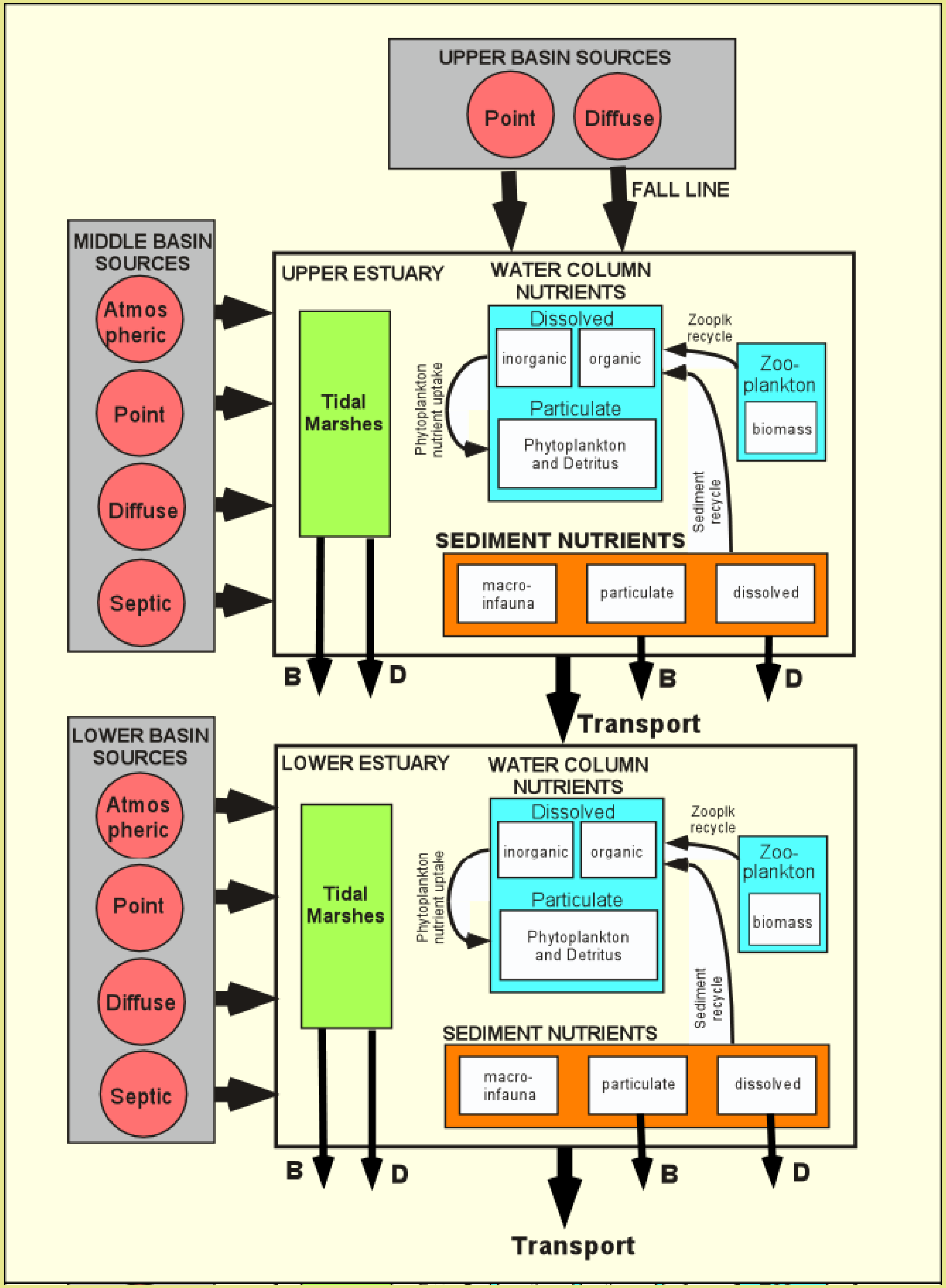
    USGS river monitoring

    Landscape model output

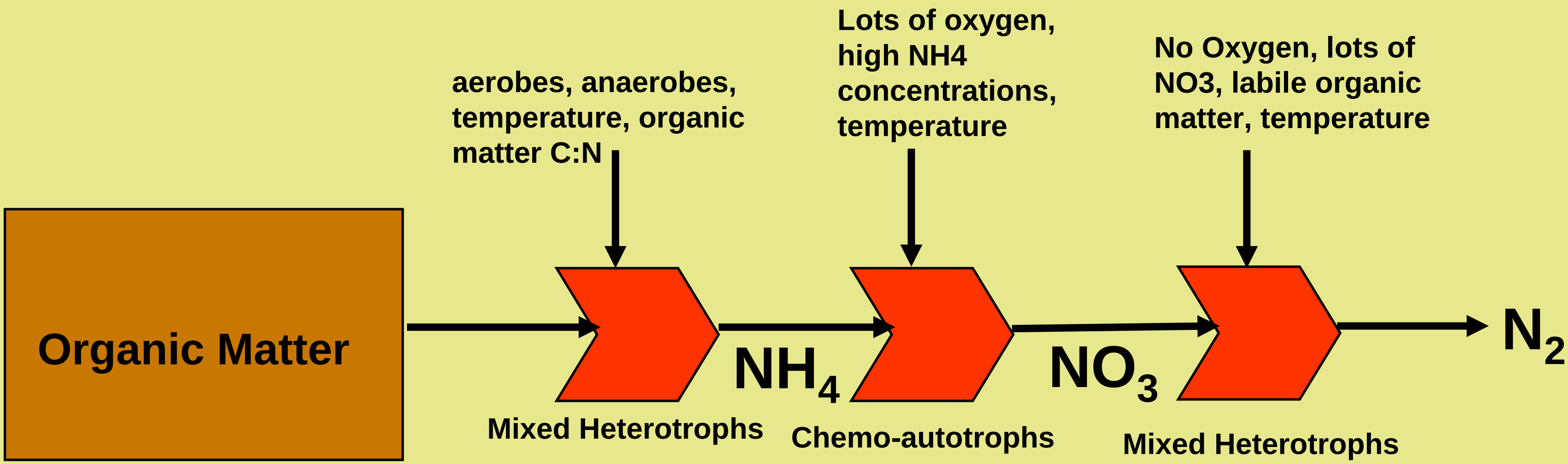
    Estuary monitoring data

    Atmospheric deposition monitoring

    Field Studies…lots of them



Denitrification Sequence



