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Understanding Nutrients in the Chesapeake Bay Watershed and Implications for Management and Restoration – the EASTERN SHORE

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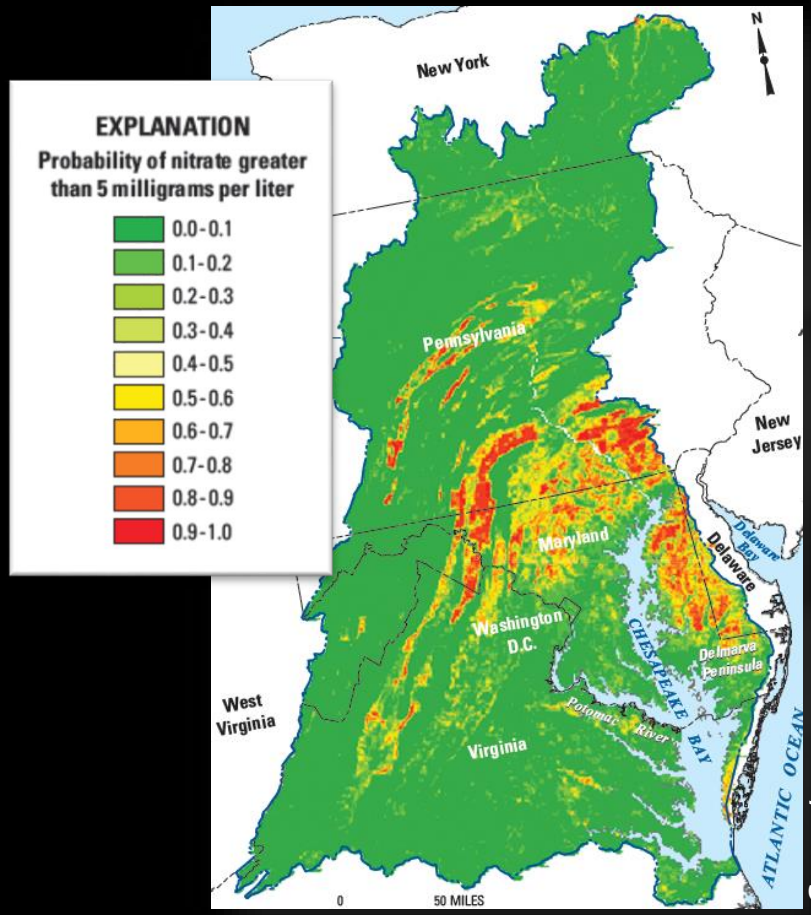
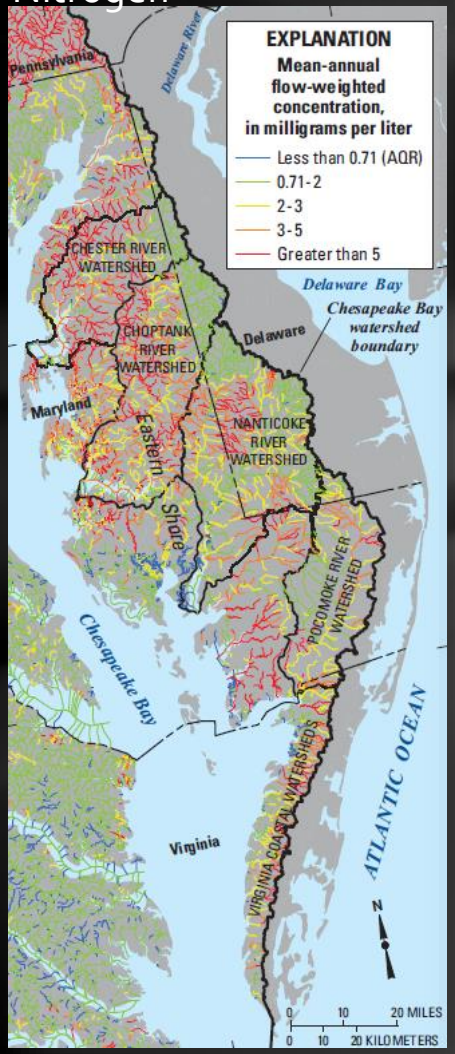
Topics

