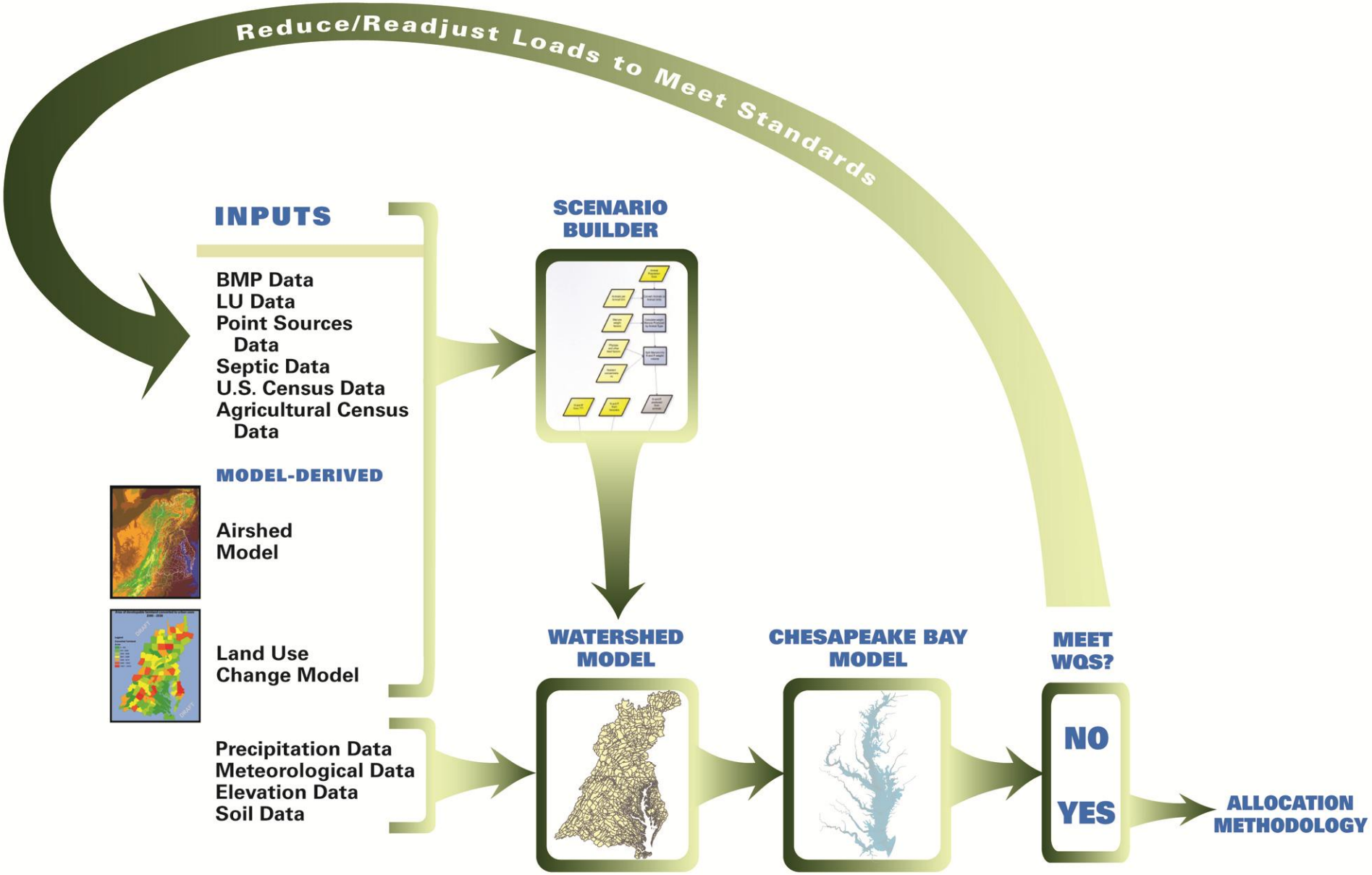
The Chesapeake Bay Program Partnership's Watershed Model

Gary Shenk

Presentation to COG

10/4/2012

Chesapeake Bay Partnership Models



CBP Modeling Tools

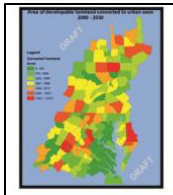
Interaction Tools

NEIEN
Environmental Information eXchange Network

CAST

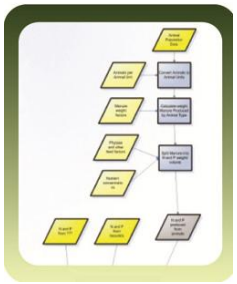
ChesapeakeStat
BayTAS
Chesapeake Bay TMDL Tracking and Accounting System