Detailed reaction sequence

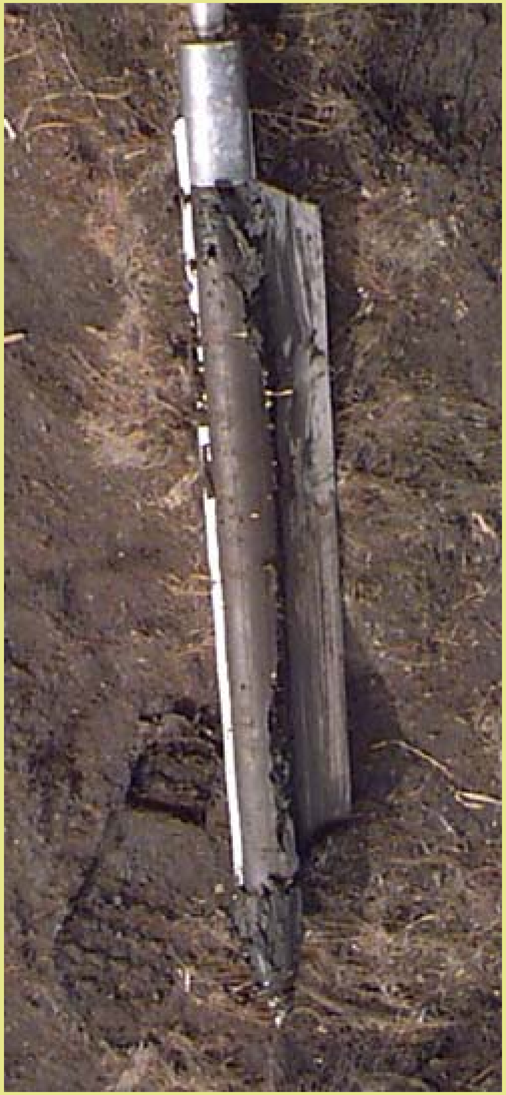
$$NO_3 \rightarrow NO_2 \rightarrow NO \rightarrow N_2O \rightarrow N_2 \rightarrow$$

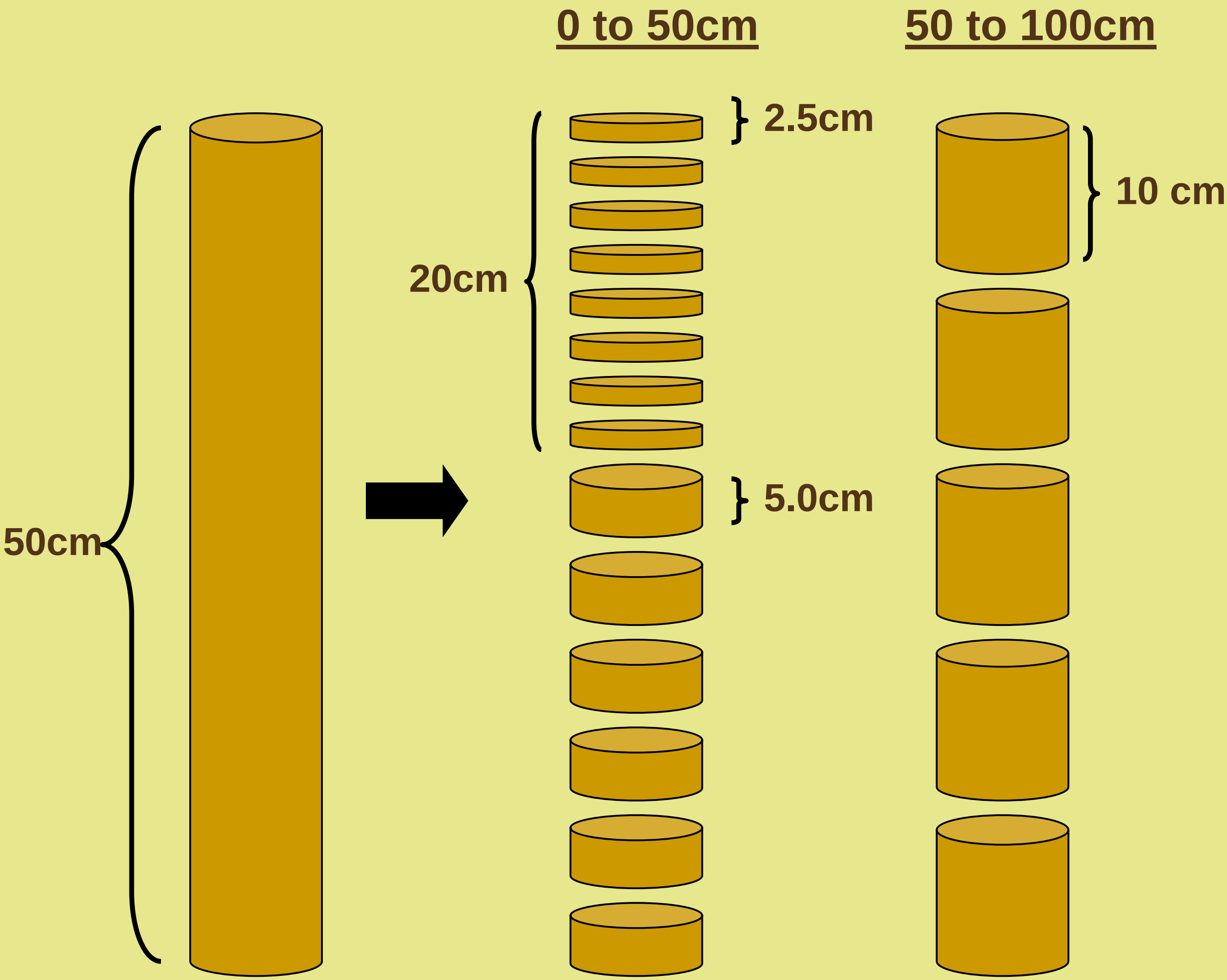
Data Collection for Denitrification

Cores taken by hand from high, mid and low marsh.