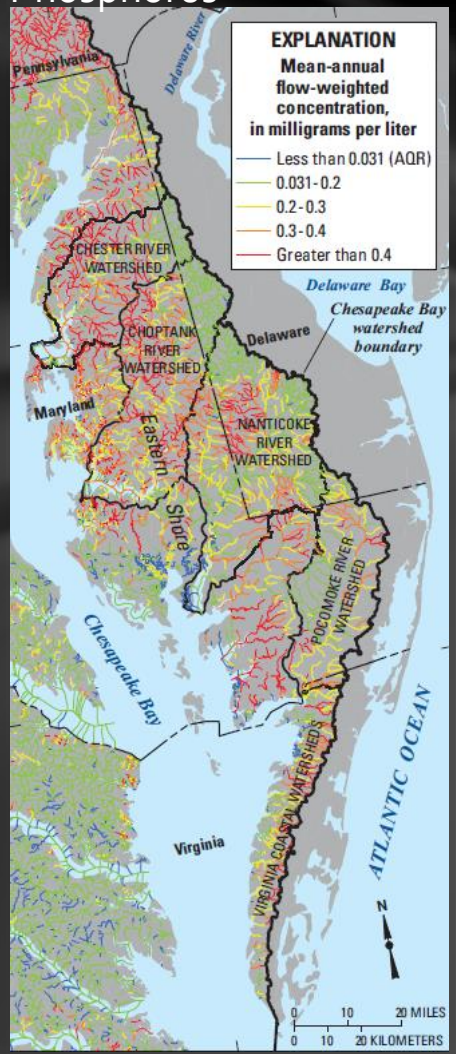


Greene et al., 2005

Nitrogen



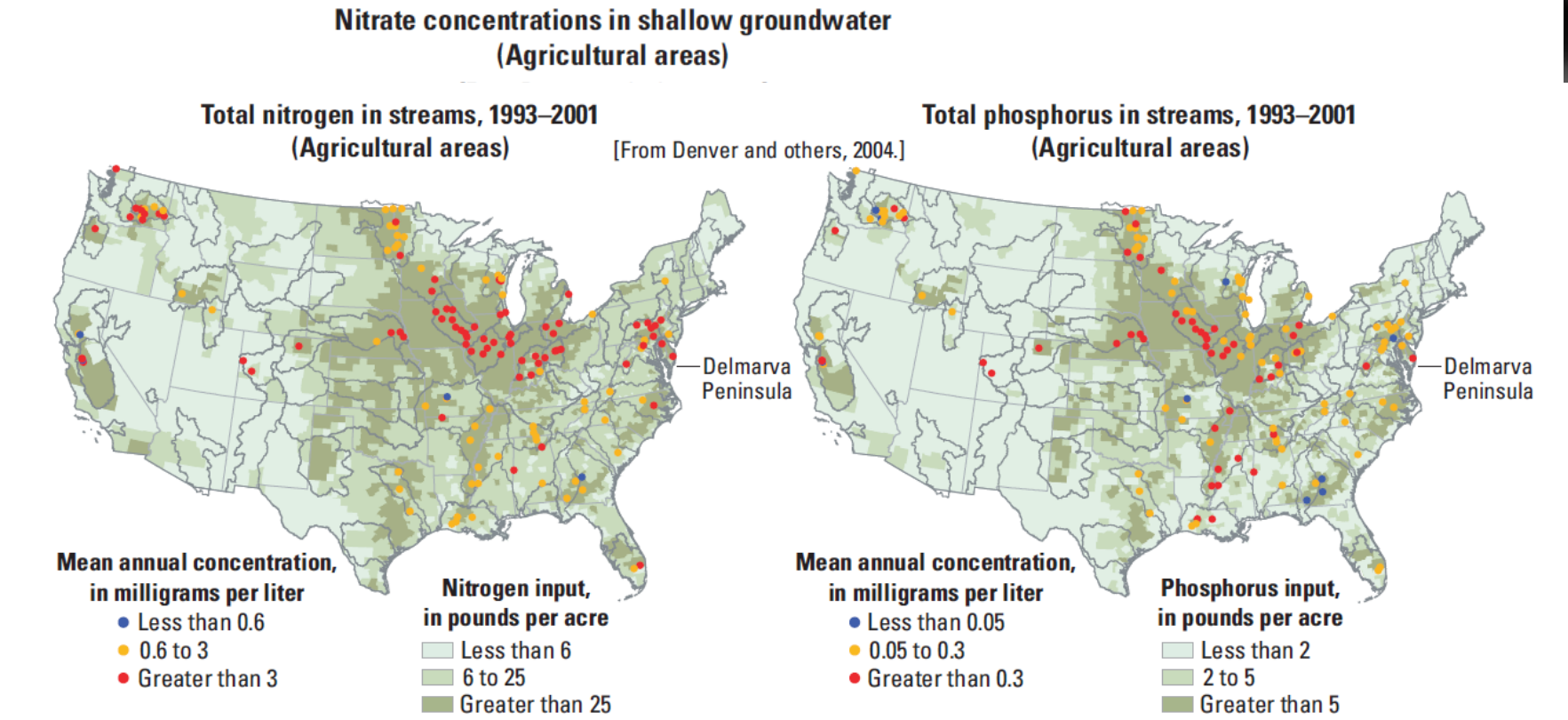
Phosphorus



Ator et al., 2011

Topics

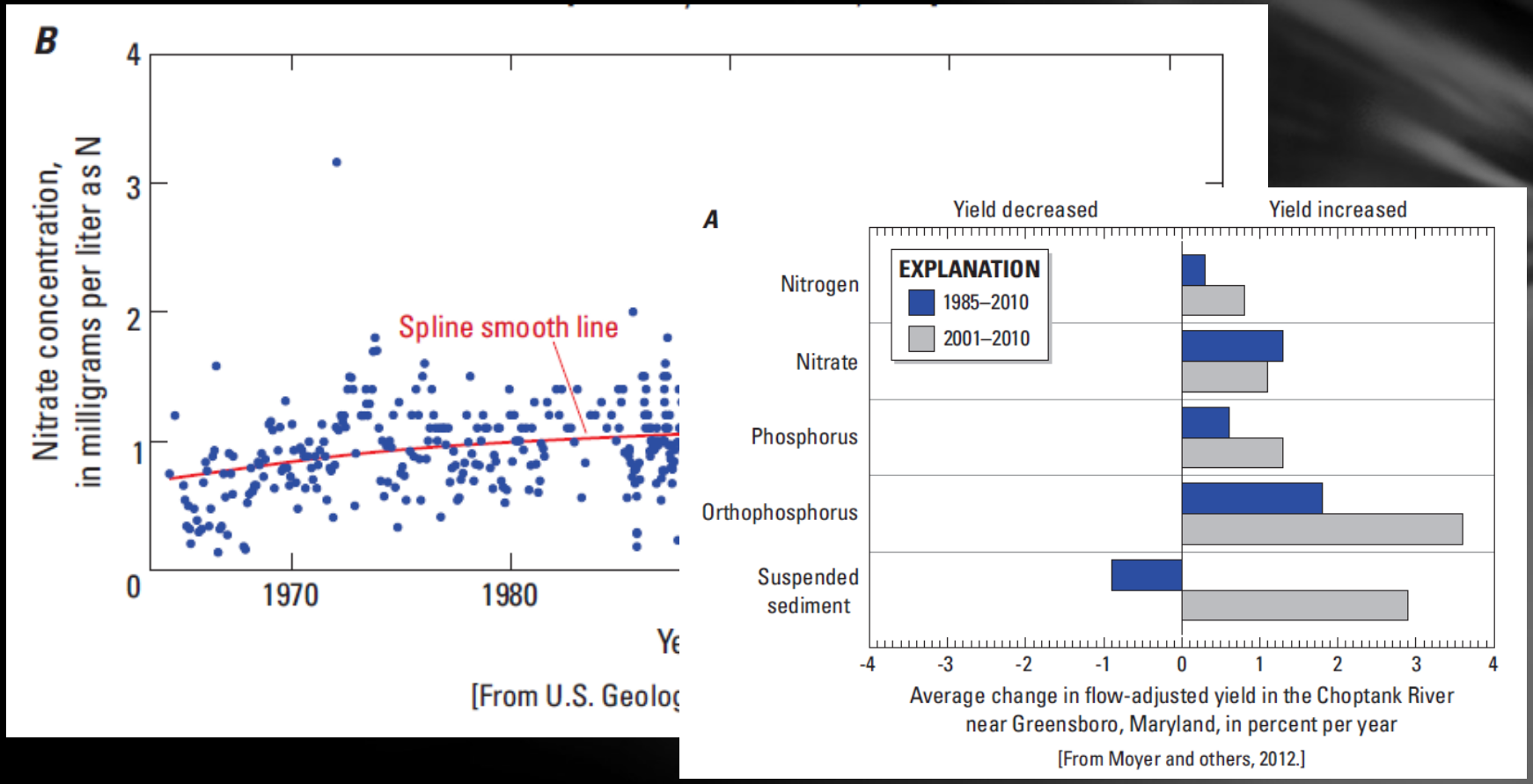
Denver et al., 2004



- Why are nutrient concentrations elevated in streams and (for nitrogen) groundwater on the Eastern Shore?

Topics

Choptank River near Greensboro, MD



Moyer et al., 2012

- Why are nutrient concentration in streams and (for nitrogen) groundwater increasing?

Topics

- How long might it take to realize full water-quality benefits from management practices?

  ….or short-term intermediate benefits?

- What are the implications for the design of management practices to reduce nitrogen and phosphorus?

Outline

- Sources of nitrogen and phosphorus to the landscape
- Movement of nitrogen and phosphorus from upland source areas to groundwater and streams
- Explaining trends in groundwater and streams
- Response times and management implications

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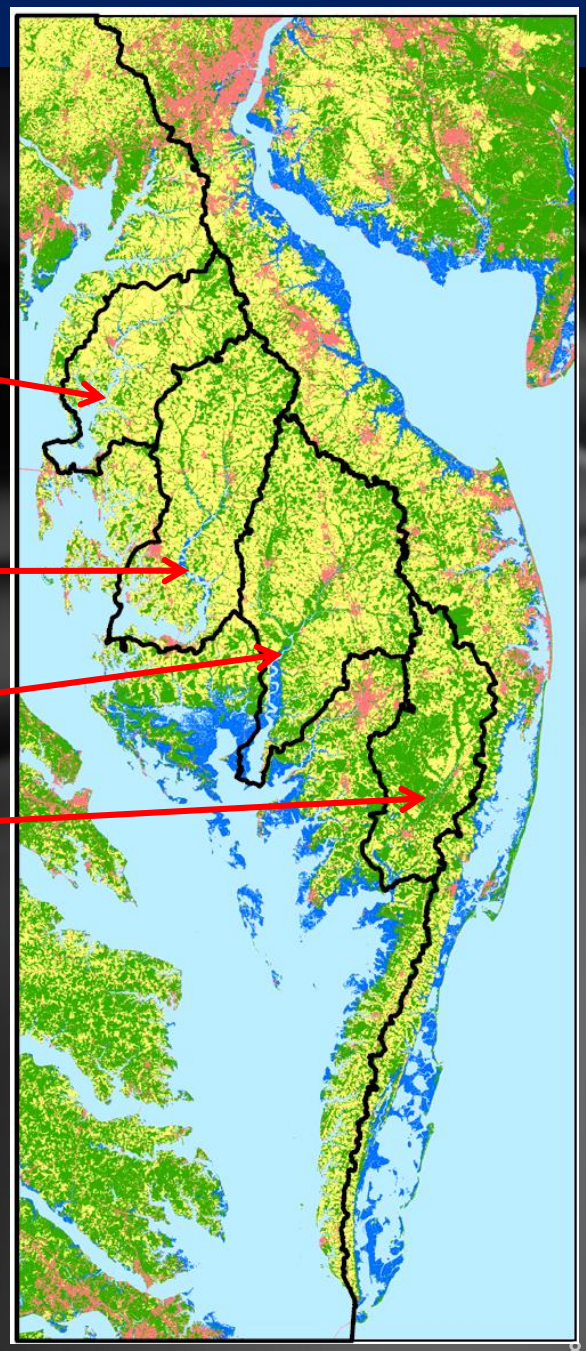
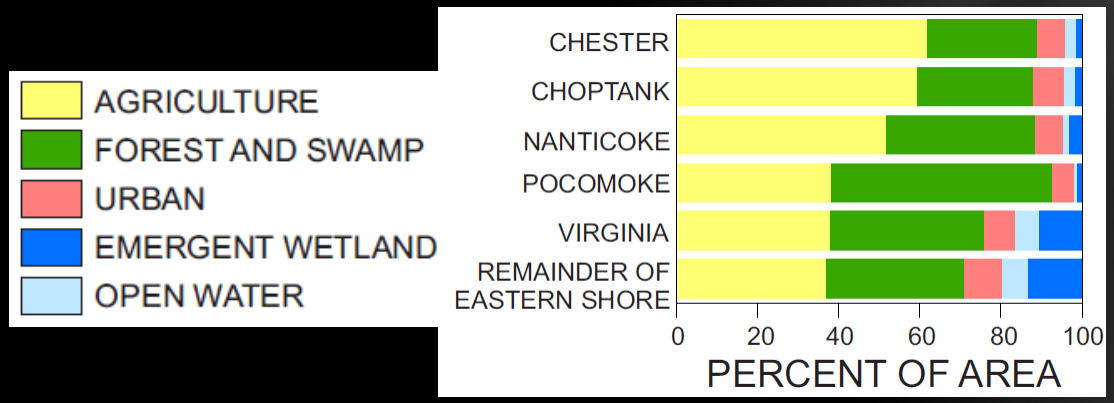
Sources

- Agriculture has been the dominant land use on the Eastern Shore for several centuries.
- Only 3 percent of the Eastern Shore is urban.