Decision Models/ Databases


Land Use Change Model

CMAQ
NOAA
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SCENARIO BUILDER

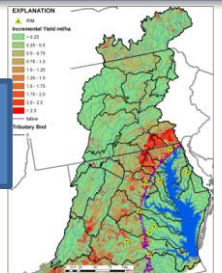


WATERSHED MODEL

Bay WQSTM

Related Tools

sparrow

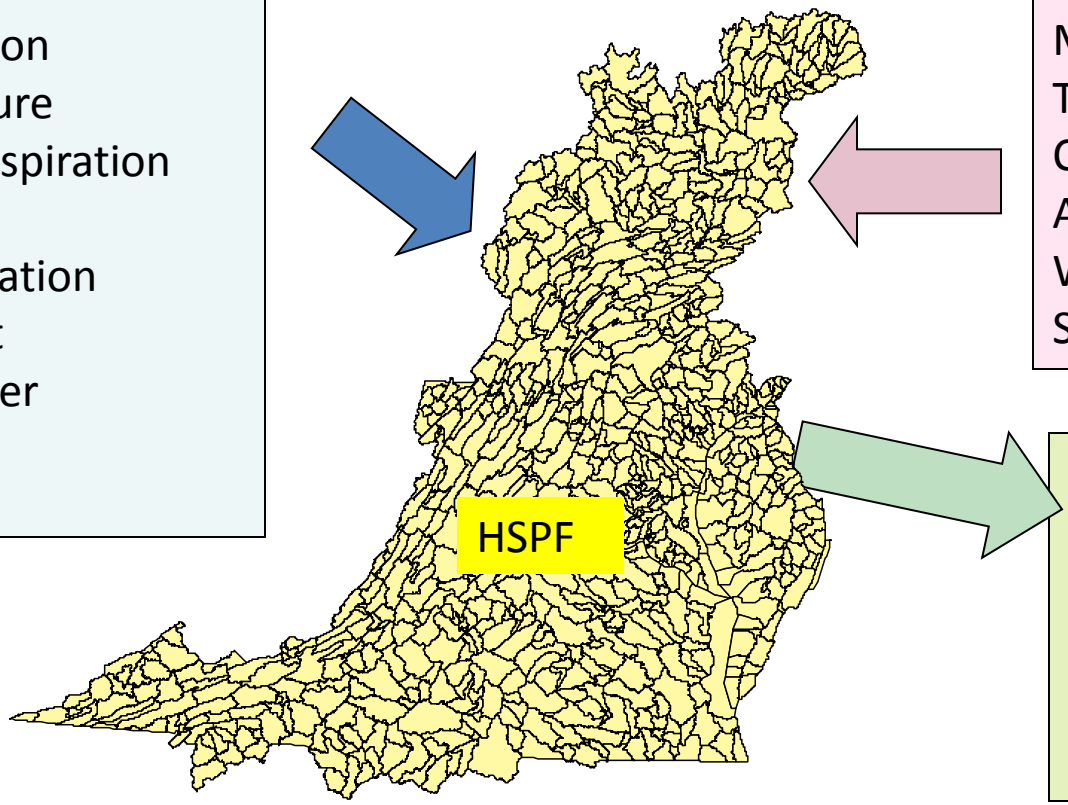


How the Watershed Model Works

Calibration Mode

Hourly or daily values of Meteorological factors:

Precipitation
Temperature
Evapotranspiration
Wind
Solar Radiation
Dew point
Cloud Cover



Annual, monthly, or daily values of anthropogenic factors:

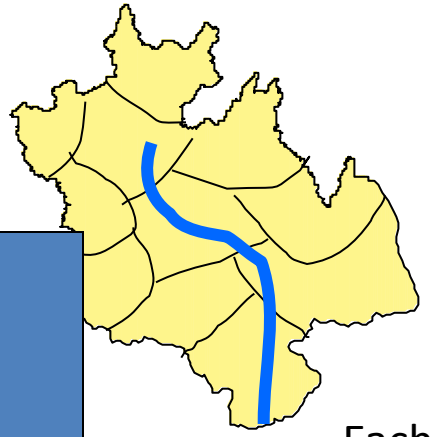
Land Use Acreage
BMPs
Fertilizer
Manure
Tillage
Crop types
Atmospheric deposition
Waste water treatment
Septic loads

Daily flow, nitrogen, phosphorus, and sediment compared to observations over 21 years

How the Watershed Model Works

Each segment consists of 30 separately-modeled land uses:

- Regulated Pervious Urban
- Regulated Impervious Urban
- Unregulated Pervious Urban
- Unregulated Impervious Urban
- Construction
- Extractive
- Combined Sewer System
- Wooded / Open
- Disturbed Forest



Plus: Point Source and Septic Loads, and Atmospheric Deposition Loads

- Corn/Soy/Wheat rotation (high till)
- Corn/Soy/Wheat rotation (low till)
- Other Row Crops
- Alfalfa
- Nursery
- Pasture
- Degraded Riparian Pasture
- Afo / Cafo
- Fertilized Hay
- Unfertilized Hay
  - Nutrient management versions of the above