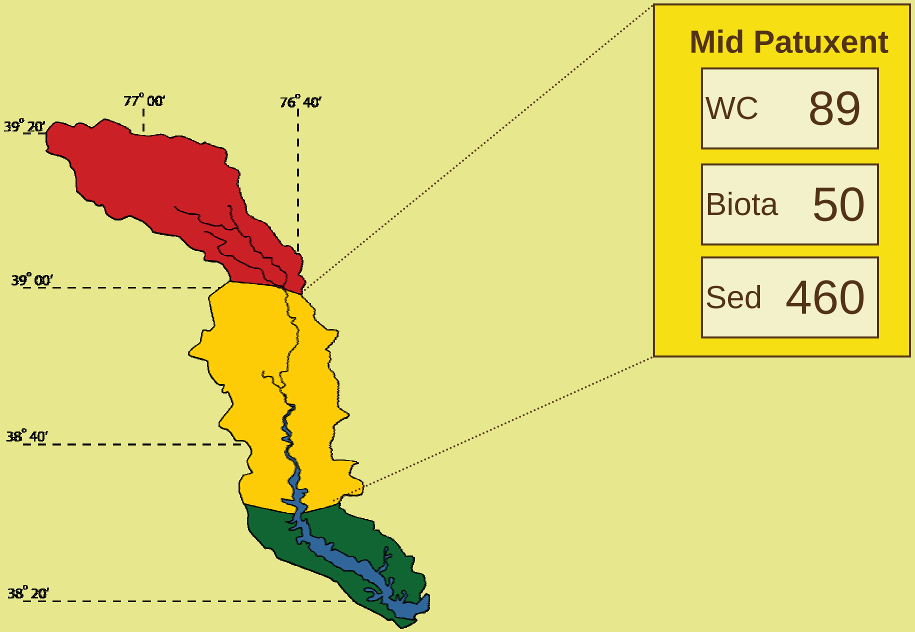
Marsh creek cores taken with a pole corer.

Sediment Cores were used for making Nutrient Burial Estimates





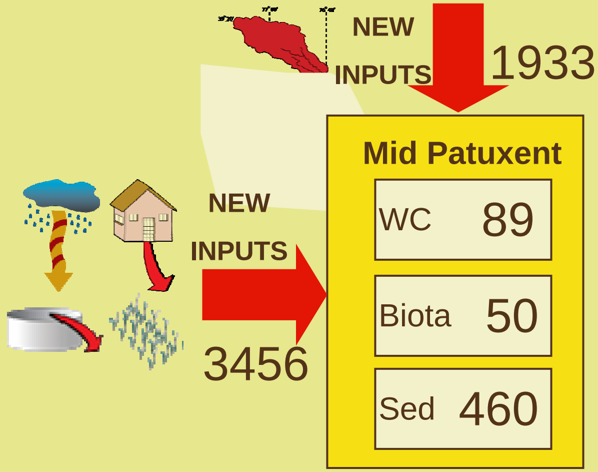
Total nitrogen inputs, transport, and losses in the Mid-Patuxent estuary



Mid Patuxent	
Inputs	?
Denitrification	?
Burial	?
Export	?
Net	?

Flows kg N day^{-1}
Stocks kg $x10^3$ N

Total nitrogen inputs, transport, and losses in the Patuxent estuary

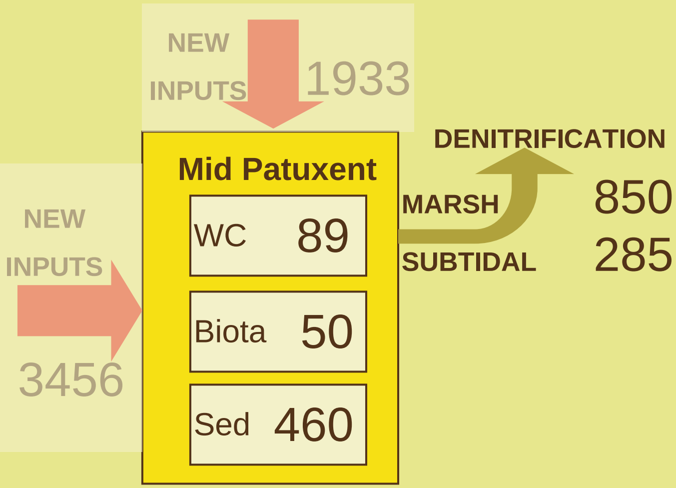


Mid Patuxent	
Inputs	5389
Denitrification	?
Burial	?
Export	?
Net	?

Flows kg N day^{-1}

Stocks kg $\times 10^3$ N

Total nitrogen inputs, transport, and losses in the Patuxent estuary

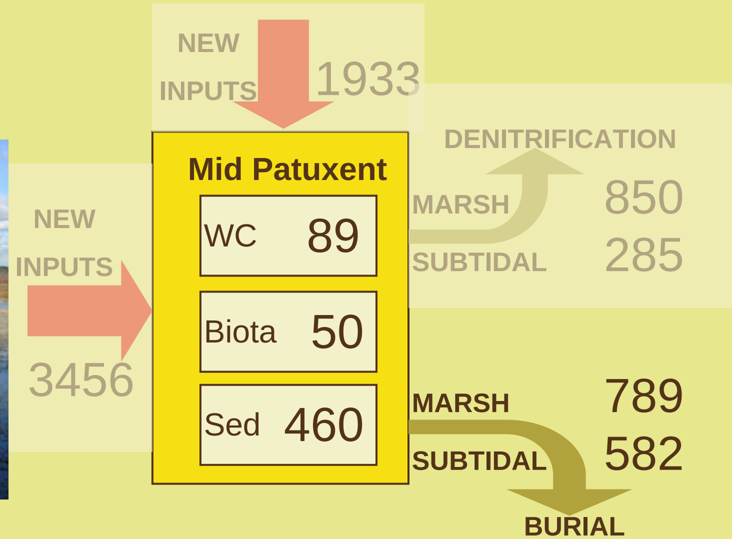


Mid Patuxent	
Inputs	+5389
Denitrification	-1135
Burial	?
Export	?
Net	?

Flows kg N day^{-1}

Stocks kg $x10^3$ N

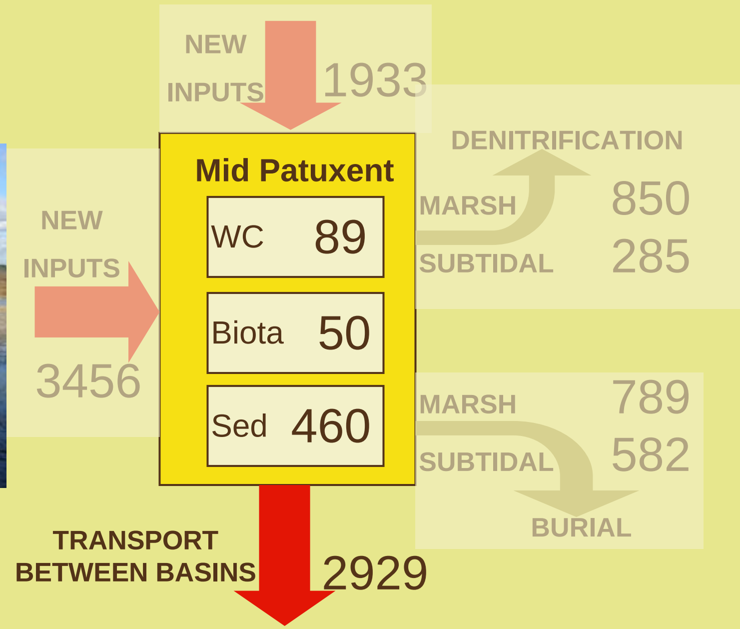
Total nitrogen inputs, transport, and losses in the Patuxent estuary



Mid Patuxent	
Inputs	+5389
Denitrification	-1135
Burial	-1371
Export	?
Net	?