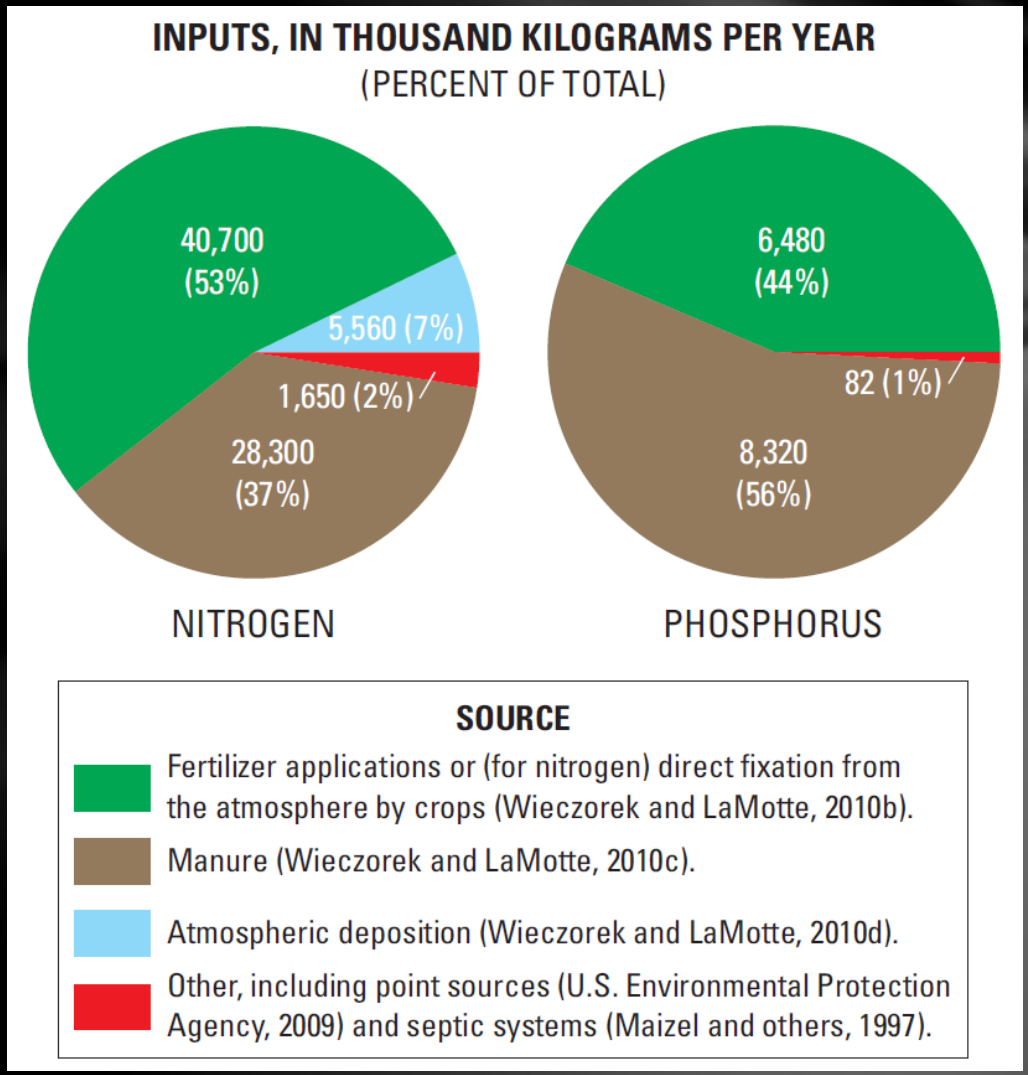


NLCD 2001 Data, processed by LaMotte, 2008a, b

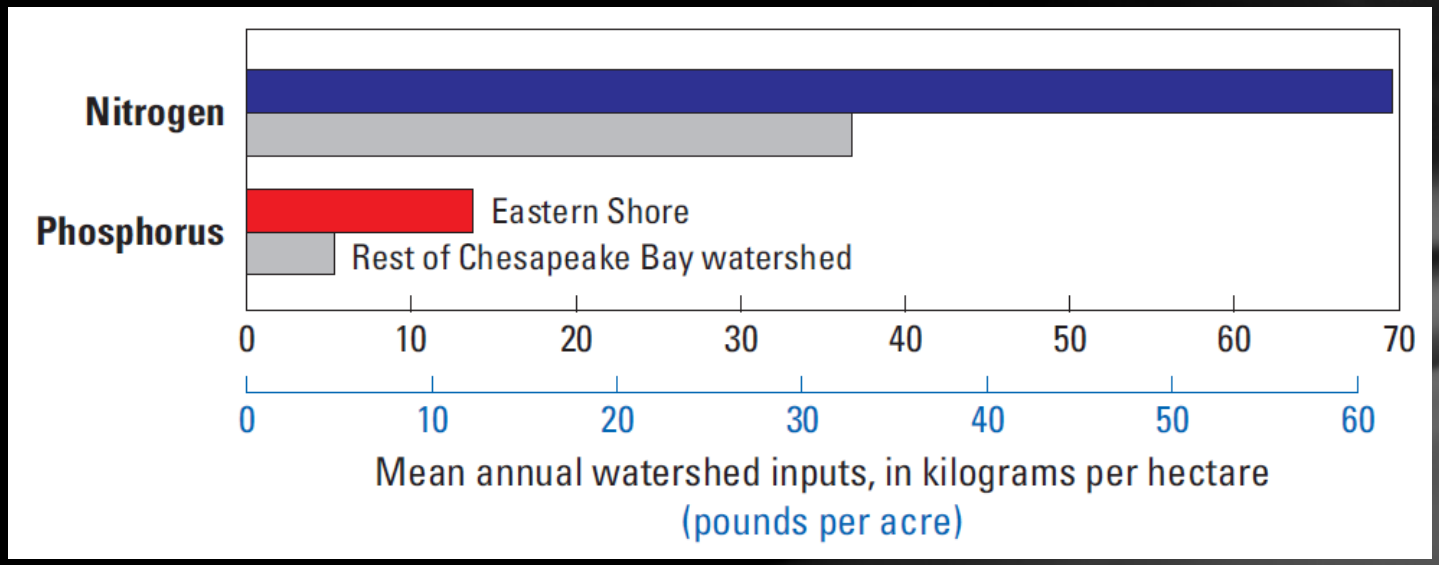


Sources

- Source of nitrogen and phosphorus to the Eastern Shore landscape are dominantly (greater than 90 percent) agricultural.



Sources



Adapted from Bachman et al., 1998; Wieczorek and LaMotte, 2010a, 2010b, 2010c, 2010d; Ator et al., 2011

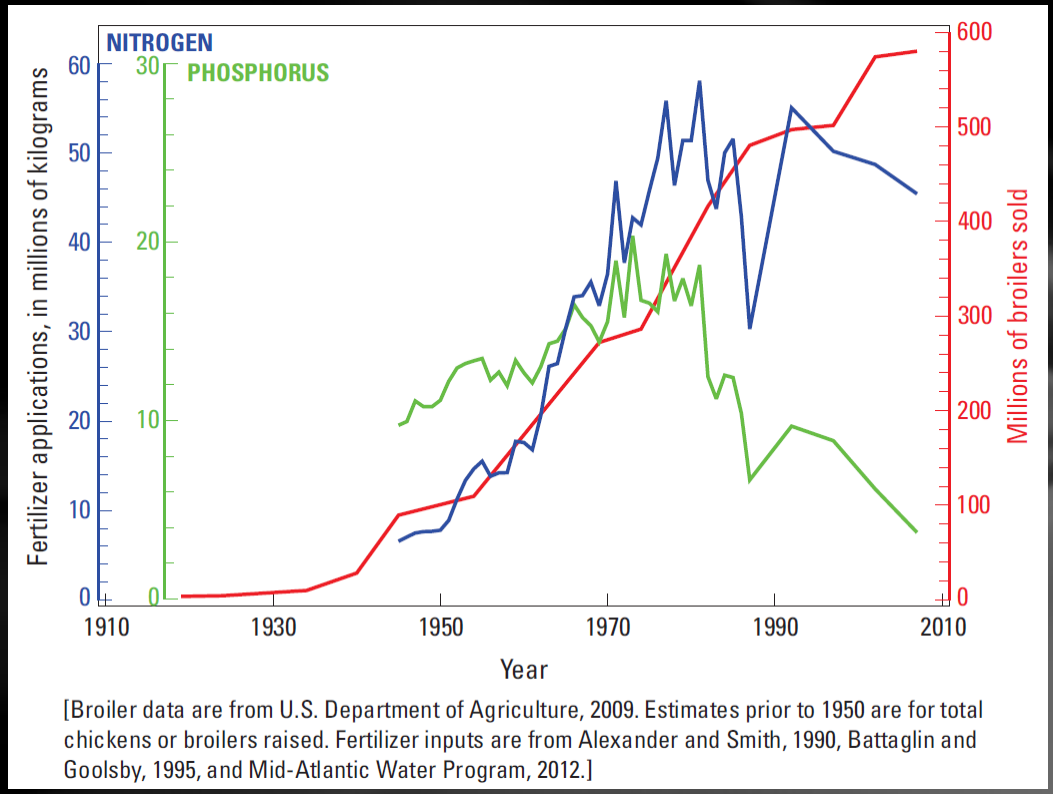
- Inputs* of nitrogen and phosphorus to the Eastern Shore are more intensive, on average, than to the remainder of the Chesapeake Bay watershed.

*inputs from:

- Fertilizer and manure
- Direct fixation by crops
- Undifferentiated urban
- Atmospheric
- Point sources
- Mineral sources