Each calibrated to nutrient and Sediment targets

How the Watershed Model Works

Precipitation

Fertilizer
Manure
Atmospheric deposition

Management filter

Runoff

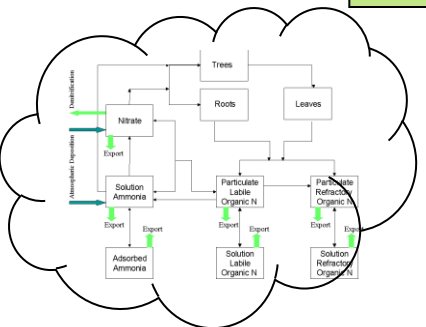
River

Hydrology submodel

Sediment submodel

Phosphorus submodel

Nitrogen submodel

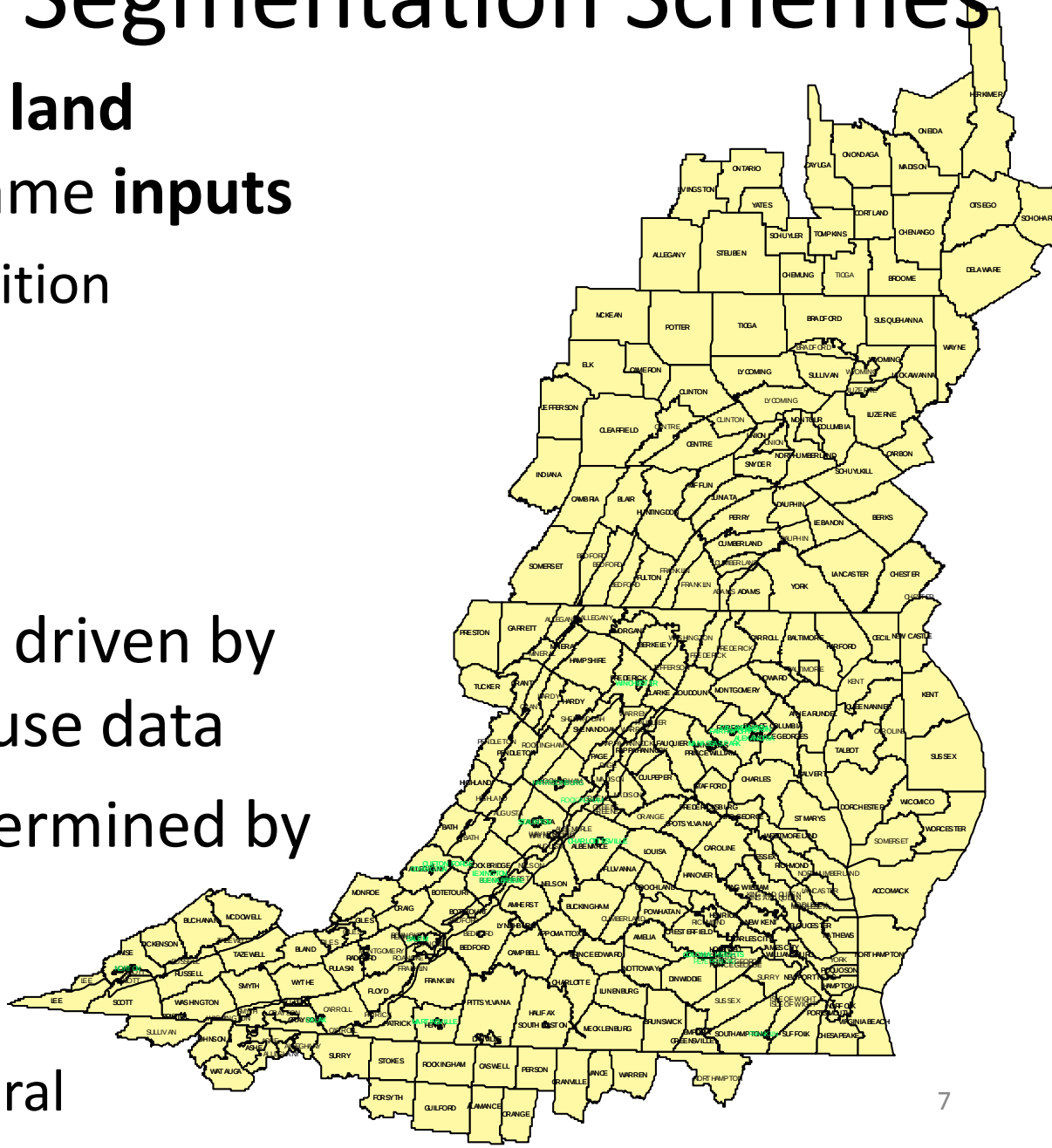


hourly

Buffers
wetlands

