Lessons from
Chesapeake Bay
restoration efforts:
Understanding the role
of nutrient reduction
activities in improving
water quality

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Lessons from Chesapeake Bay restoration efforts:
Understanding the role of nutrient reduction activities in improving water quality

Bill Dennison
University of Maryland Center for Environmental Science

Scientific, Technical Assessment and Reporting Meeting
November 20, 2013

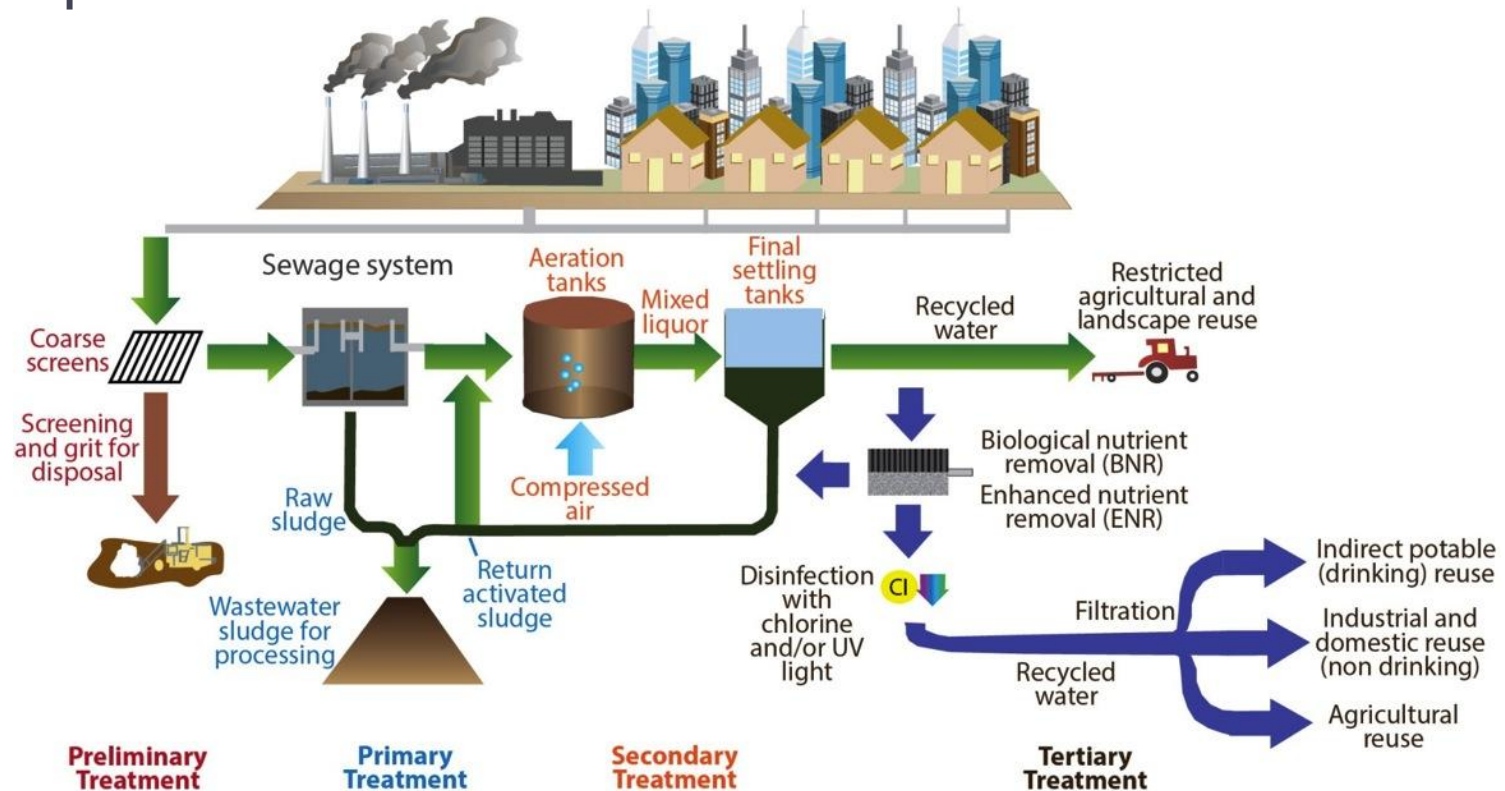**Authors:** Christina M. Lyerly, Ana L. Hernández Cordero, Katherine L. Foreman and William C. Dennison

Lessons from Chesapeake Bay Restoration Efforts

- Seven lessons under three broad categories:

  1. **What's Working**
  2. **Challenges & Opportunities**
  3. **Adapting to New Information**

- Presented at the Coastal and Estuarine Research Federation conference (November 5th)

- Accepted as a poster presentation at the December 2013 Maryland Water Monitoring Council conference
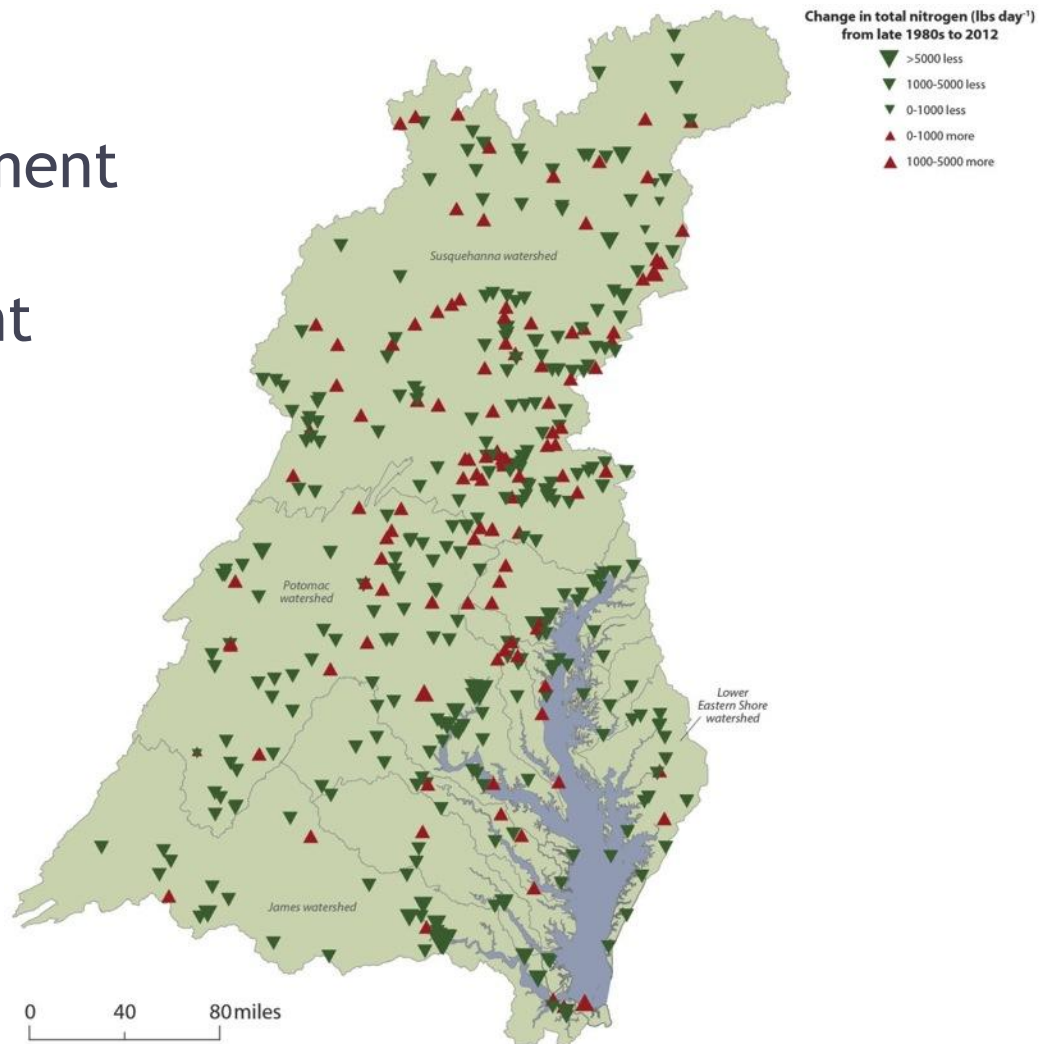
- Scheduled for release January 2014