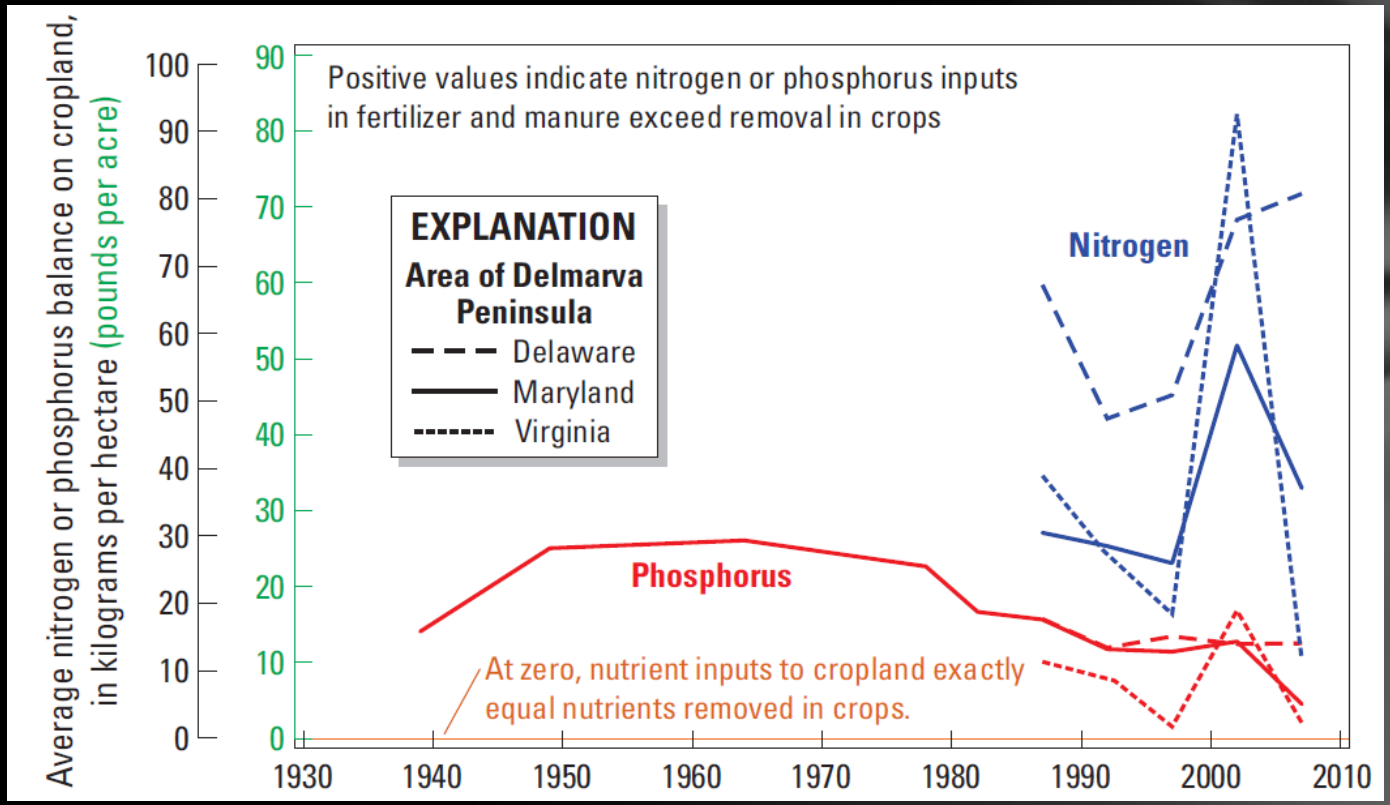
Sources

- Fertilizer applications of nitrogen and phosphorus increased substantially from the 1940s through the 1970s, but have since stabilized or decreased.
- Poultry production has increased by more than 100x since the early 20th century.



[Broiler data are from U.S. Department of Agriculture, 2009. Estimates prior to 1950 are for total chickens or broilers raised. Fertilizer inputs are from Alexander and Smith, 1990, Battaglin and Goolsby, 1995, and Mid-Atlantic Water Program, 2012.]

Sources

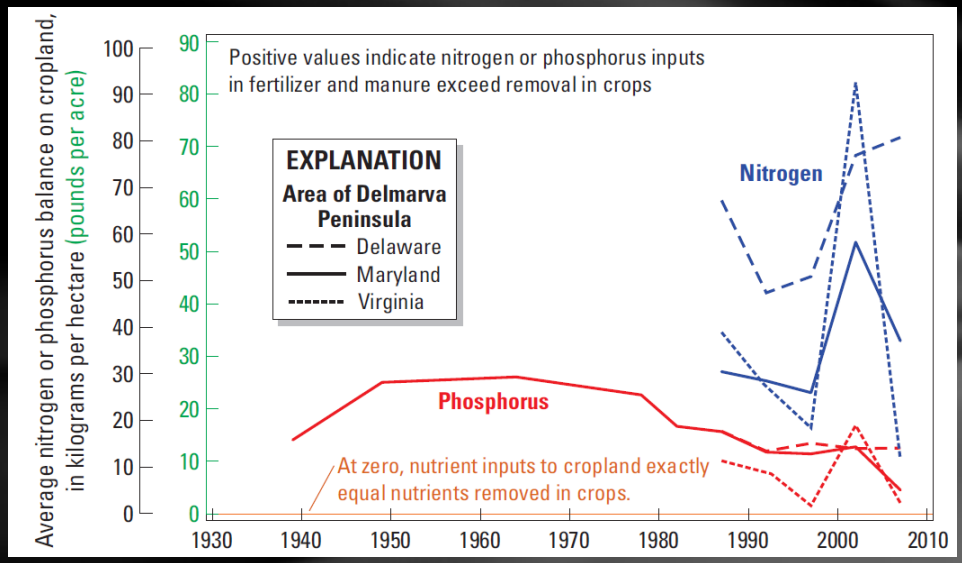


Balances were computed from estimates of the Mid-Atlantic Water Program, 2012

- Inputs of nitrogen and phosphorus to cropland have generally exceeded removal in crops for several decades.

Summary of Sources

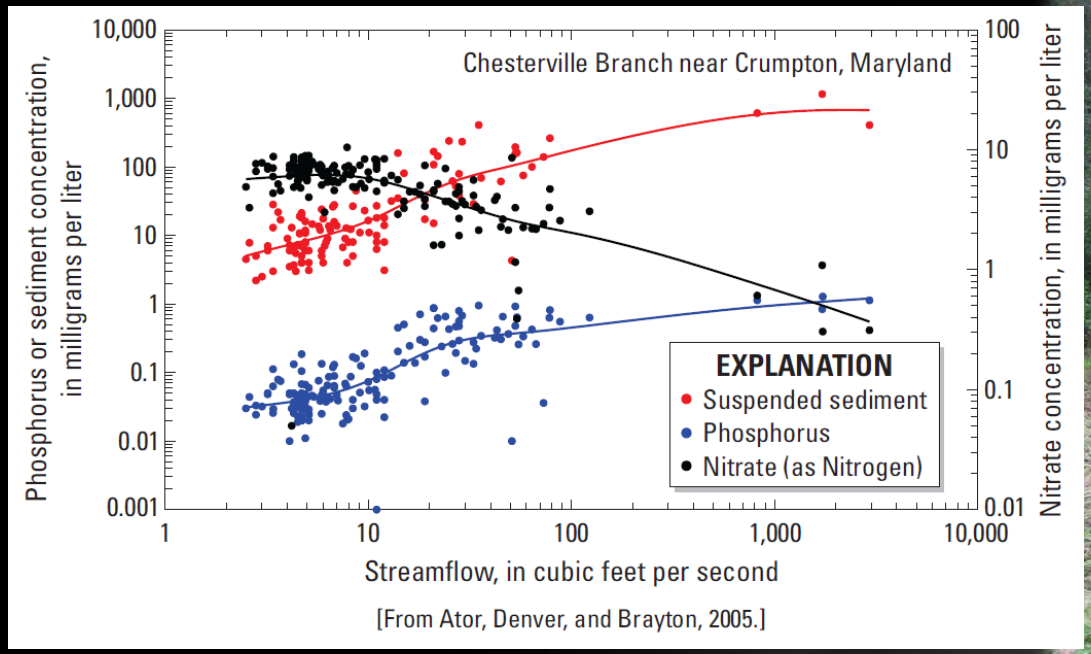
- Nitrogen and phosphorus sources to the Eastern Shore landscape are dominantly (greater than 90 percent) agricultural.
- Inputs are more intensive, on average, than in the remainder of the Chesapeake Bay watershed.
- Applications of nitrogen and phosphorus to cropland have generally exceeded removal in crops in recent decades.



Outline

- Sources of nitrogen and phosphorus to the landscape
- Movement of nitrogen and phosphorus from upland source areas to groundwater and streams
- Explaining trends in groundwater and streams
- Response times and management implications