Two Separate Segmentation Schemes

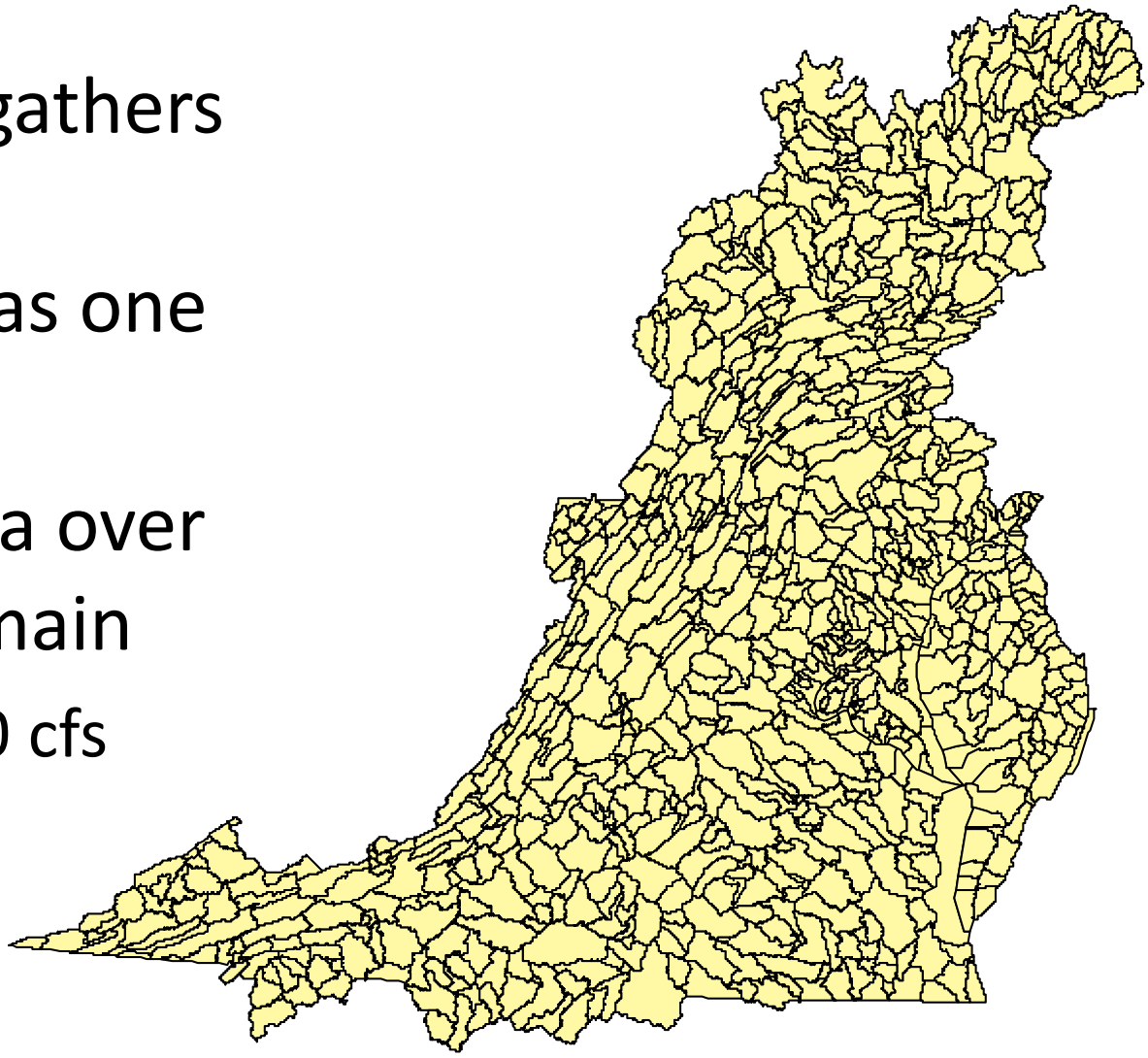
- A land use within a **land segment** has the same **inputs**
  - atmospheric deposition
  - fertilizer
  - manure
  - precipitation
- Land segmentation driven by availability of land use data
- Land segments determined by
  - County lines
  - Rainfall Variances
  - Federal / Non-Federal