Lesson 1

○ Upgrades in both nitrogen and phosphorus wastewater treatment result in rapid local water quality improvements

Sewage system

Aeration tanks

Final settling tanks
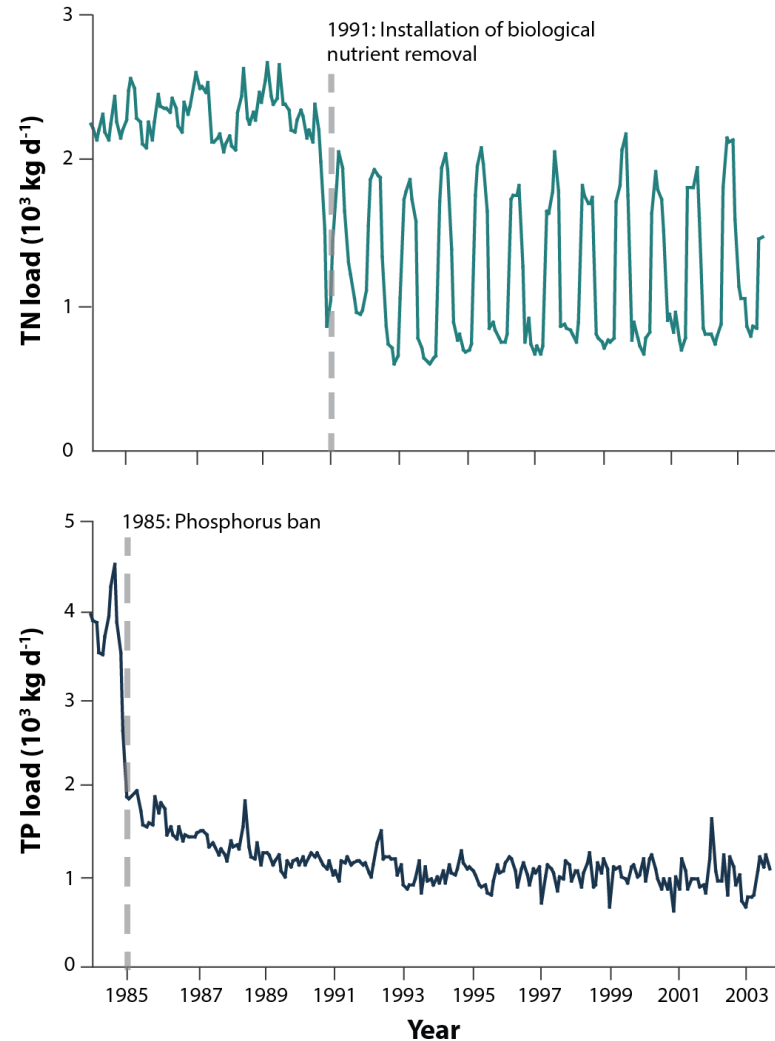
Coarse screens

Screening and grit for disposal

Mixed liquor

Recycled water

Restricted agricultural and landscape reuse

Compressed air

Raw sludge

Return activated sludge

Wastewater sludge for processing

Disinfection with chlorine and/or UV light

Biological nutrient removal (BNR)

Enhanced nutrient removal (ENR)

Filtration

Recycled water

Indirect potable (drinking) reuse

Industrial and domestic reuse (non drinking)

Agricultural reuse

Preliminary Treatment

Primary Treatment

Secondary Treatment

Tertiary Treatment

Trends in Wastewater Treatment Plant Loads

- Wastewater treatment plants yet to be upgraded represent opportunities for continued improvement

Change in total nitrogen (lbs day⁻¹) from late 1980s to 2012

- ▼ >5000 less
- ▼ 1000-5000 less
- ▼ 0-1000 less
- ▲ 0-1000 more
- ▲ 1000-5000 more

Susquehanna watershed

Potomac watershed

Lower Eastern Shore watershed

James watershed

0   40   80 miles

Upper Patuxent River

○ Upgrades to a wastewater treatment plant reduced nitrogen loads to the Upper Patuxent River

Changes in TN and TP loads (1984-2004)

1991: Installation of biological nutrient removal

1985: Phosphorus ban

Data from Testa et al., 2008

Upper Patuxent River

- Decreased wastewater treatment plant nutrient loads contributed to a resurgence of submerged aquatic vegetation

Vallisneria americana *(wild celery). Photo © Cassie Gurbisz*

Changes in SAV (1978-2008)

Data from Boynton et al., 2008

Upper Potomac River

- Submerged aquatic vegetation abundance increased
- Total nitrogen concentrations decreased at the Piscataway Creek monitoring station

Changes in total SAV abundance in the Upper Potomac River (1990-2008)