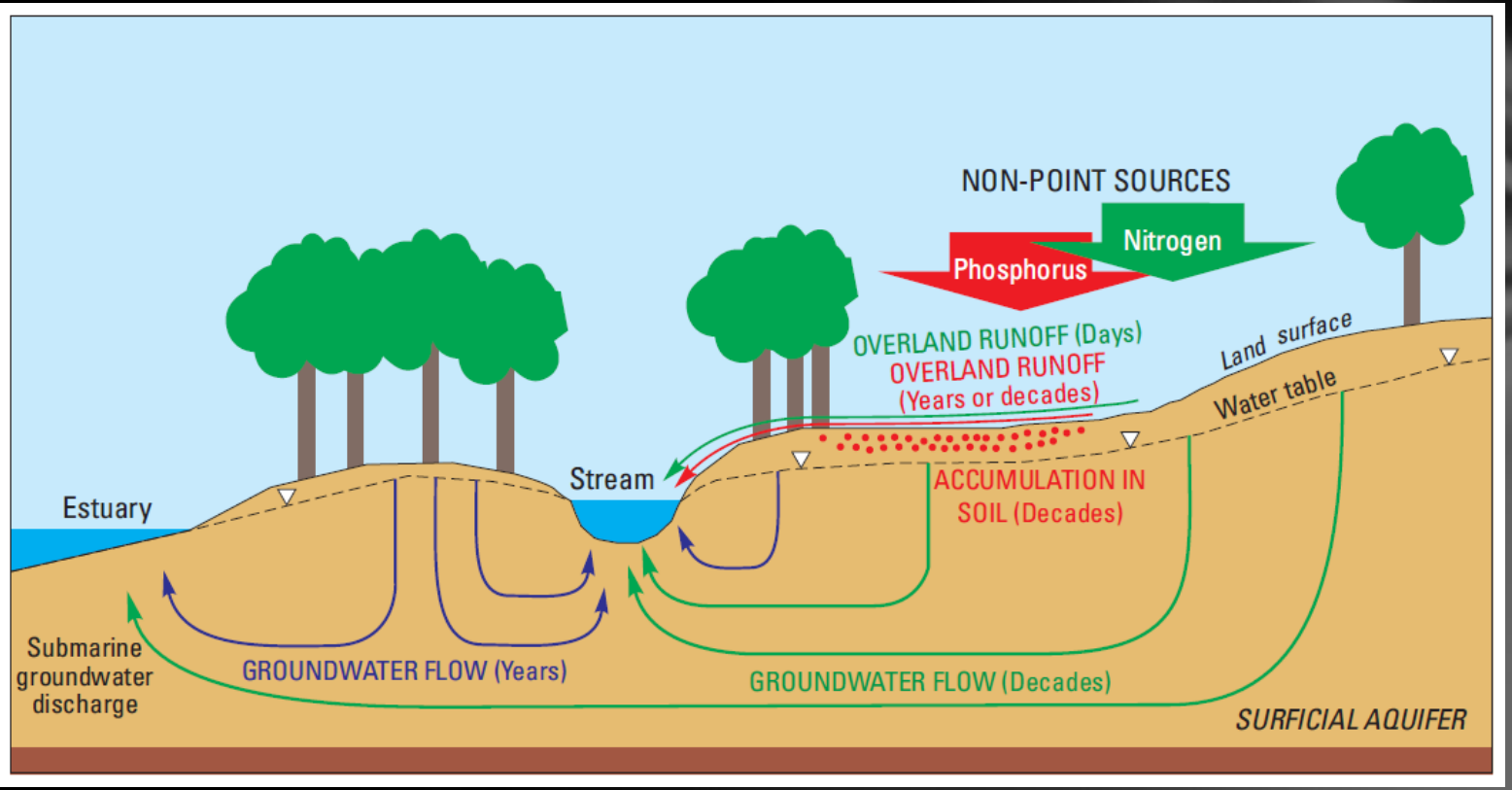
Fate and Transport



[From Ator, Denver, and Brayton, 2005.]

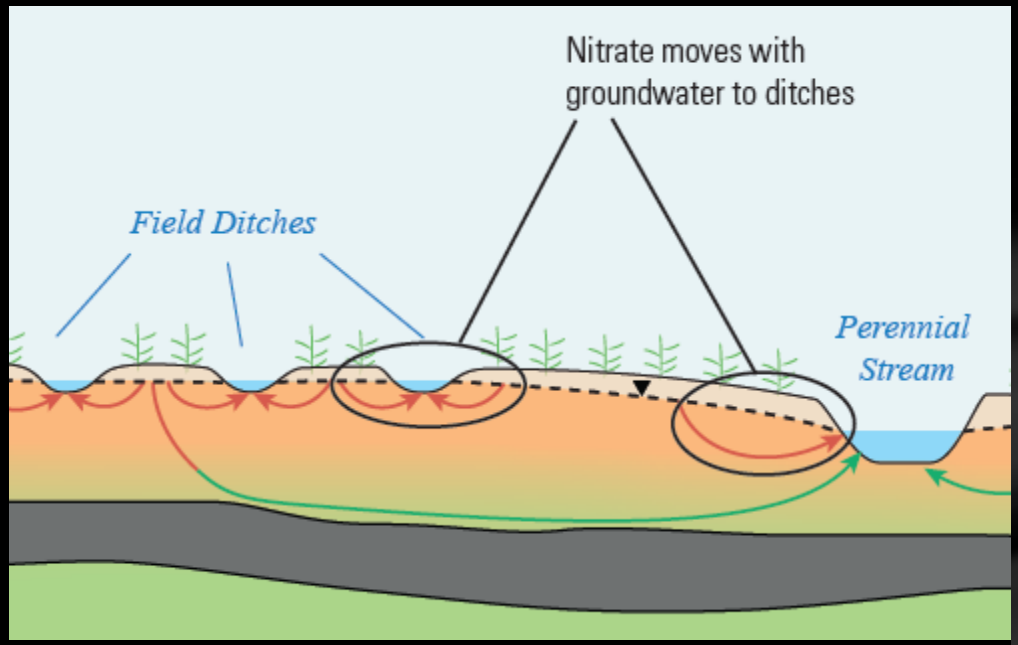
- Water is the dominant mechanism for nitrogen and phosphorus transport from uplands to streams.
- Changes in stream chemistry with increasing flow reflect different dominant processes transporting nitrogen and phosphorus.

Fate and Transport

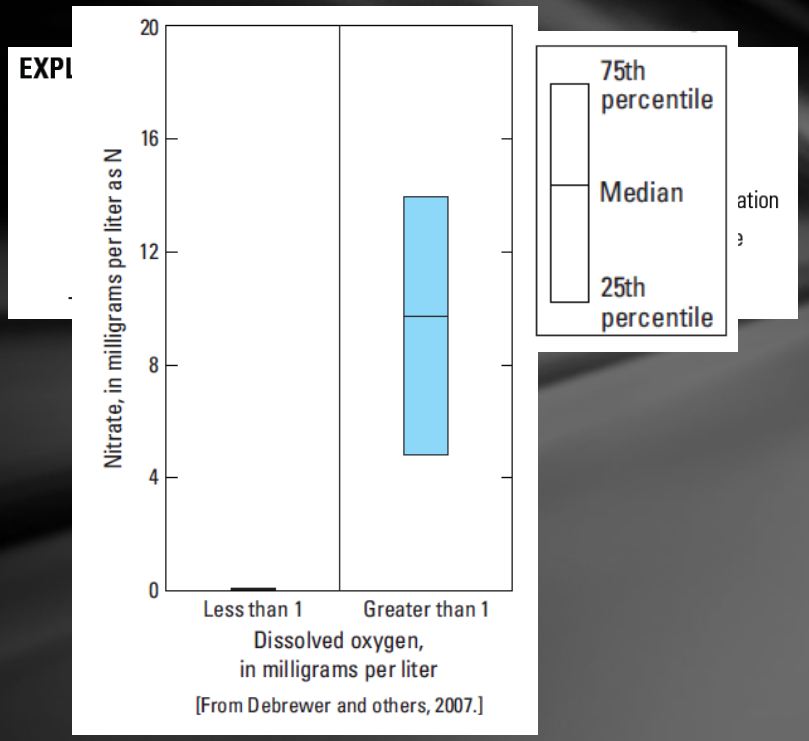


- Nitrogen transport to streams occurs primarily through groundwater in the form of nitrate (NO_3^-).
- Phosphorus transport to streams occurs primarily over the land surface.

Fate and Transport



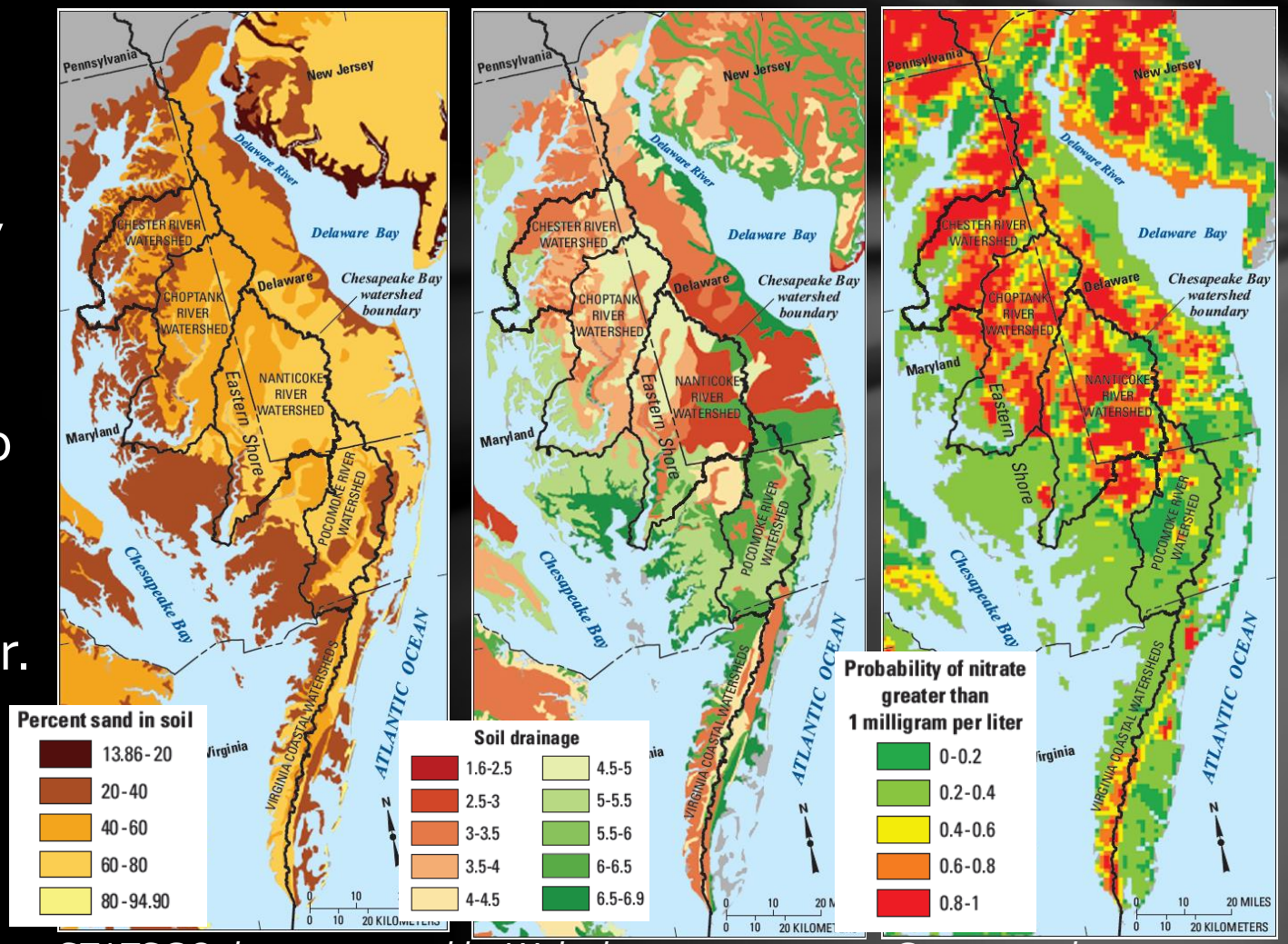
Phillips and Donnelly, 2003; Ator et al., 2005; Denver et al., 2010; McCoy et al., 2010



- Nitrate can be lost from soils and groundwater to the atmosphere through denitrification.
- Denitrification is most common in areas with abundant organic matter and little dissolved oxygen.