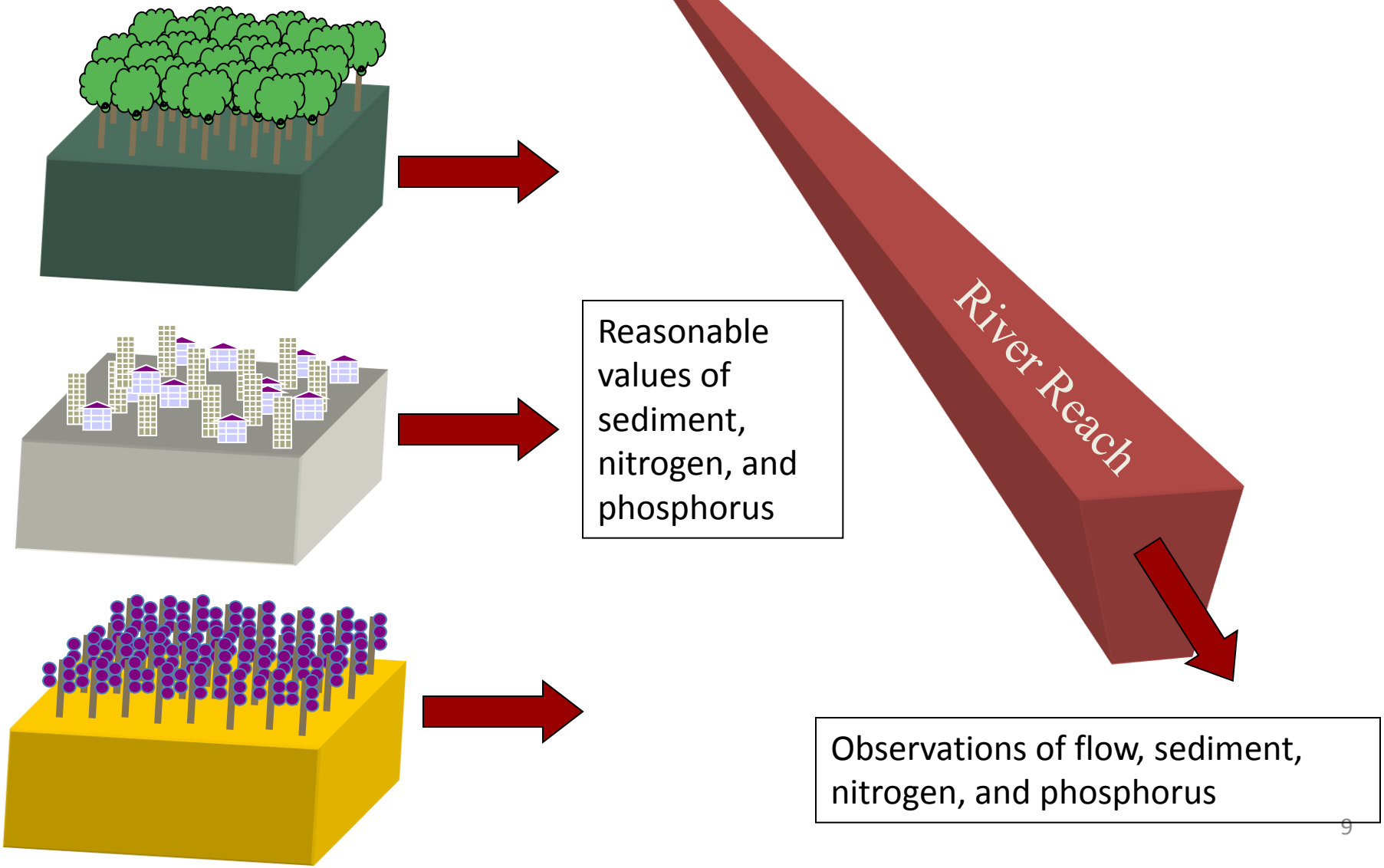
Phase 5 river segmentation

- A river segment gathers inputs from the watershed and has one simulated river
- Consistent criteria over entire model domain
  - Greater than 100 cfs

    or
  - Has a flow gage



How do we calibrate?



Reasonable values of sediment, nitrogen, and phosphorus

Observations of flow, sediment, nitrogen, and phosphorus

Average Targets

Land Use	**TN**	**TP**
Forest	2.0	0.15
Harvested Forest	20.0	0.80
Crop	23.0	2-2.5
Hay	6.0	0.4-0.8
Pasture	4.5	0.7
Urban	9.3	1.5
Extractive	12.5	3.5
Nursery	240	85

- Vary spatially according to input/output

Figure 2 Median TP concentration in NPDES Phase 1 storm water data
Using data from Pitt, undated. Error bars are one standard deviation