Flows kg N day^{-1}
Stocks kg $x10^3$ N

Total nitrogen inputs, transport, and losses in the Patuxent estuary

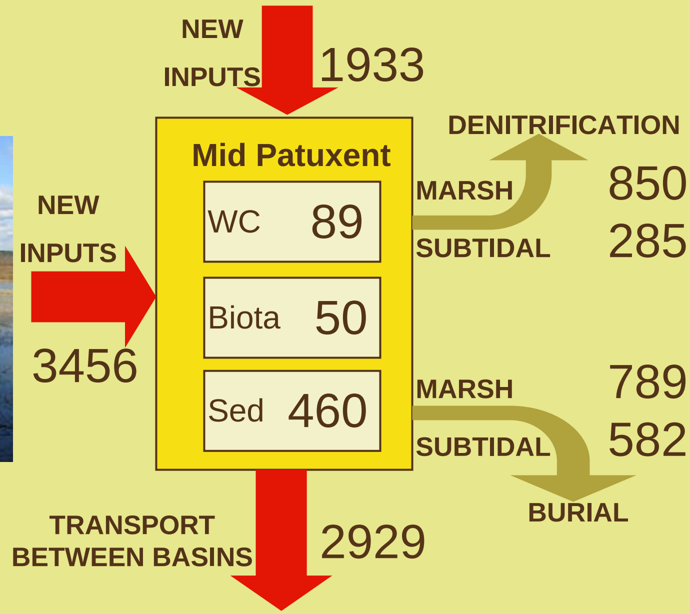


Mid Patuxent	
Inputs	+5389
Denitrification	-1135
Burial	-1371
Export	-2929
Net	?

Flows kg N day^{-1}

Stocks kg $\times 10^3$ N

Total nitrogen inputs, transport, stocks and losses in the Patuxent estuary

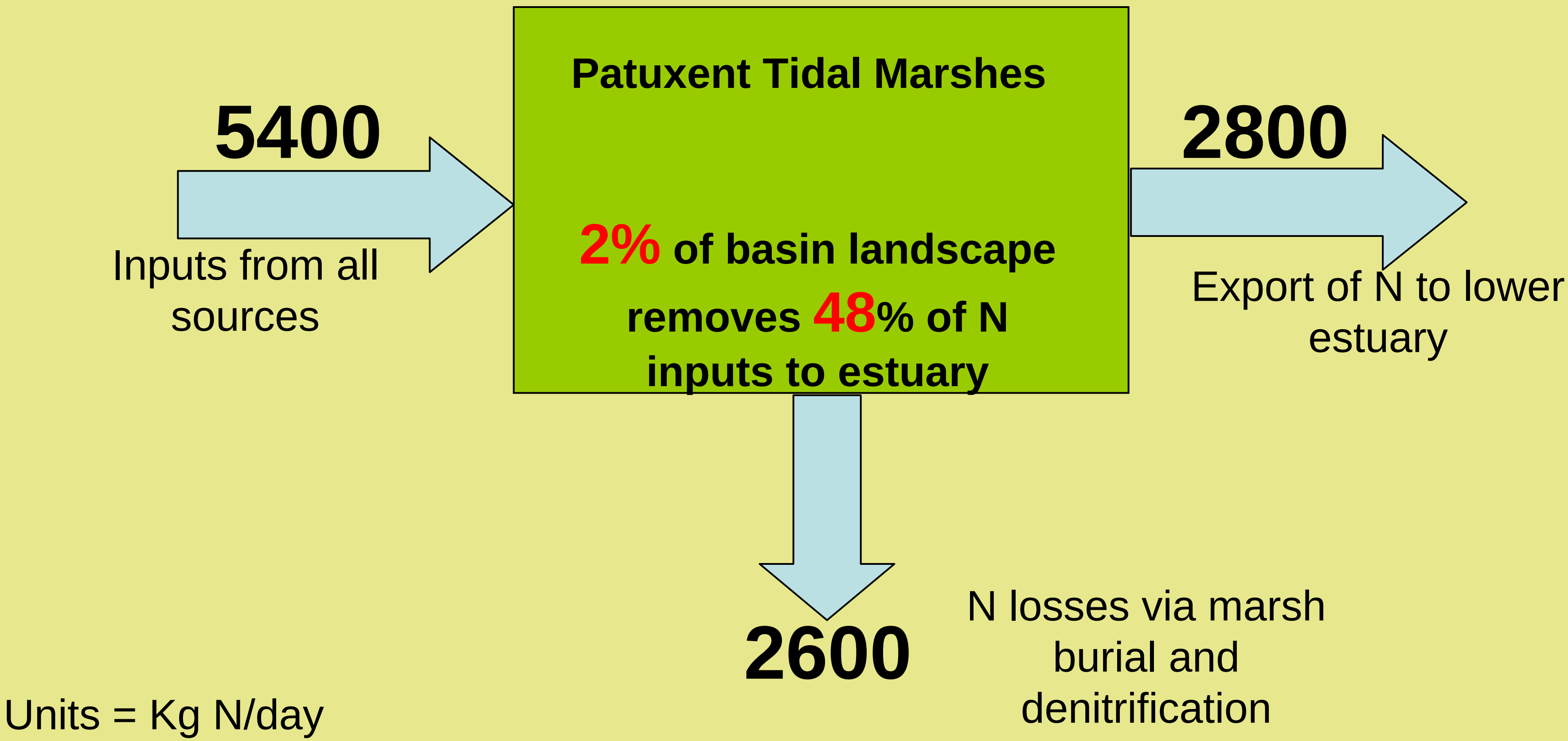


Mid Patuxent	
Inputs	+5389
Denitrification	-1135
Burial	-1371
Export	-2929
Net	46