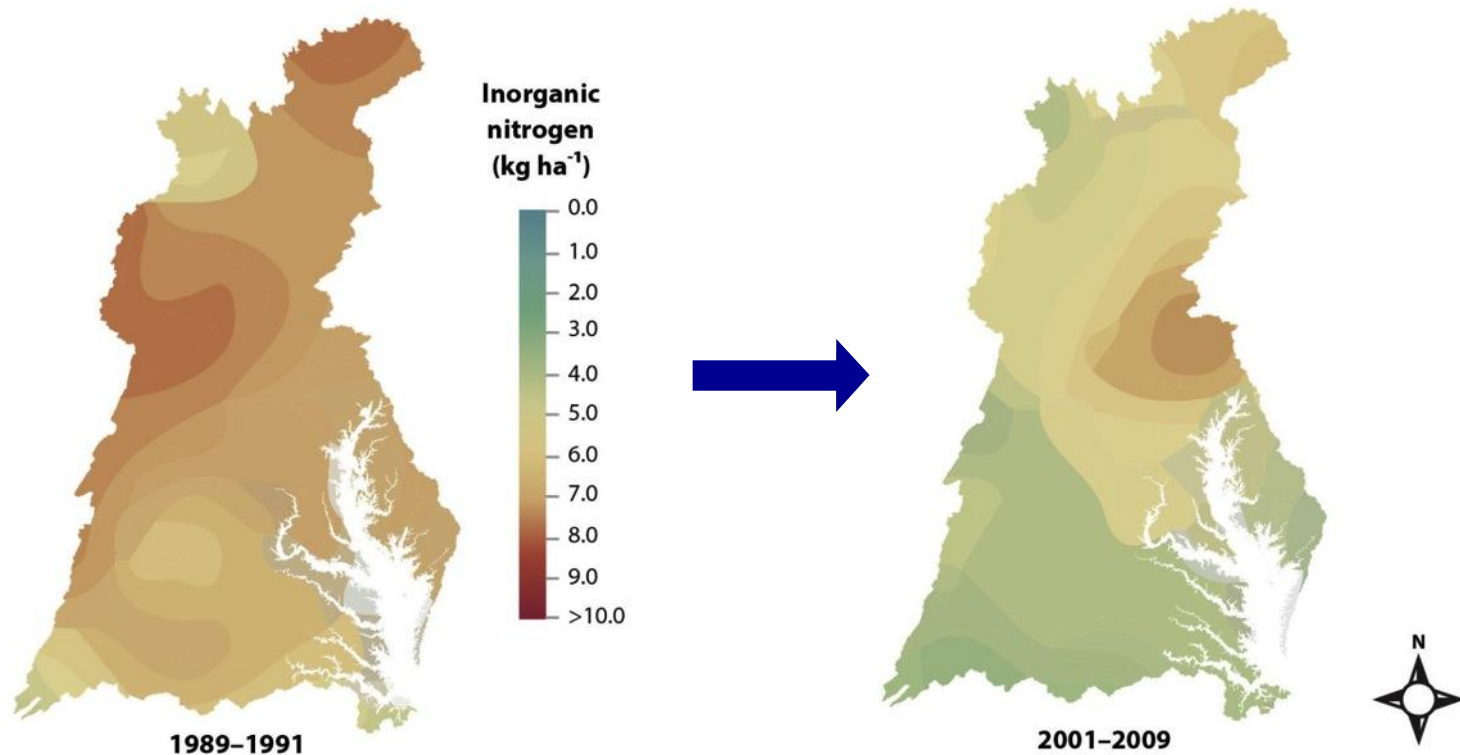**Changes in mean monthly surface TN concentrations at a monitoring station near Piscataway Creek (1985-2013)**
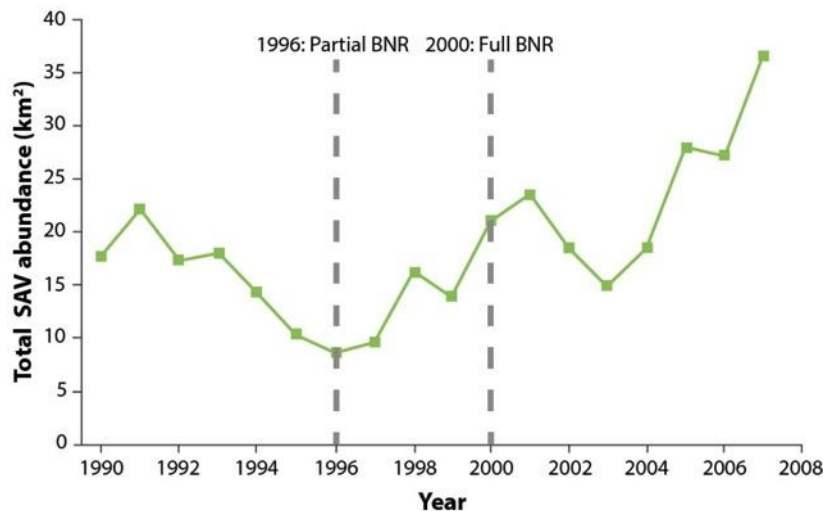
Data from Ruhl and Rybicki, 2010

Data from Romano and Buchanan, 2011

Lesson 2

- Improvements in air quality lead to reductions in atmospheric nitrogen deposition

**Annual mean wet inorganic nitrogen deposition**

Inorganic nitrogen (kg ha^{-1}): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, >10.0

1989–1991 → 2001–2009

US EPA Clean Air Markets: 2009 Results

Point Source Emissions and Surface Water Quality

- Decreases in atmospheric point source emissions and nitrogen deposition are linked to increased surface water quality in 9 mostly-forested subwatersheds
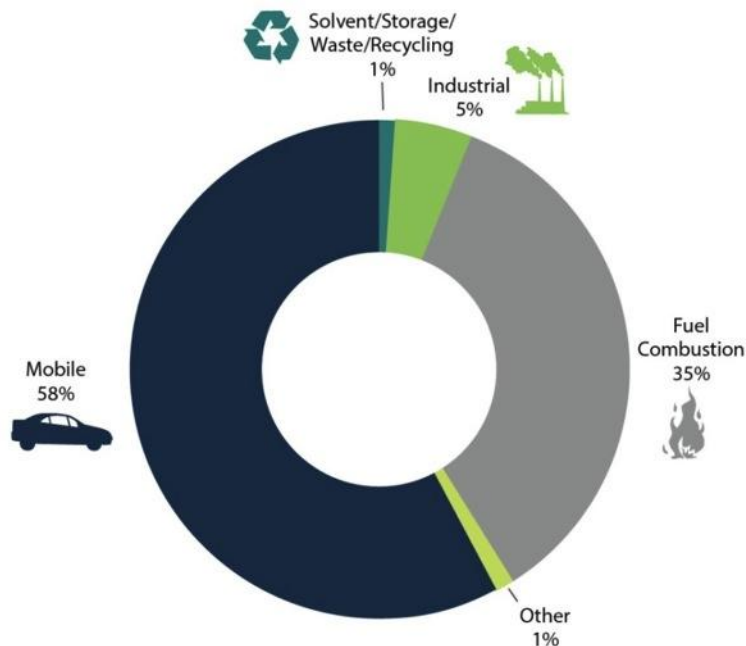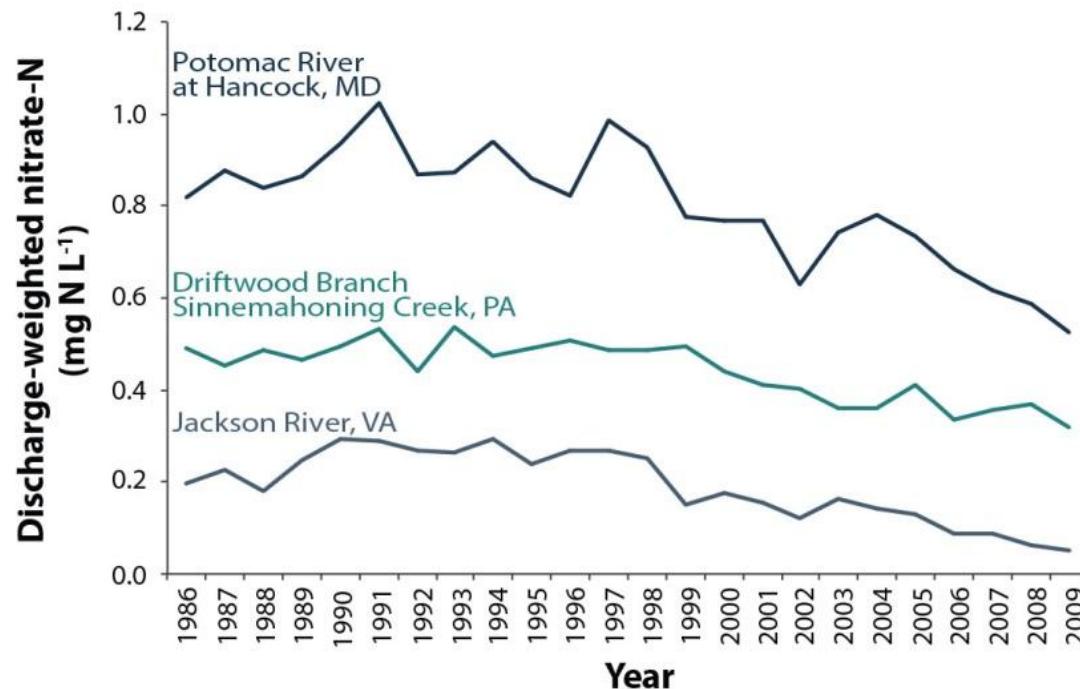
Changes in nitrate-N concentrations at 3 water quality monitoring stations (1986-2009)

Data from Eshleman et al., 2013

Nonpoint Source Emissions

- Mobile sources represent the majority of NO_x air emissions

U.S. NO_x emissions by category (2006)

Adapted from US EPA 2007 Progress Report: Vehicle and Engine Compliance Activities

Pre 1970s. Over concern from early smog studies in Los Angeles, CA, the catalytic converter was invented in the 1950s by Eugene Houndry, a French mechanical engineer living in the United States. Catalytic converters were further developed by John J. Mooney and Carl D. Keith, creating the first production catalytic converter in 1973.