Fate and Transport

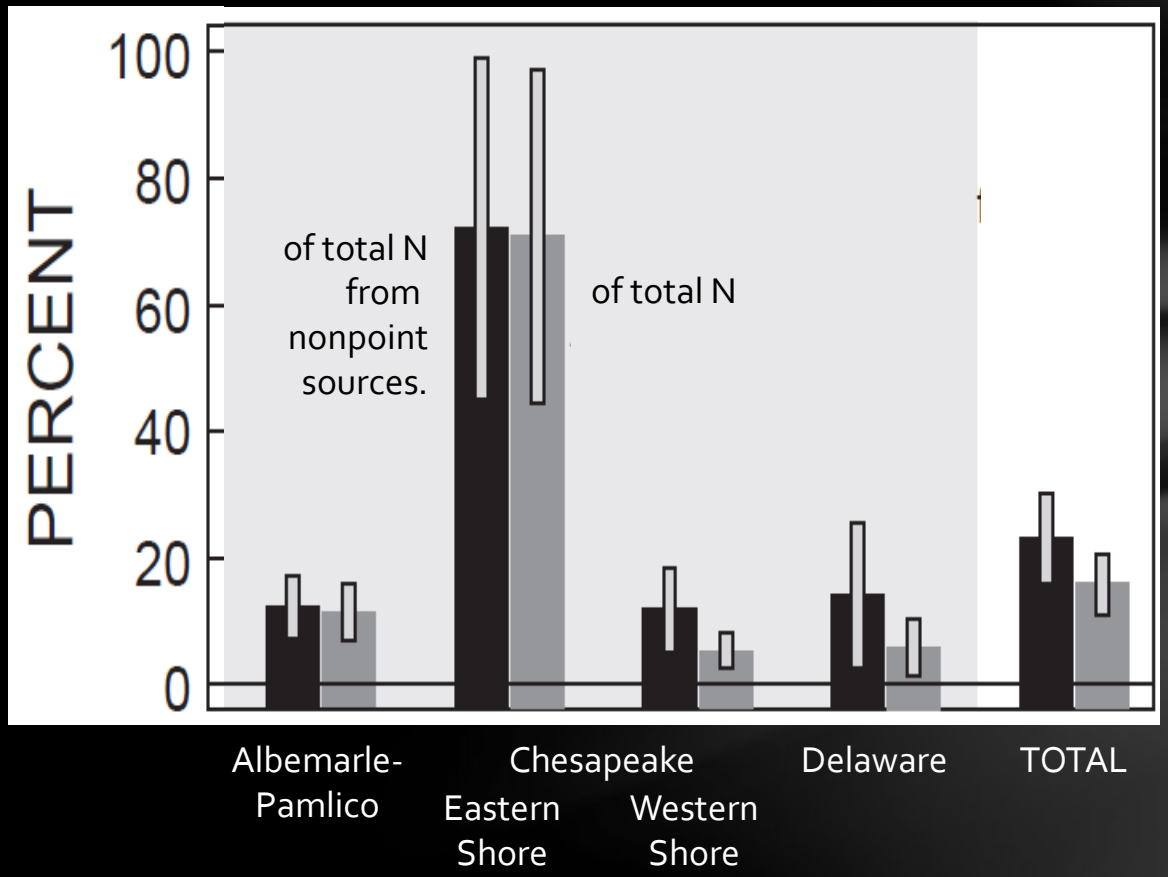
- Much of the Eastern Shore is underlain by soils and sediment conducive to nitrate transport in groundwater.

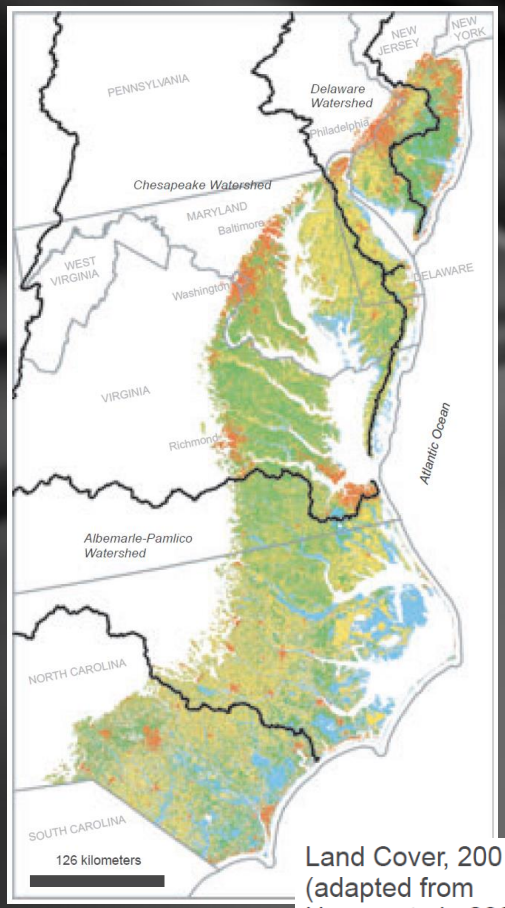


STATSGO data processed by Wolock, 1997

Greene et al., 2005

Fate and Transport



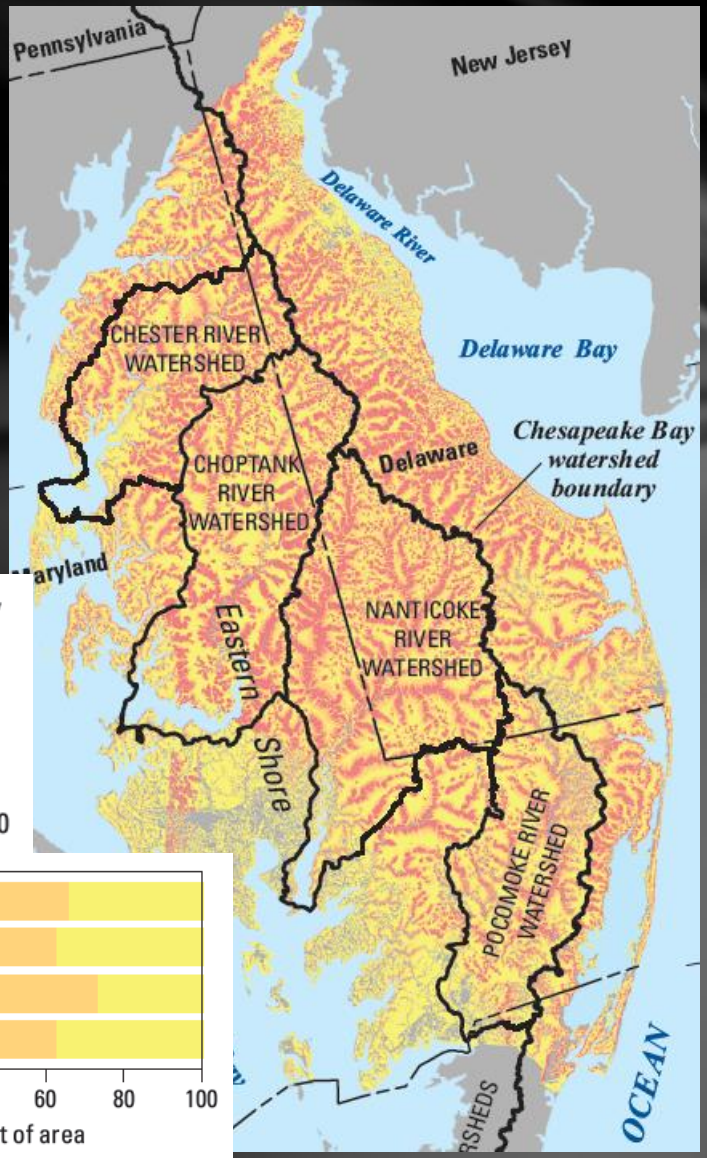


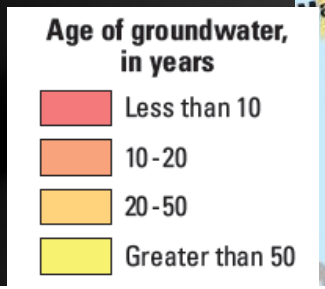
Ator and Denver, 2012

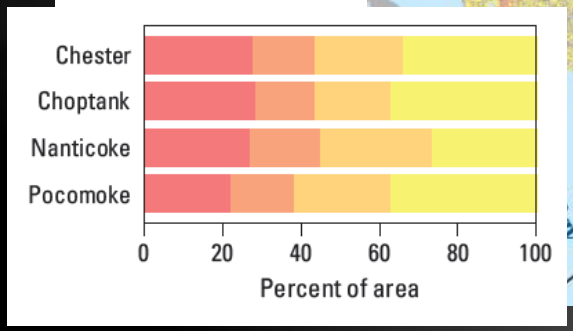
- 70% of the nitrogen load in Eastern Shore streams travels from uplands to streams through groundwater.

Fate and Transport

- Groundwater ages in the surficial aquifer range from 1 to more than 50 years with a median of between 20 and 30 years (Sanford et al., 2012).
- Several decades may be required for nitrate transport through groundwater to streams.
- Phosphorus transport over the land surface is intermittent.