Flows kg N day^{-1}

Stocks kg $\times 10^3$ N

Tidal Marshes: ***Hotspot*** in the Landscape



Treatment Plants vs Tidal Marshes

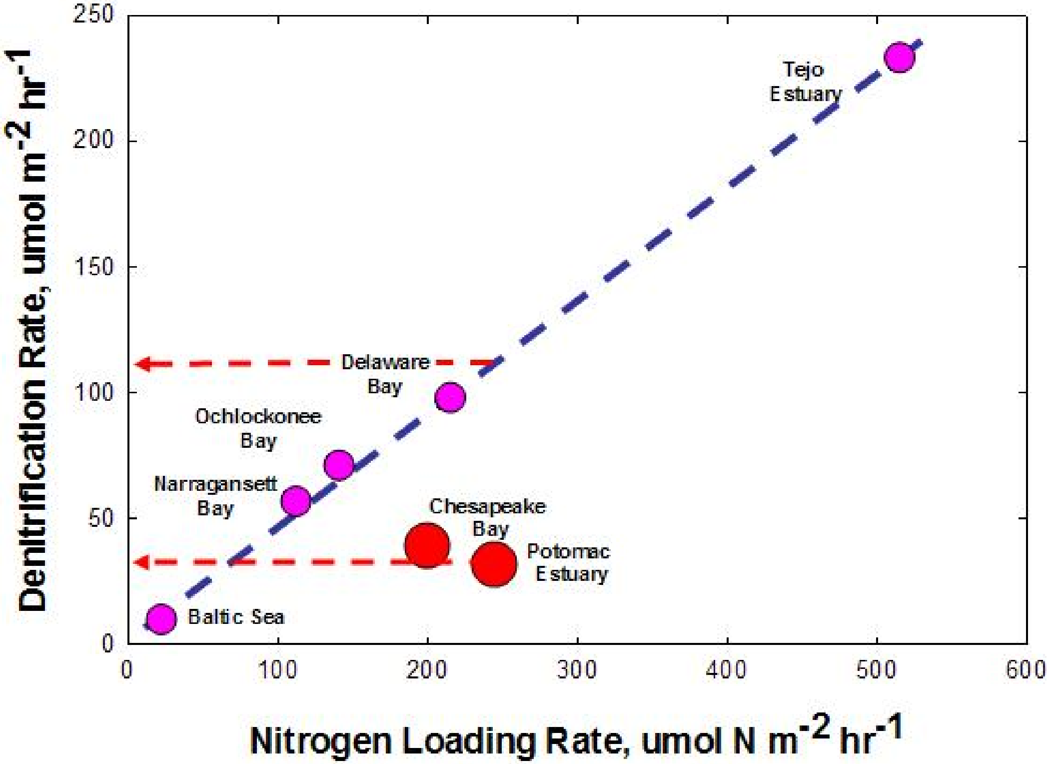
- Wastewater Treatment Plant N Removal via Denitrification **= 0.8 million Kg/year**

- Tidal Marsh N Removal via N burial and denitrification = **0.9 million Kg/year**

- **Both important**...need to promote denitrification in the landscape!

Nitrogen Losses via Denitrification…
The big N- purging process

- Denitrification removes biologically active N from the system (to atmosphere)
- In NON_HYPOXIC systems about 50% of N entering estuary leaves as N2 gas
- Chesapeake systems have much lower N-removal rate likely because of so much hypoxia
- So, increase bottom water DO concentrations!!!!!