1975. The U.S. EPA requires that all new cars be equipped with catalytic converters. These two-way converters combine carbon monoxide (CO) and unburned hydrocarbons (HC) to produce carbon dioxide (CO_2) and water (H_2O).

1981. To keep up with the Clean Air Act of 1970, a new generation of catalytic converters act as a three-way catalyst, converting carbon dioxide (CO_2) and hydrocarbons (HC) to water (H_2O), and reducing nitrogen oxides (NO_x) to elemental nitrogen (N) and oxygen (O).

Lesson 3

- Reductions of agricultural nutrient sources result in improved stream quality

Cover crops

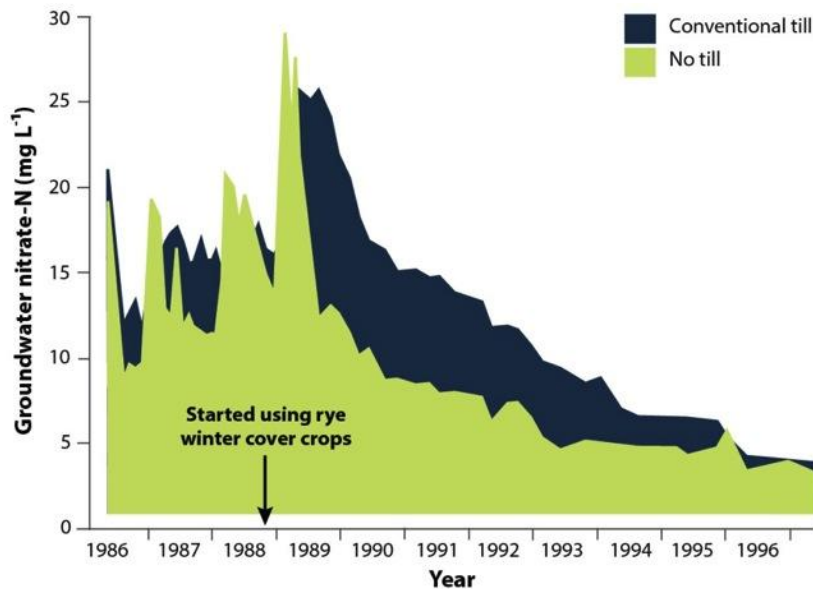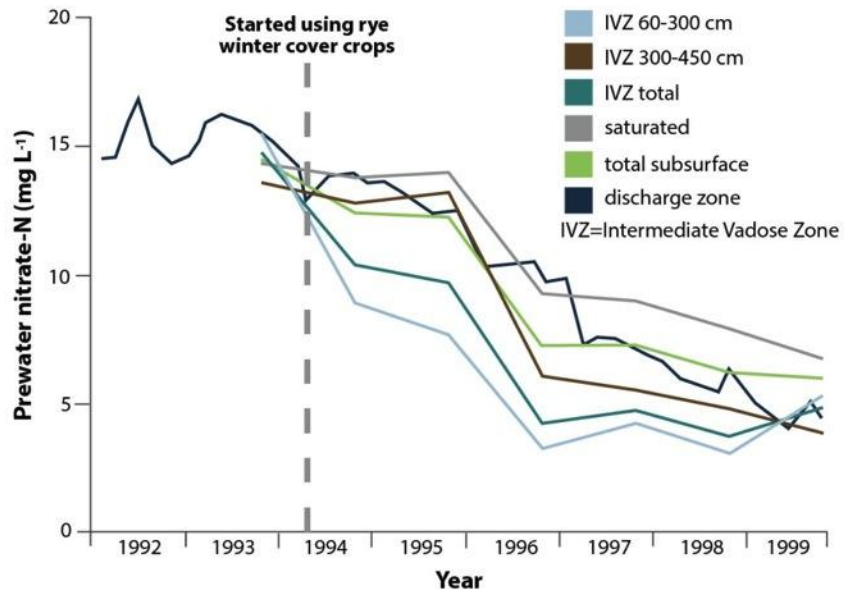**Livestock exclusion**

Waste management

Wye River Drainage Basin

○ Winter cover crops planted in the Wye River drainage basin improved water quality

Changes in groundwater nitrate-N concentrations in 2 agricultural fields (1986–1998)

Changes in nitrate-N concentrations in different subsurface zones on an agricultural field (1992-1999)

Data from Staver and Brinsfield, 1995 & 2000

Practices for Further Study

- Rotational grazing may provide some benefits but has shown mixed results

- Cattle feed composition may influence the volatilization of ammonia from animal waste

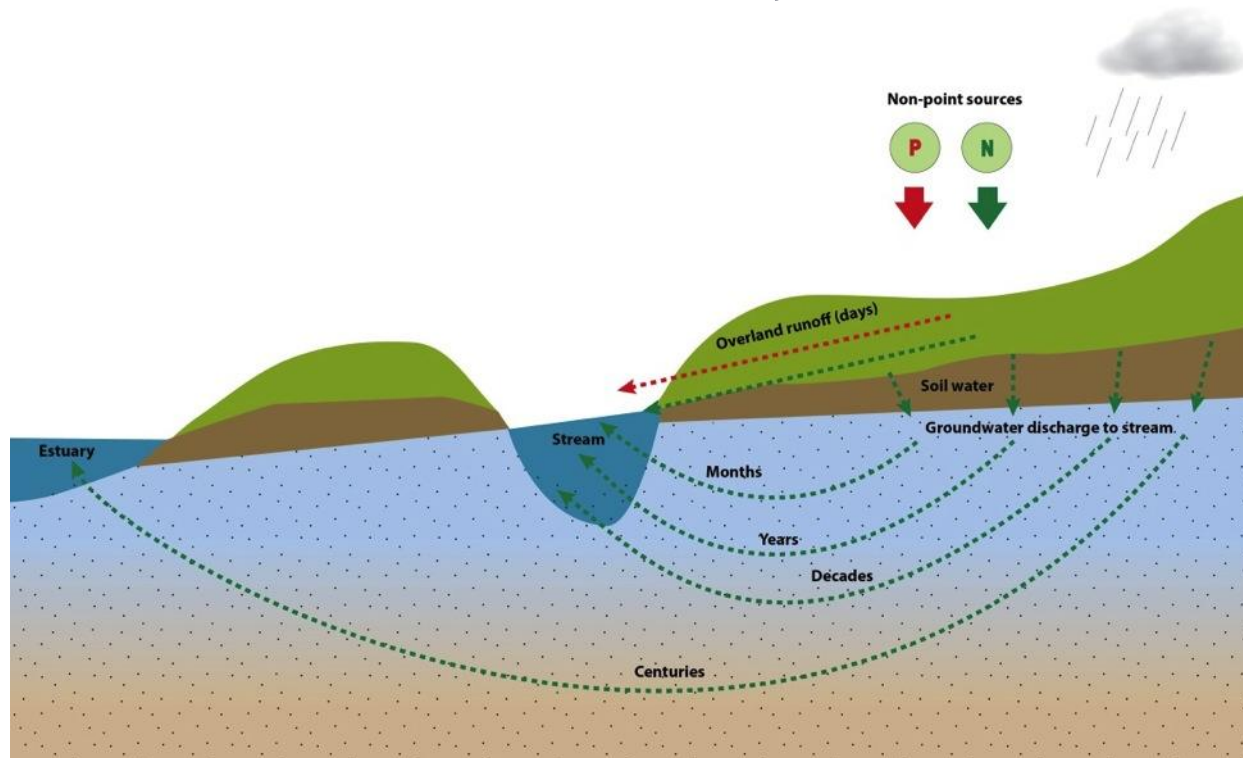- Ventilation construction may affect ammonia emitted from poultry houses