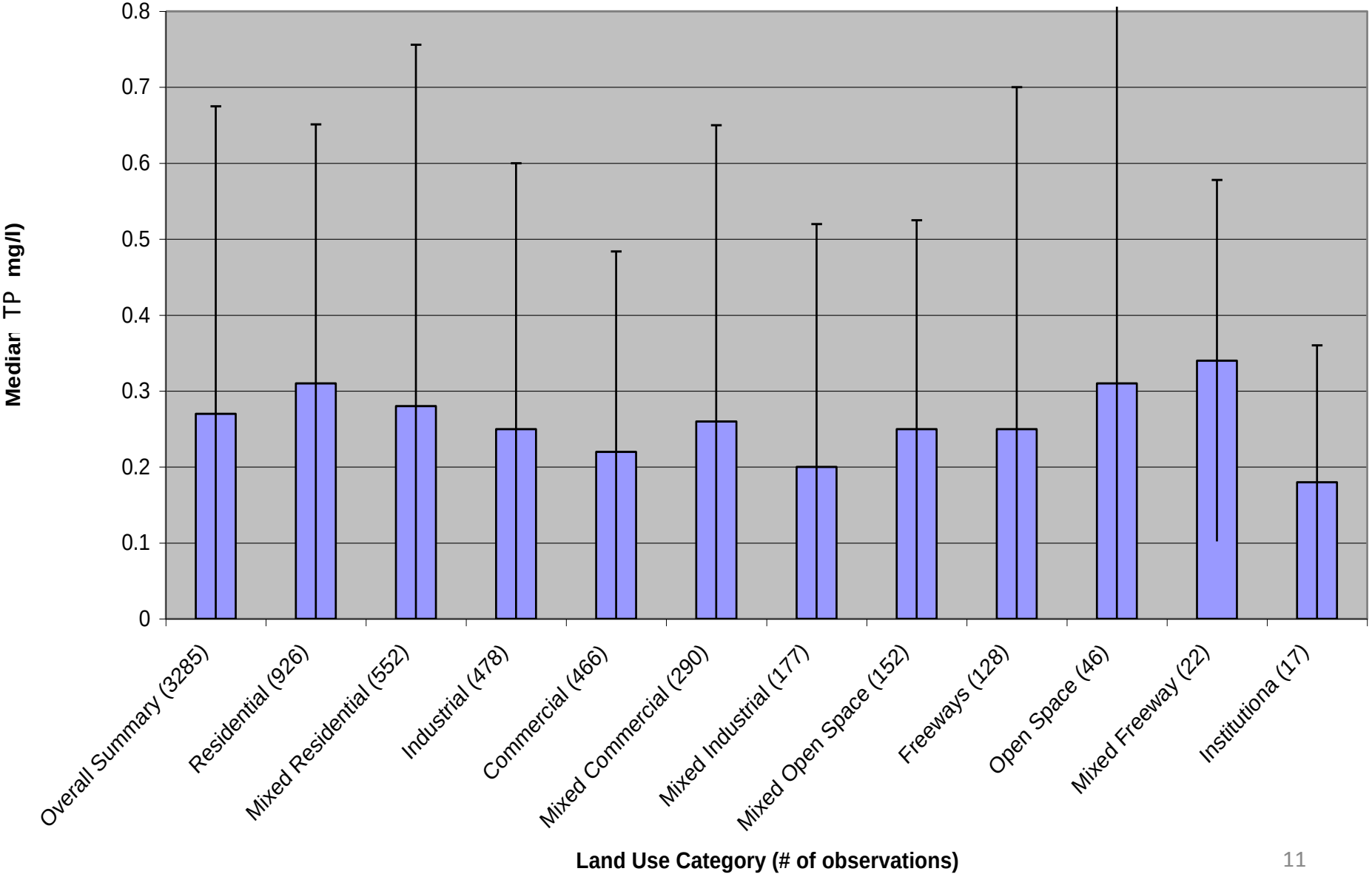
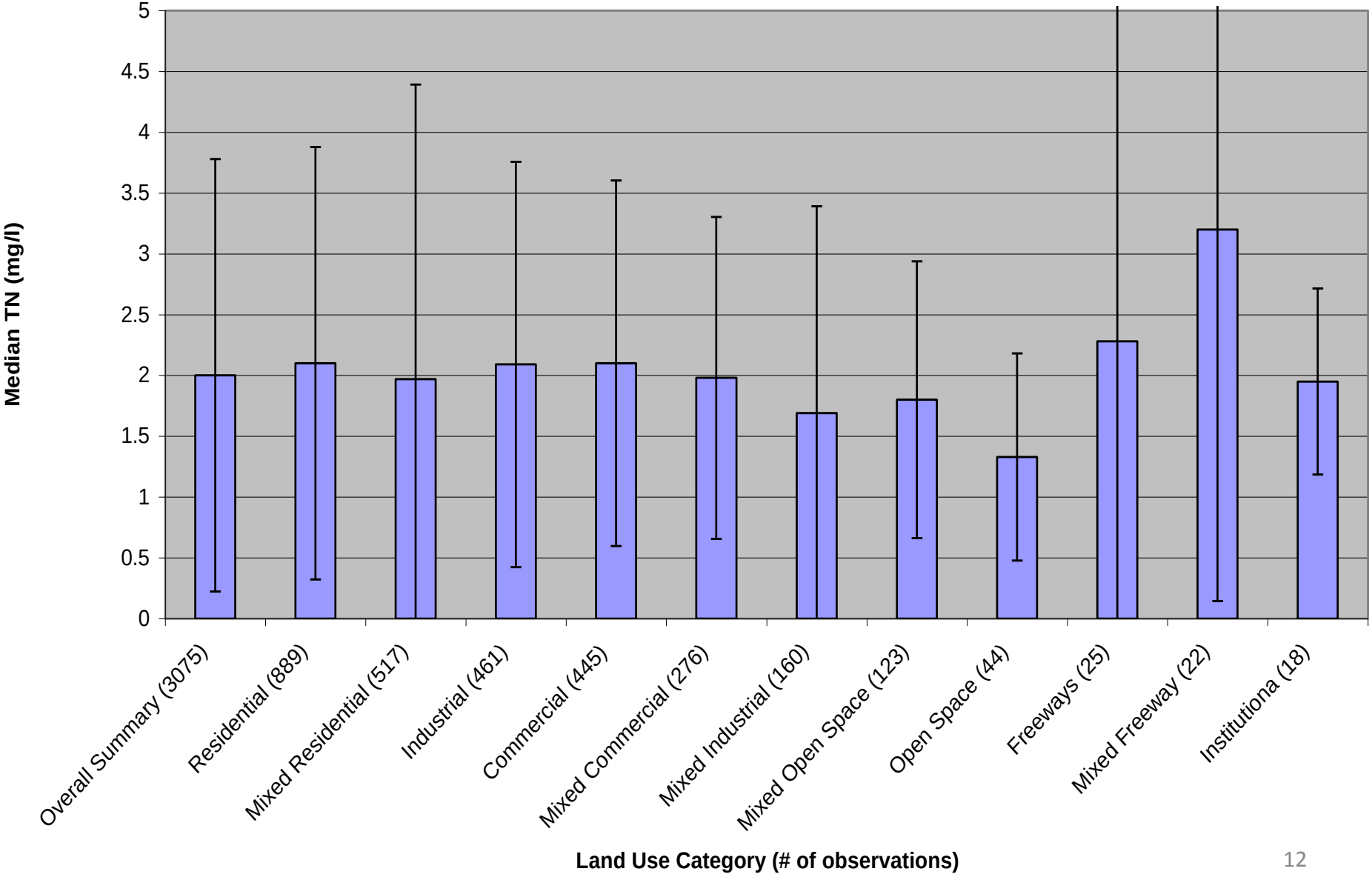


Figure 1 Median TN concentration in NPDES Phase 1 storm water data using data from Pitt, undated. Error bars are one standard deviation