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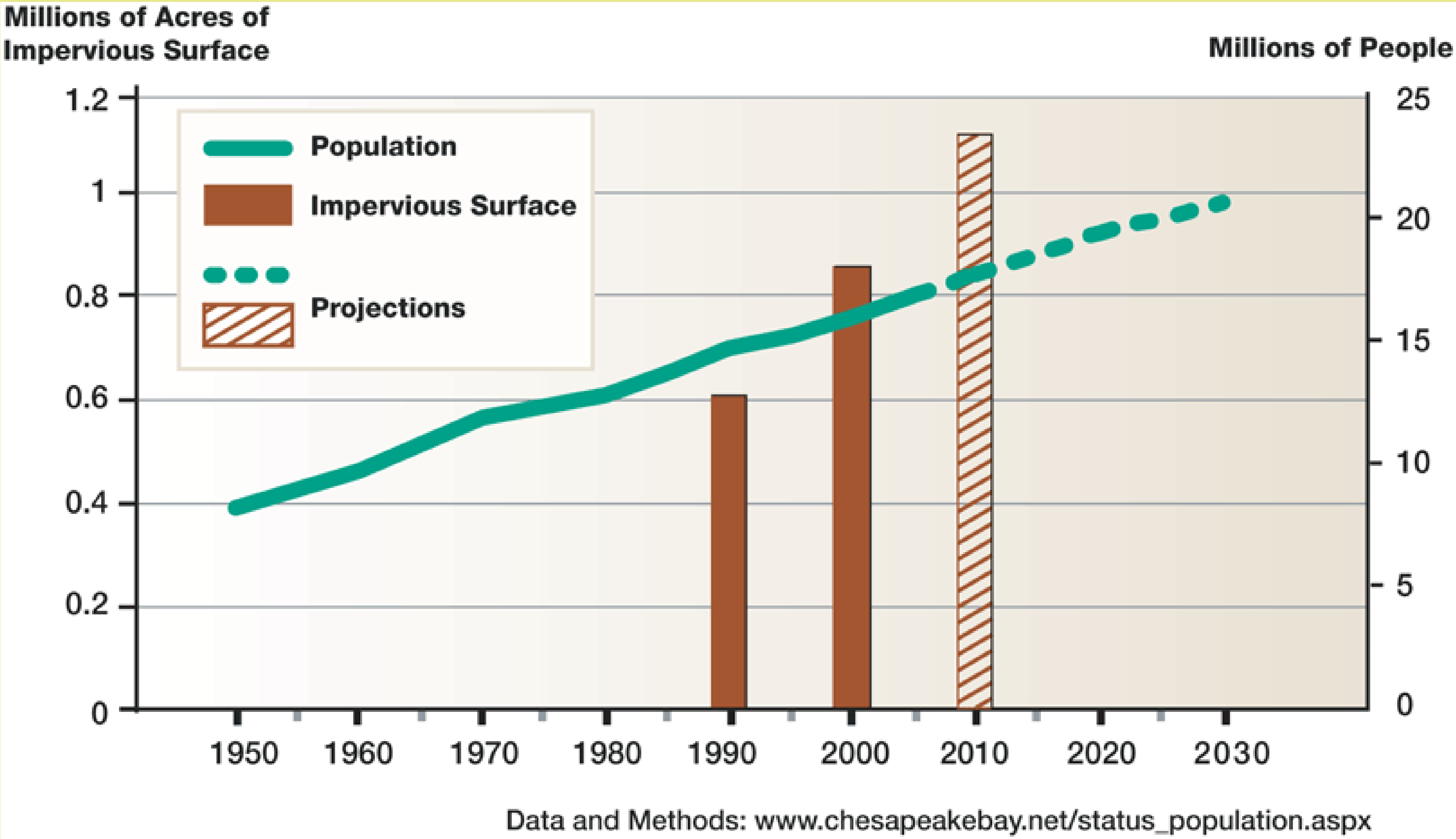
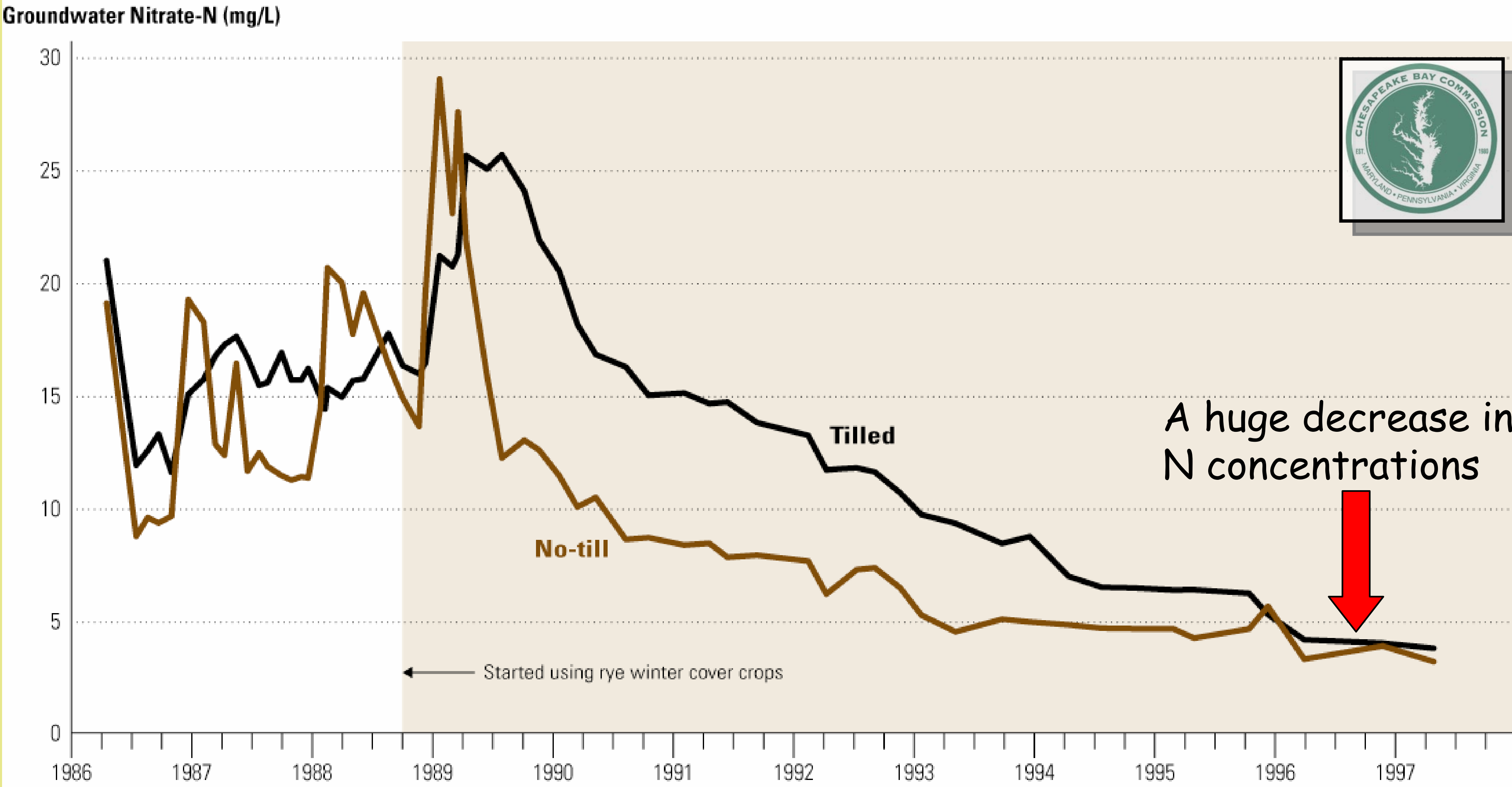
Bay Watershed Population and Impervious Surface



Development and Land Use Change Still Going Strong

Conservation Practices Deliver Water Quality Benefits

Average Nitrate-N concentrations in shallow groundwater under two field watersheds planted continuously with corn at 140 lbs. N/acre, 1986-1997.



SOURCE: STAVER AND BRINSFIELD. J. SOIL AND WATER CONS. 53: 230-240, 1998.

Some Ideas from Paleoecologists

- Pre-colonial landscape covered with forests and MANY WETLANDS
- In past 300 years (especially last 50 years) nutrient loads have diversified and INCREASED about 6-8 fold.
- Pre-colonial N cycle maintained by balance of N-fixation and denitrification…for >1000 years.
- Deforestation and wetland loss led to loss of landscape sites for denitrification
- BEAVERS were important for denitrification sites…likely 5 million of these busy rodents in pre-colonial watershed (~1940 human population)
- Restore the pre-colonial wet and marshy condition…mimic the beavers coupled with other more conventional approaches…
- This is a huge effort and results will take time because of lags in groundwater transport.

From Brush 2008

Storm Water Management: Wet Pond Example

Pollutant Removal Efficiencies:
TSS: 46%
TP: 46%
TN: 32%

There have been many of these constructed in the Patuxent Basin…HOW or IF they work is largely unknown.