Photo © jlastras

Lesson 4

- Many practices provide initial water quality improvements in runoff; however, full benefits to stream conditions can be delayed

Sanford et al., 2012
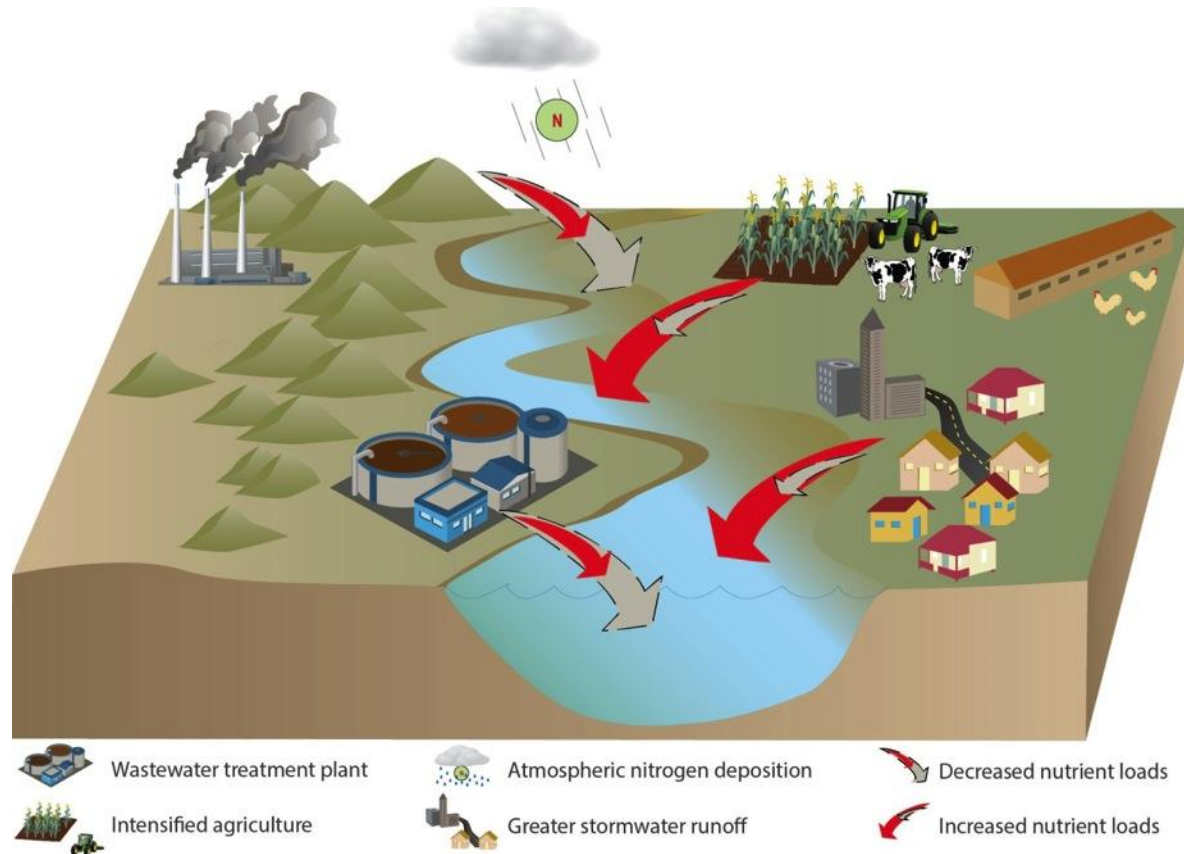
Delmarva Peninsula

- Groundwater ages can range from less than a year to more than 100 years

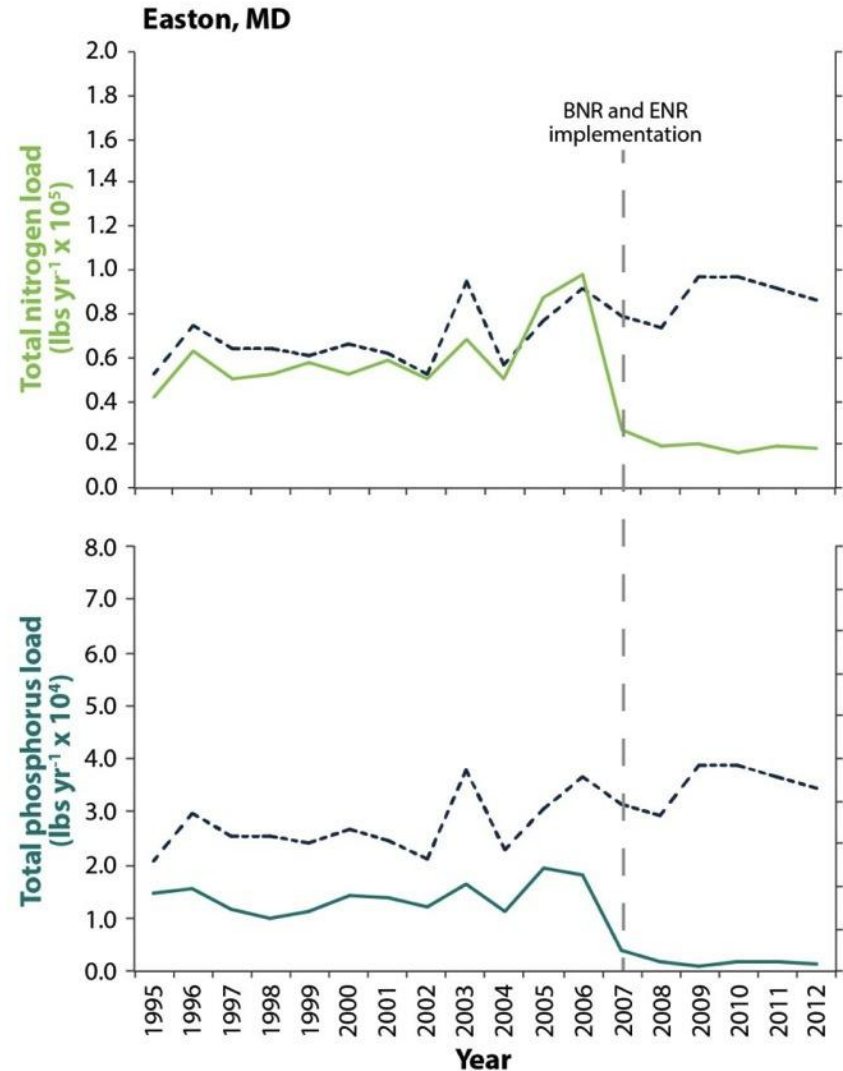**Simulated return time of groundwater traveling from the water table to its discharge location**