Sanford et al., 2012

Summary of Fate and Transport

- Nitrogen moves from upland application areas to streams primarily through groundwater in the form of nitrate.
- Nitrate can be lost to denitrification in some areas, but much of the landscape in the Eastern Shore is not conducive to denitrification.
- Phosphorus moves primarily from uplands to stream channels over the land surface.
- Several decades are commonly required to complete travel along groundwater flow paths; phosphorus transport over the land surface is intermittent.

Outline

- Sources of nitrogen and phosphorus to the landscape
- Movement of nitrogen and phosphorus from upland source areas to groundwater and streams
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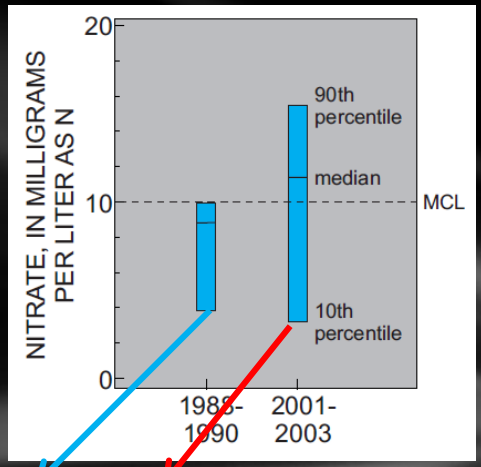
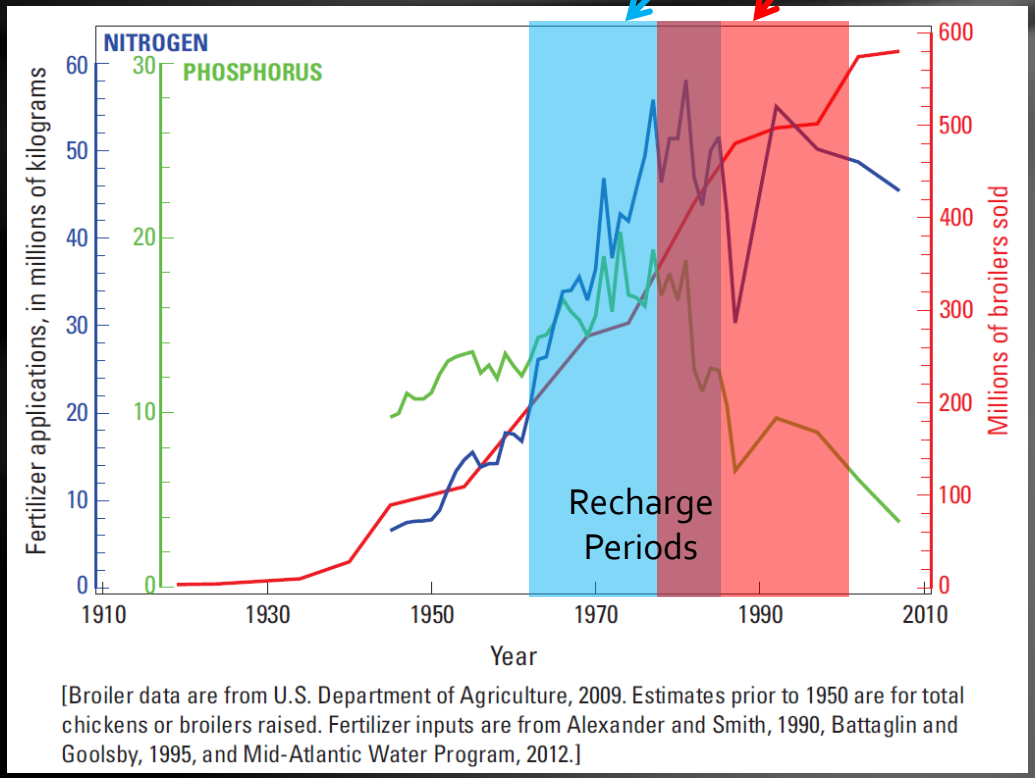
Nitrogen Trends

- Because of the time required for groundwater flow, increasing nitrate in groundwater reflects increasing applications in the past.
- Increasing nitrogen in the Choptank River reflects continued increasing nitrate in groundwater contributions (Hirsch et al., 2010).

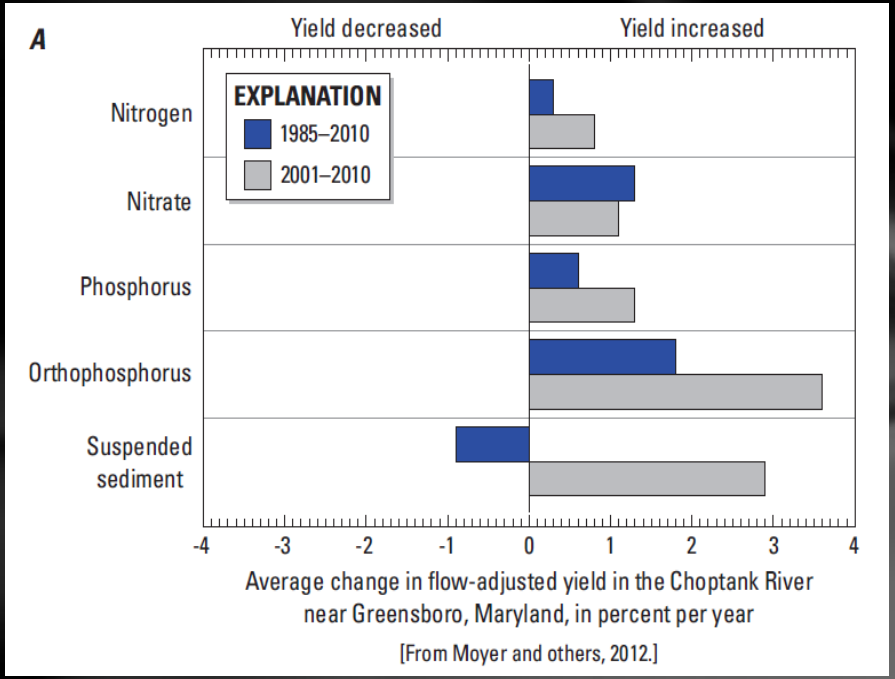


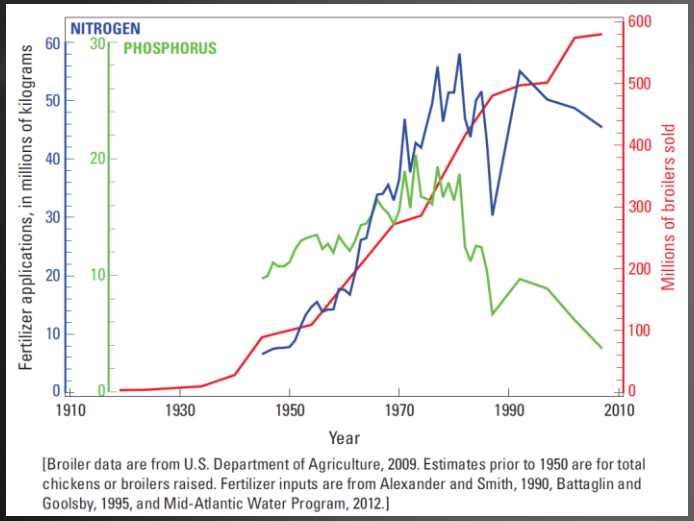


Debrewer et al., 2007; 2008

Phosphorus Trends

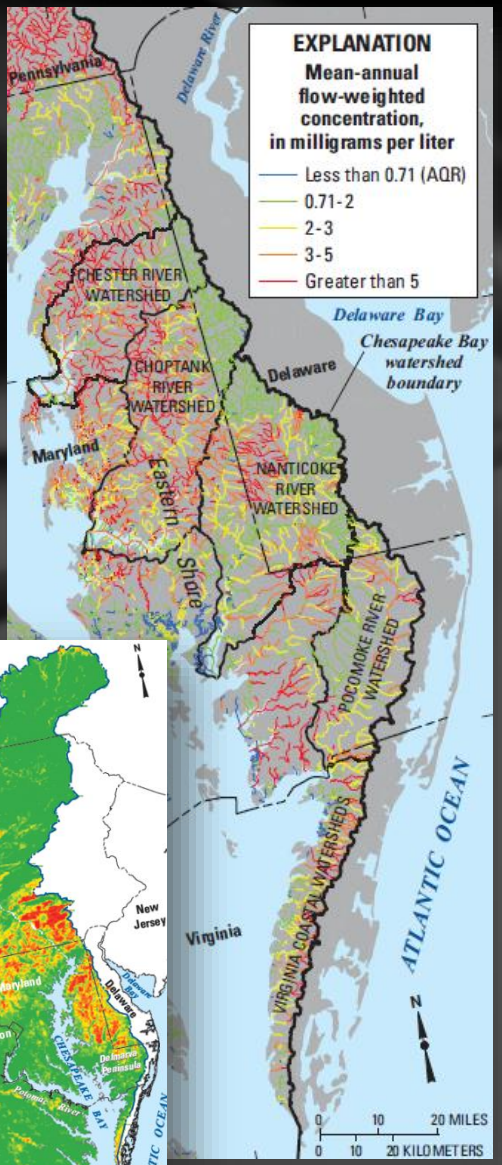
- Increasing phosphorus coincident with decreasing suspended sediment in the Choptank River suggests (possibly):
  - Greater phosphorus on sediment grains (on average)
  - Increasing dissolved phosphorus transport
- Either of these conditions may result from increasing phosphorus saturation in soils.