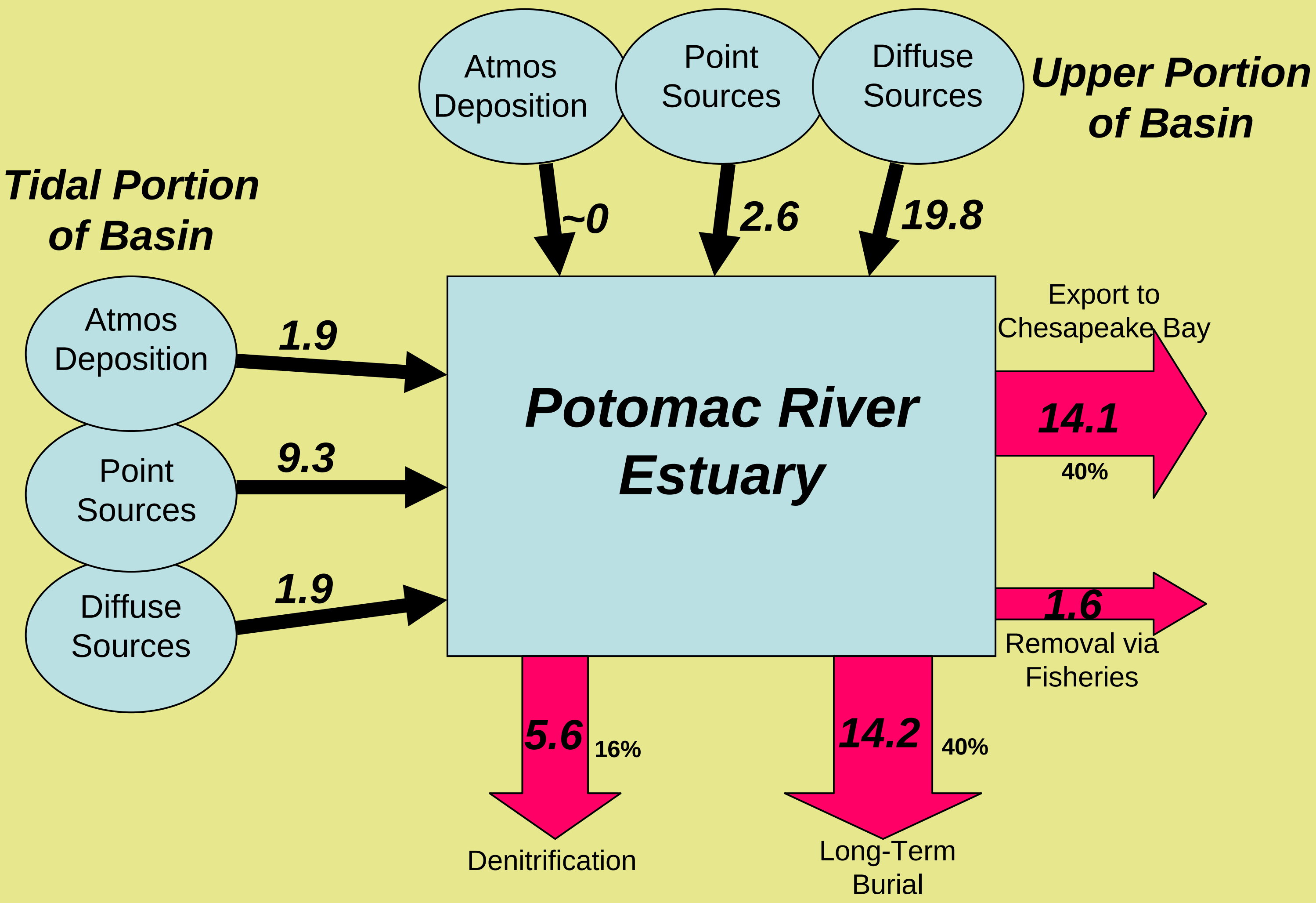
We need effective SWM systems…the new Federal administration (ECOLOGICAL) infra-structure initiative

Concluding Thoughts

- Restoration in the face of high growth rates is tough…it has largely not worked for diffuse sources or just managed to"hold the line"…total loads have remained high
- The Potomac is a typical"OVER-ENRICHED" estuary…too much of a good thing
- Diffuse sources dominate, need serious attention and will likely be expensive…creativity is needed up in the basin.
- There is a need to focus on basin "hot spots" both for preservation (tidal marshes and other wetlands) and restoration (adding "ecological plumbing") to urban and suburban areas

Potomac River Estuary Nitrogen Budget

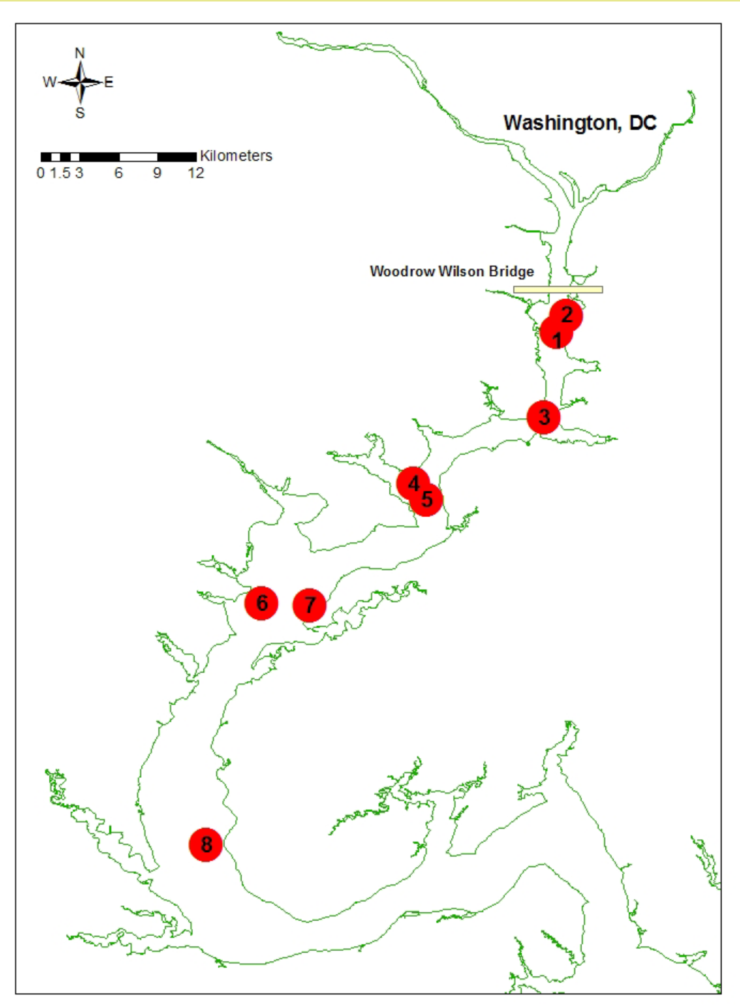
(1985-1986)