Sanford et al., 2012
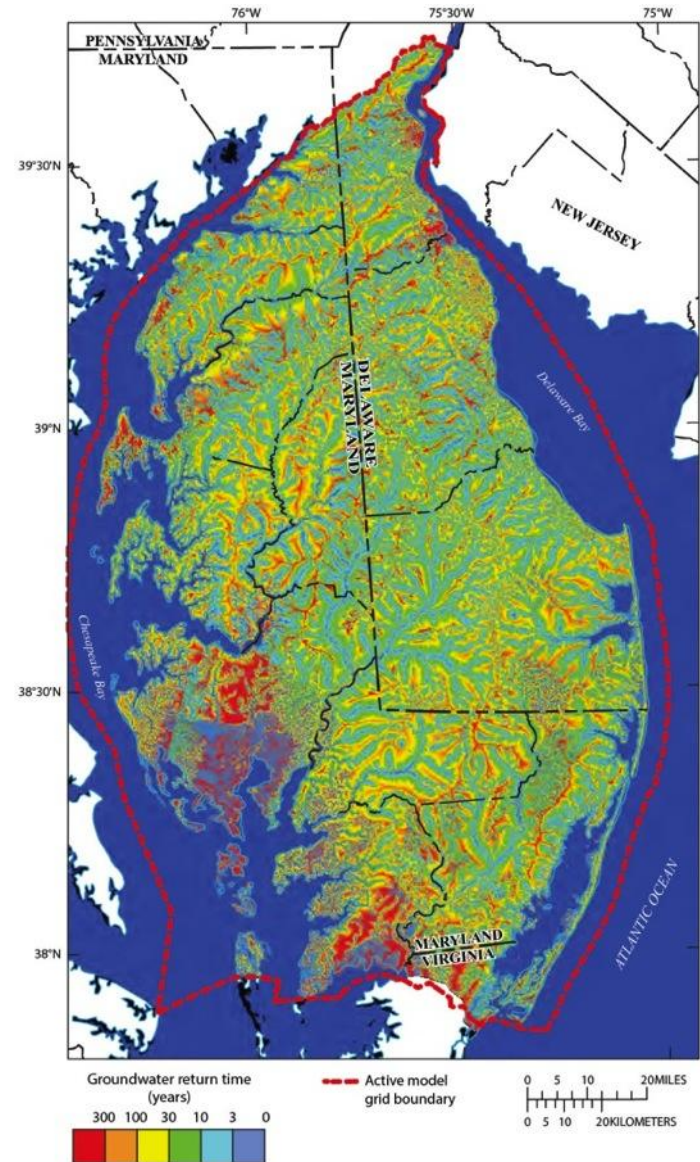
Lesson 5

- Improvements in water quality can be counteracted by changes in nutrient sources and land-use practices

Wastewater treatment plant	Atmospheric nitrogen deposition	Decreased nutrient loads
Intensified agriculture	Greater stormwater runoff	Increased nutrient loads

Choptank River

- Wastewater treatment plant flow has increased in some locations, but WWTP upgrades have decreased nutrient loads

**Changes in flow, N and P loads from the Easton wastewater treatment plant (1995-2012)**

Easton, MD

Total nitrogen load (lbs yr⁻¹ x 10⁵)

BNR and ENR implementation

Total phosphorus load (lbs yr⁻¹ x 10⁴)

Year

Data from Karrh, 2012

Choptank River

- Agricultural nutrient sources have counteracted reductions in wastewater treatment plant nutrient loads

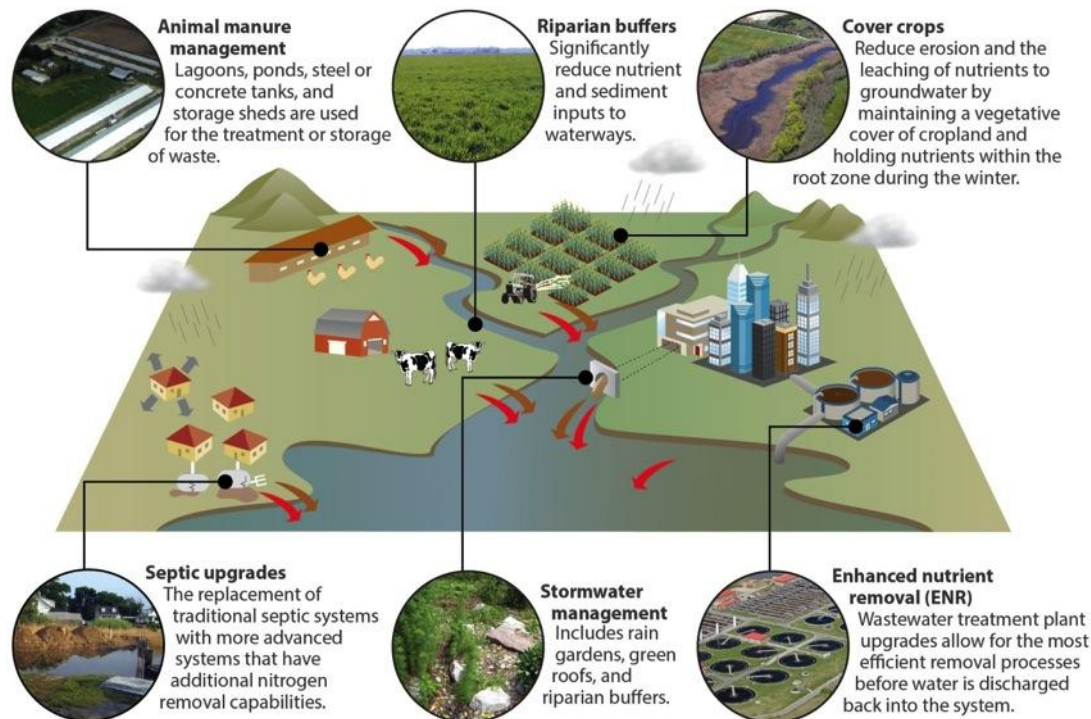**Increases in TN and TP at Greensboro water quality monitoring station (1968-2012)**