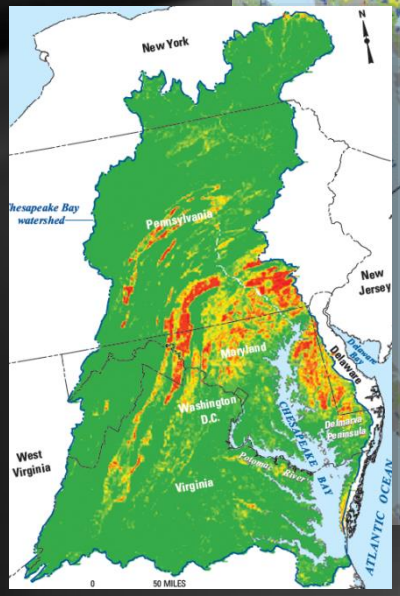




Summary of Current Status

- Historical nitrogen and phosphorus applications to cropland have exceeded crop uptake.
- Landscape conditions (especially hydrogeology) on the Eastern Shore promote:
  - the stability and movement of nitrogen into groundwater as nitrate
  - slow drainage from the landscape
- Consequently, nitrogen and phosphorus have accumulated in the environment and are increasing in streams:
  - nitrogen as nitrate in groundwater
  - phosphorus in soils





Outline

- Sources of nitrogen and phosphorus to the landscape
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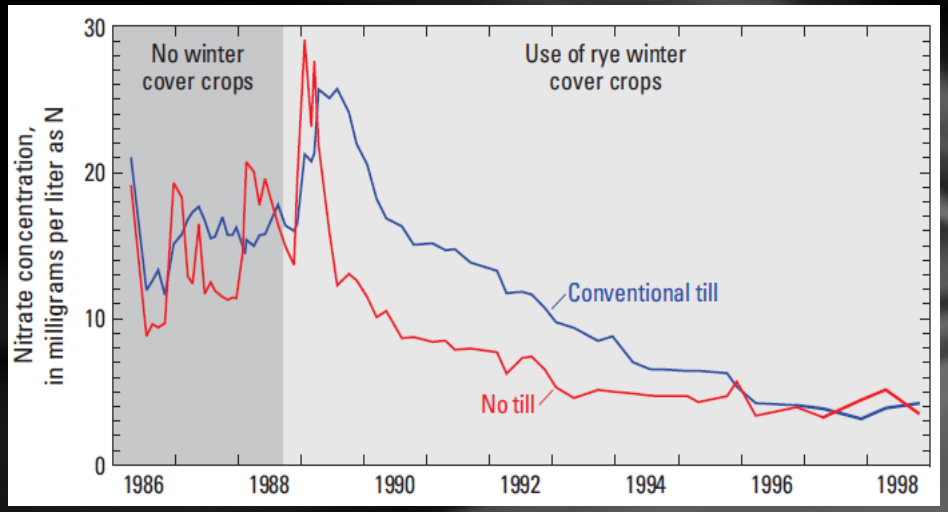
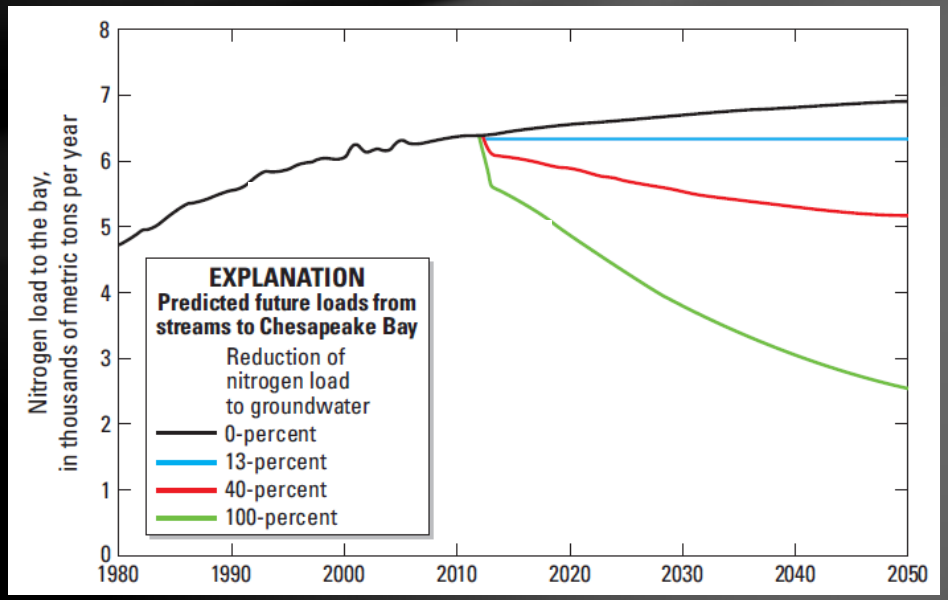
Response Times and Management Implications

- Limiting infiltration of nitrate to the water table could reduce nitrate relatively quickly in shallow groundwater.
  - Cover crops
  - Precision applications
  - Increasing denitrification
- Practices intended to limit runoff and erosion may promote the movement of nitrate to groundwater.



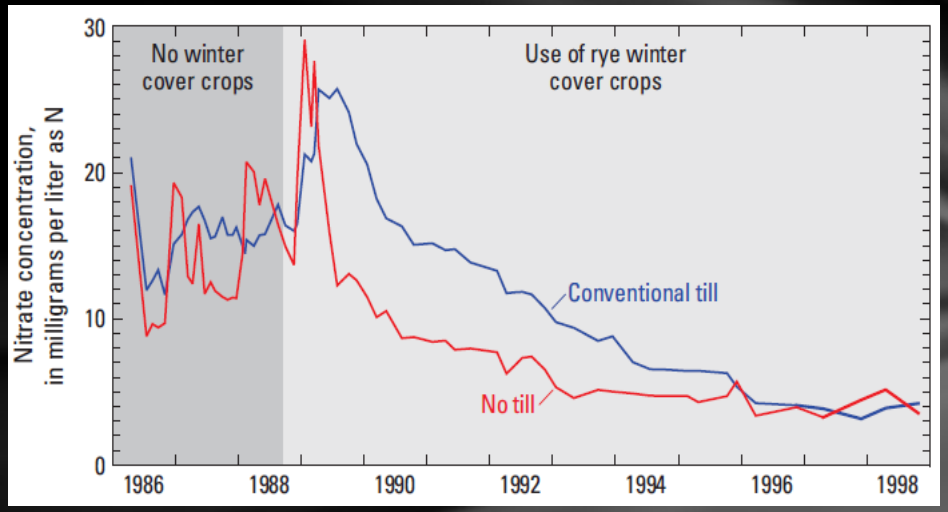


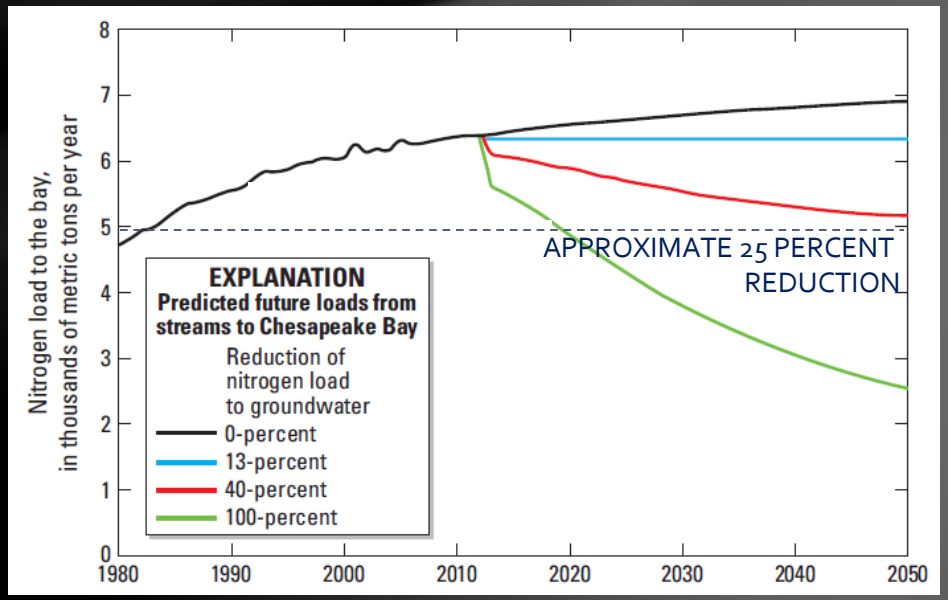
Data from K. Staver (U of Md); see also Staver and Brinsfield, 1998.

Sanford and Pope, 2013

Response Times and Management Implications

- Decades will be required before significant reductions of loads to the bay are realized.
  - A 13 percent reduction in nitrogen load to groundwater will be required to maintain loads to the bay at 2012 levels
  - Even a 40 percent reduction in loads to groundwater will not cause a 25 percent reduction in loads to the bay until at least 2050.





Data from K. Staver (U of Md); see also Staver and Brinsfield, 1998.

Sanford and Pope, 2013

Response Times and Management Implications

- Erosion control to retain sediment and associated phosphorus on the land surface can reduce transport to streams, but may increase dissolved phosphorus transport (Staver and Brinsfield, 2001; 2010; Sharpley et al., 2002).
- Phosphorus applications that are smaller than crop removal at harvest may decrease soil phosphorus relatively quickly.
- Several years or decades may be required before effects are fully realized in streams.

Summary

- The Eastern Shore contributes disproportionately large loads of nitrogen and phosphorus to Chesapeake Bay.
- Nutrient loads from the Eastern Shore to the bay continue to increase due to a long history of applications in excess of crop needs and resulting storage of nitrogen in groundwater and phosphorus in soils.
- Even if current management practices are effective at limiting nutrients on the landscape or movement to water resources, decades will be required before full reductions are realized in loads to the bay.