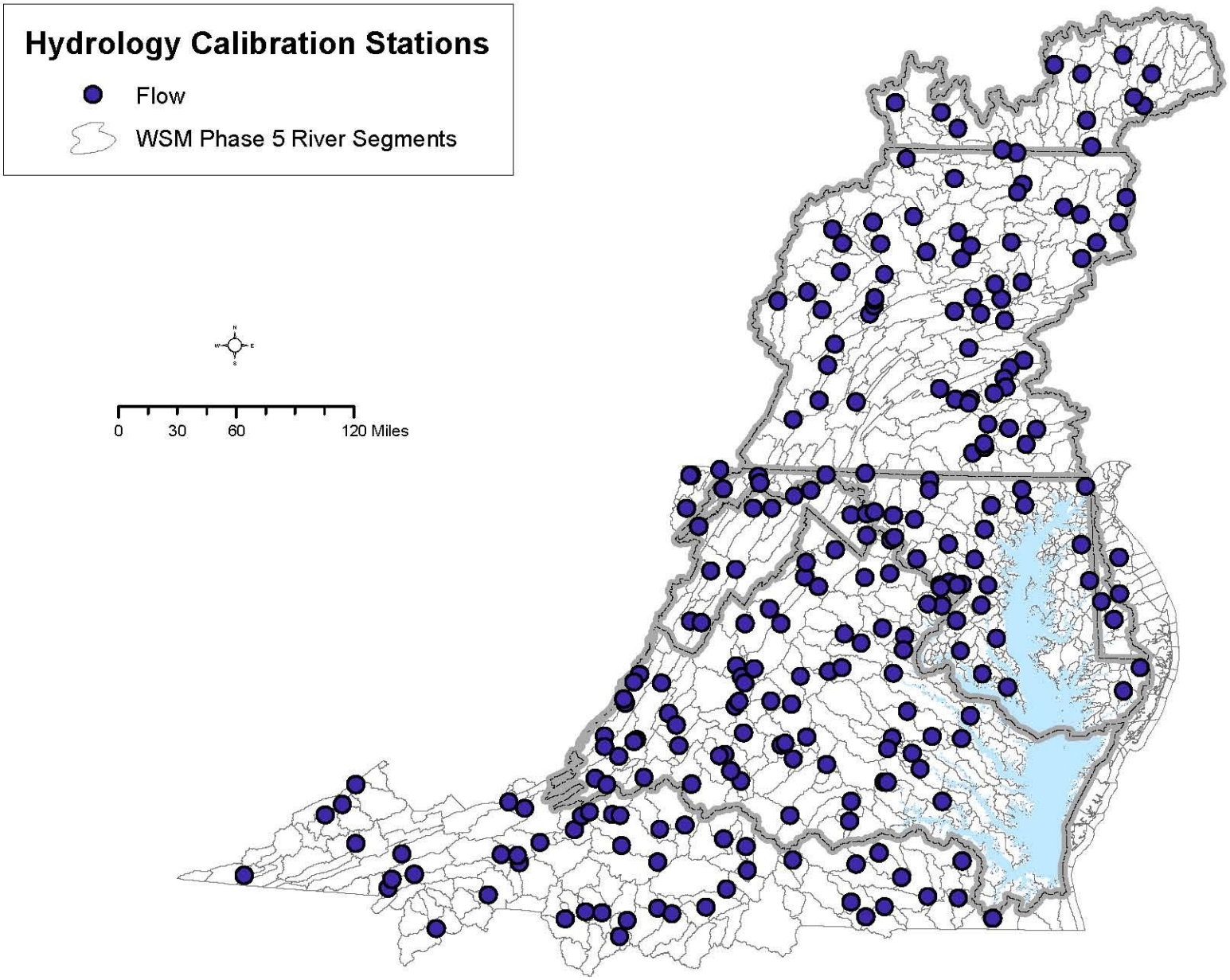


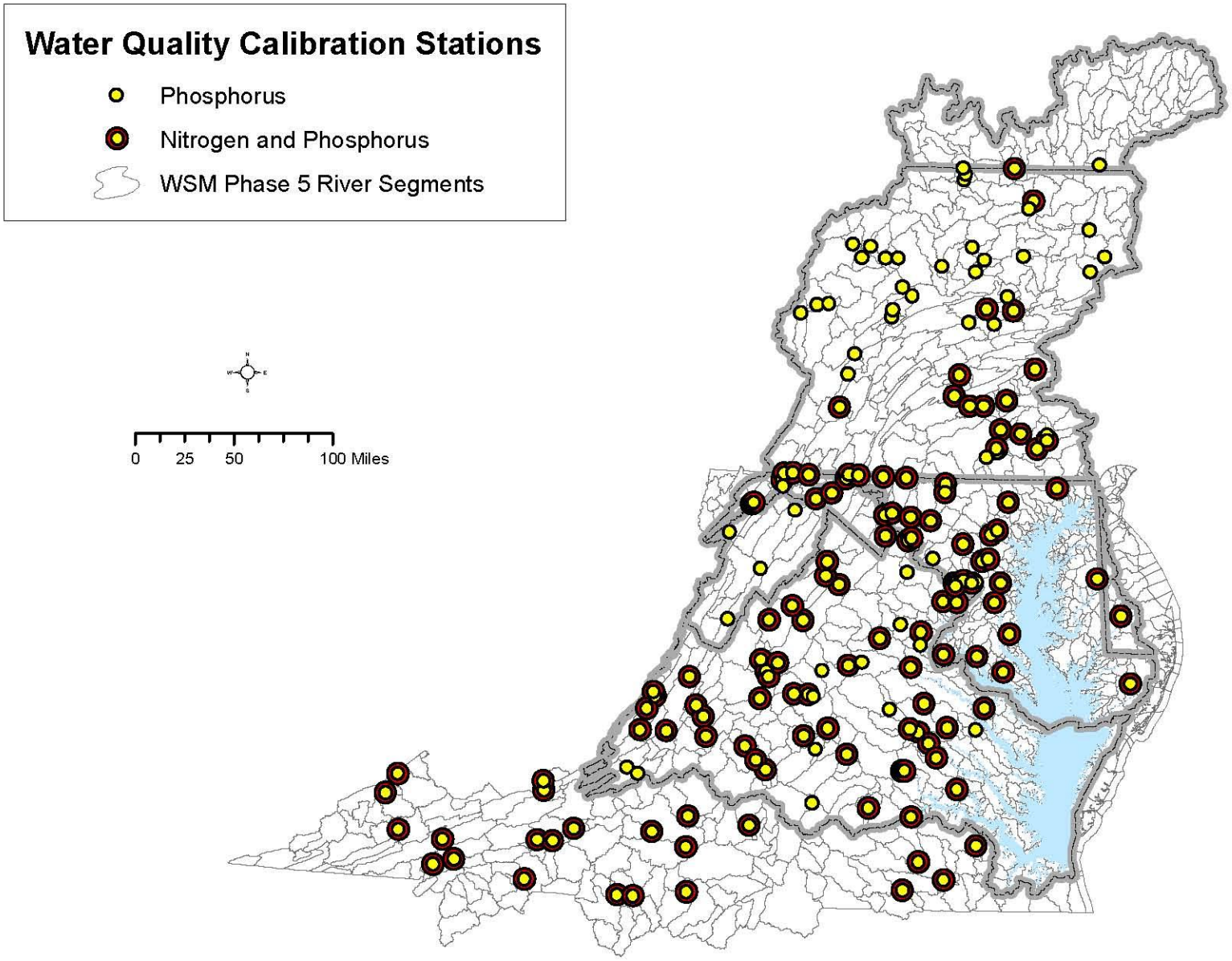
Developed Land Uses

	Regulated	Unregulated	Combined Sewer
Pervious	✓	✓	✓
Impervious	✓	✓	✓
Construction	✓		✓
Extractive	✓	✓	✓

- **Regulated vs Unregulated normally corresponds to MS4 and non-MS4. Loading rates are identical so these categories are a convenience for the state partners.**
- **Combined Sewer land uses have zero loads. The loads from WWTPs and CSOs in combined sewer areas are in the model, so including these would be double counting**