Data from Fisher, 2006
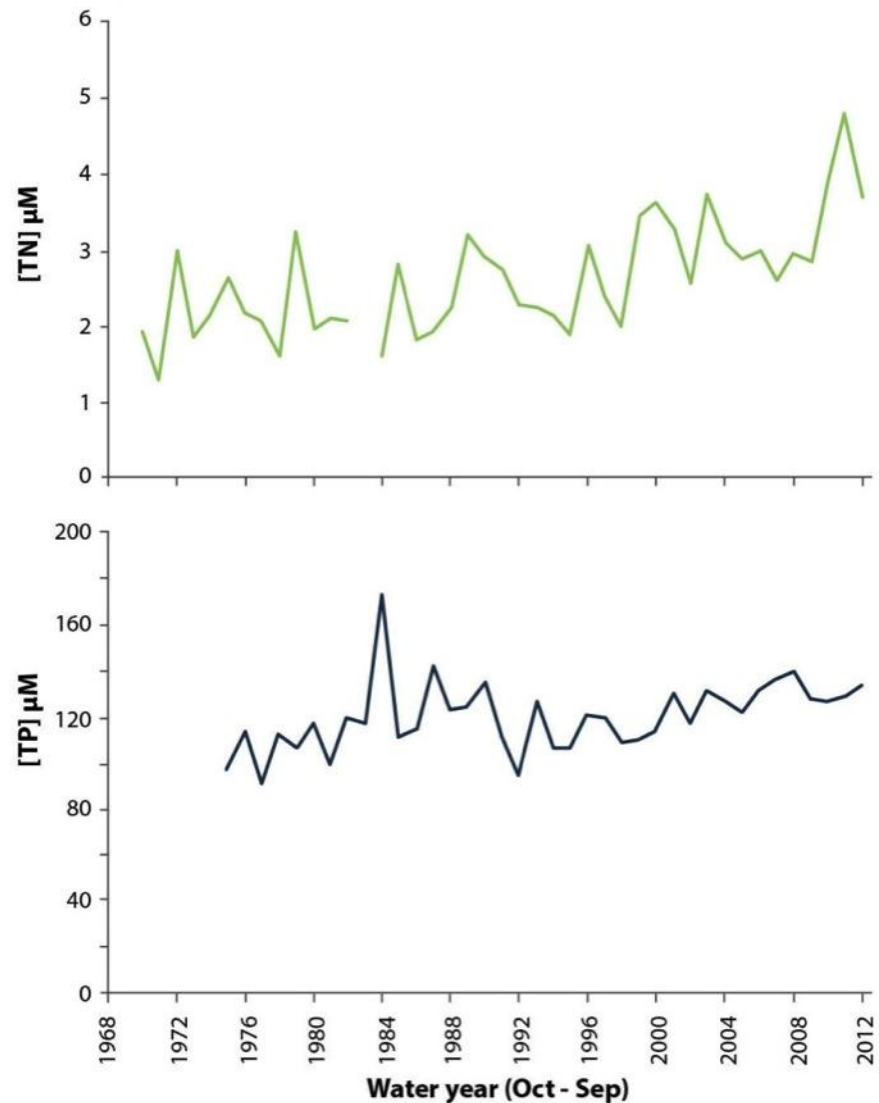
Lesson 6

- Observable water quality responses are more likely to occur if A) location specific sources of pollution are **identified** and B) **targeted** practices are implemented.

Animal manure management
Lagoons, ponds, steel or concrete tanks, and storage sheds are used for the treatment or storage of waste.

Riparian buffers
Significantly reduce nutrient and sediment inputs to waterways.

Cover crops
Reduce erosion and the leaching of nutrients to groundwater by maintaining a vegetative cover of cropland and holding nutrients within the root zone during the winter.

Septic upgrades
The replacement of traditional septic systems with more advanced systems that have additional nitrogen removal capabilities.

Stormwater management
Includes rain gardens, green roofs, and riparian buffers.

Enhanced nutrient removal (ENR)
Wastewater treatment plant upgrades allow for the most efficient removal processes before water is discharged back into the system.
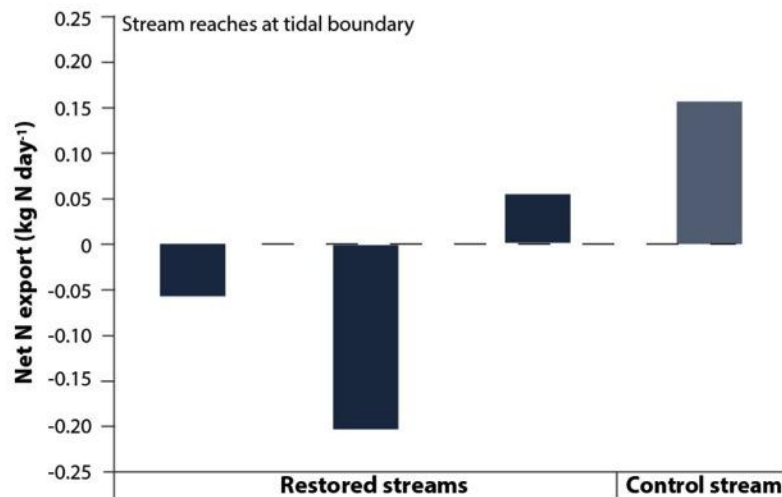
Corsica River

- Improvements in nontidal water quality in the Corsica River were observed after aggressive implementation of multiple nutrient reduction practices

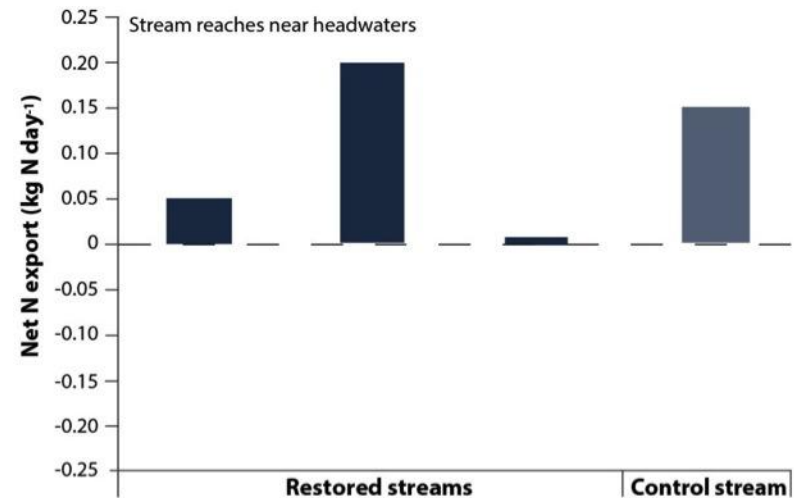**Changes in TN and TP concentrations in Three Bridges Branch and Gravel Run (2006-2011)**

Data from Batchelor et al., 2011
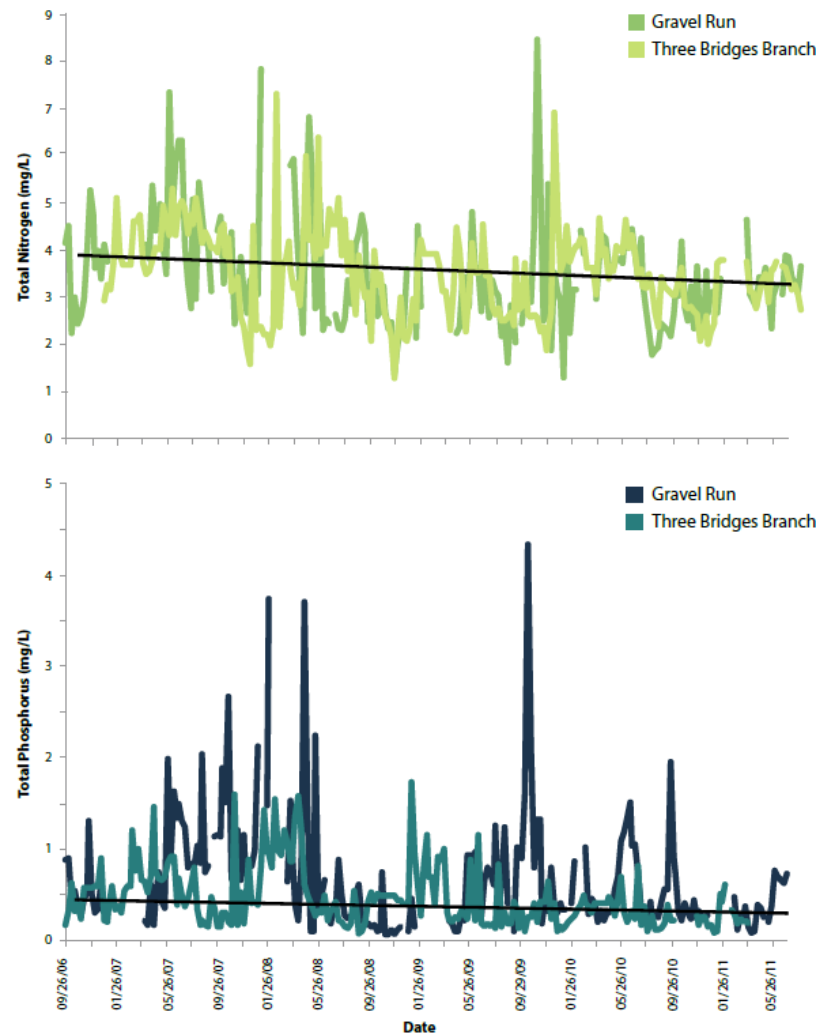
Anne Arundel County