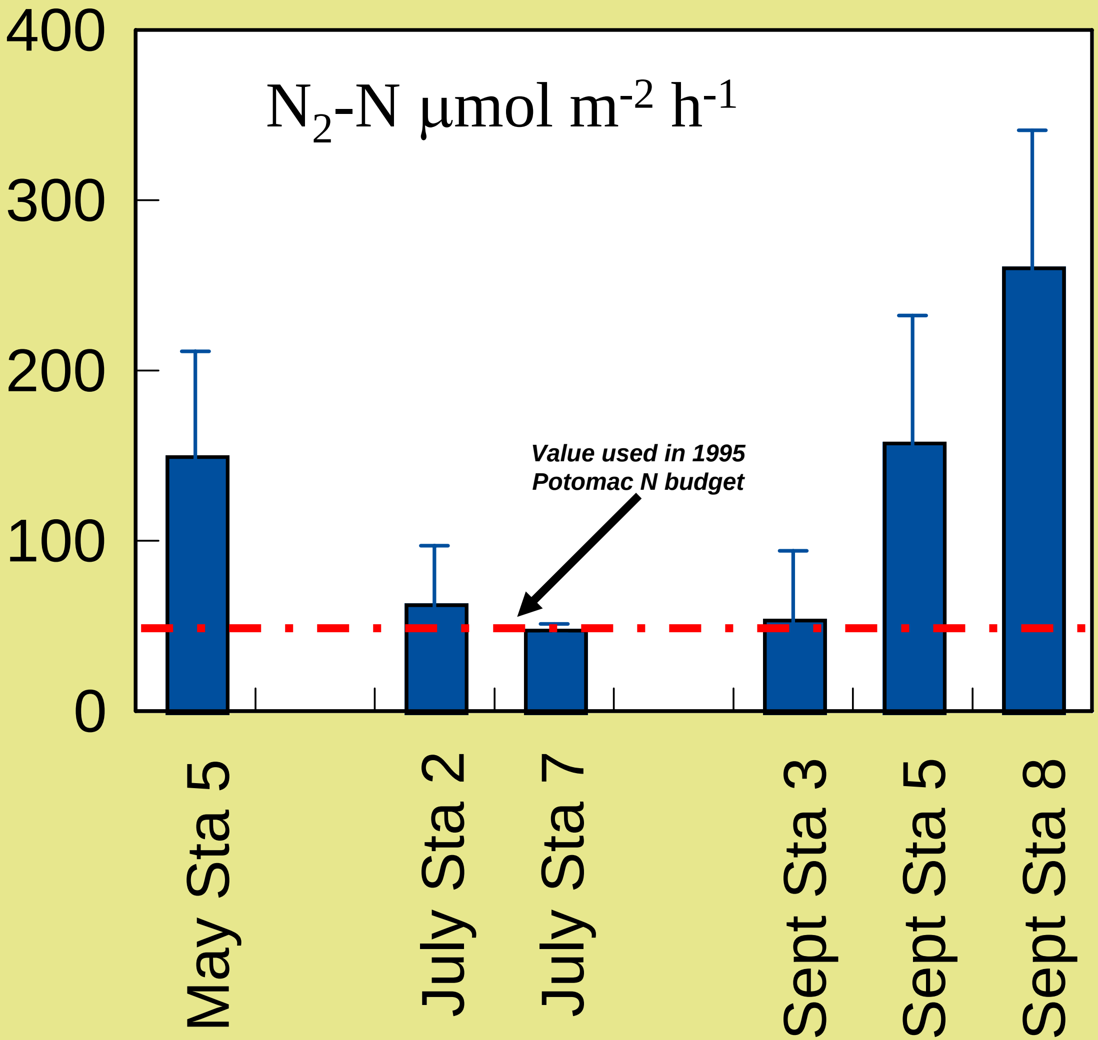


Total Load = 30-35 g m^{-2} yr^{-1}

Boynton et al 1995

Potomac River Denitrification Rates

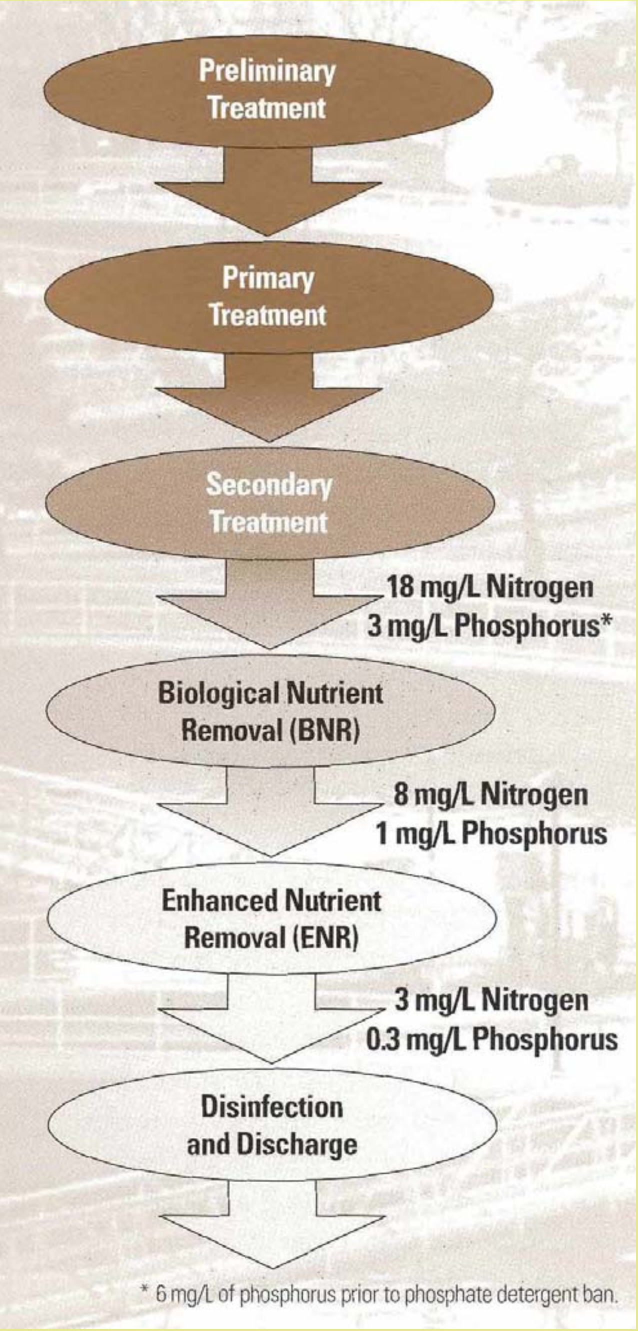




Measurements used N_2:Ar technique
Dr. J. Cornwall HPL-CES

Some Serious Money for Restoration has come on-line

- The Flush Tax for WWTP upgrades and other items (~60 M/yr)
- The Chesapeake Bay Trust Fund for diffuse source reductions in priority watersheds (~13-50 M/yr)
- The new Farm Bill…hopefully?



(SOURCE:CHESAPEAKE BAY COMMISSION 2007)