- Location matters

**Tidal Boundary Streams: 2 out of 3 restored streams retained nitrogen…Partial success**

Headwaters Streams: 0 out of 3 restored streams retained nitrogen…No success

Positive Export Values = No Nitrogen Retention = Restored Streams Not Doing Their Jobs!

Data from Filoso and Palmer, 2009

Lesson 7

- An array of practices to promote stormwater infiltration and retention are needed in urban and suburban areas

Rain gardens   **Pervious surfaces**
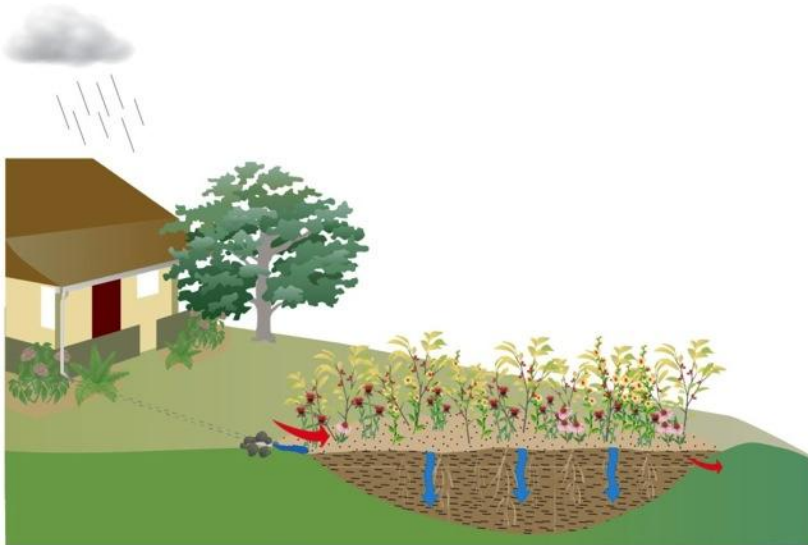
Gutters and downspouts installed onto buildings and in lawns help assist in directing rain water from the roof to the garden. A landscape of native, drought resistant plants is well adapted to local conditions and easily maintained. Plants with deep root systems encourage stormwater infiltration and help absorb excess nutrient runoff. Additionally, a berm on the downward slope of a rain garden will help hold water in the garden during heavy rains, further improving its filtering capacity.

Impervious surfaces such as cement, asphalt and roofing prevent the infiltration of stormwater, increasing the volume and velocity of surface runoff which carries nutrients and sediments with it. Pervious surfaces, such as pervious pavement or pavers, allow for stormwater to filter through the surface and into the ground, rather than into nearby streams and storm drains.

Constructed Wetlands

- Constructed wetlands in Baltimore, MD demonstrated the potential to reduce nitrate entering streams through stormwater runoff

Mean groundwater nitrate-N concentrations (A) and denitrification rates (B) in oxbow, forested, and constructed wetlands in Baltimore, MD

Harrison et al., 2011
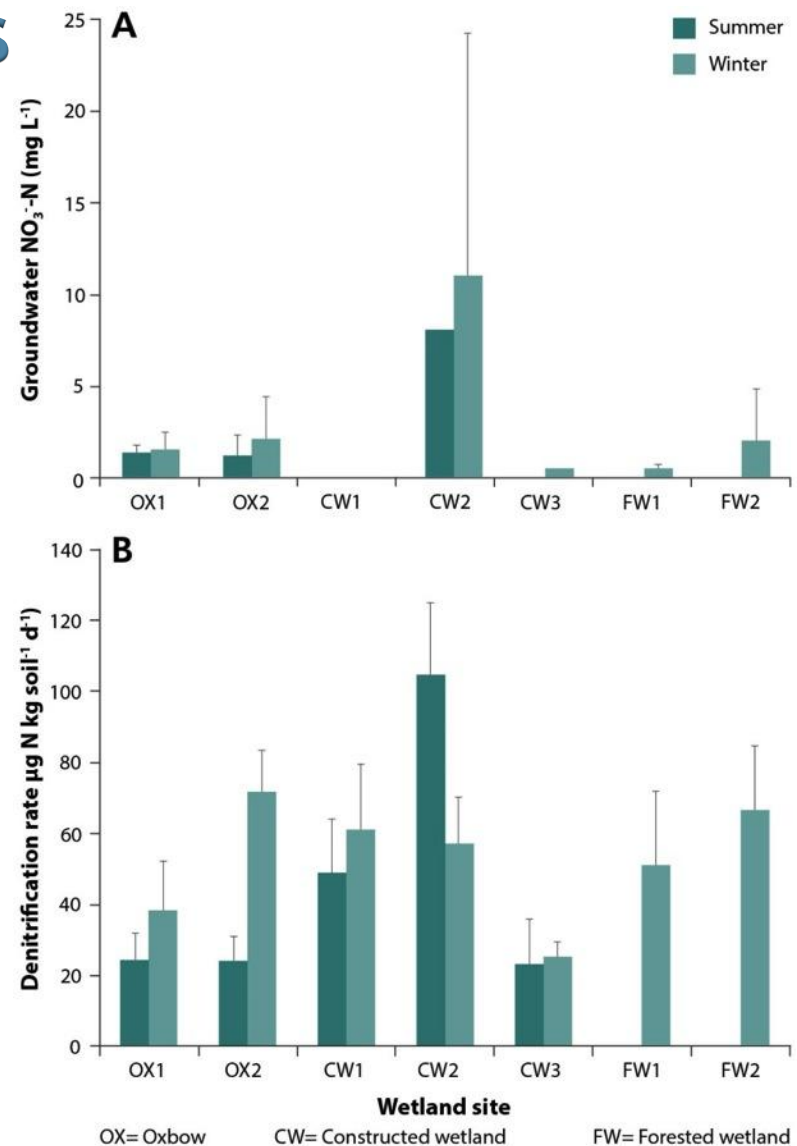
Conclusions

1. What's Working
   - The Clean Water Act is working
   - The Clean Air Act is working
   - Reducing agricultural nutrient loads can work

2. Challenges & Opportunities
   - Lag times that delay improvements mean patience and persistence are needed
   - Further improvements possible with stormwater runoff controls

3. Adapting to New Information
   - Targeting to guide restoration and monitoring to evaluate effectiveness
   - Innovative practices and testing are needed

Questions?

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