- **Also broken out as Federal / Non-Federal**

- **Determined directly from the CBP Land Data Team analysis at roughly 10 year increments**


Hydrology Calibration Stations
Flow
WSM Phase 5 River Segments
0
30
60
120 Miles

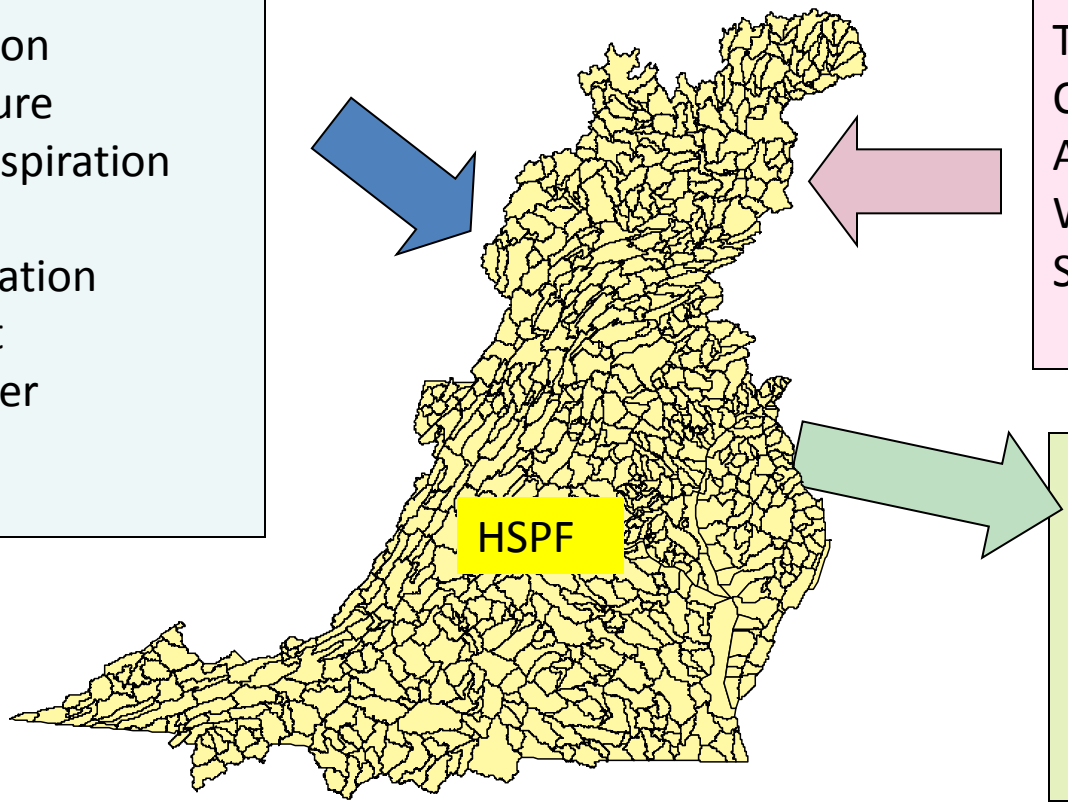

Water Quality Calibration Stations
Phosphorus
Nitrogen and Phosphorus
WSM Phase 5 River Segments
0
25
50
100 Miles

How the Watershed Model Works

Scenario Mode

Hourly or daily values of Meteorological factors:

Precipitation
Temperature
Evapotranspiration
Wind
Solar Radiation
Dew point
Cloud Cover



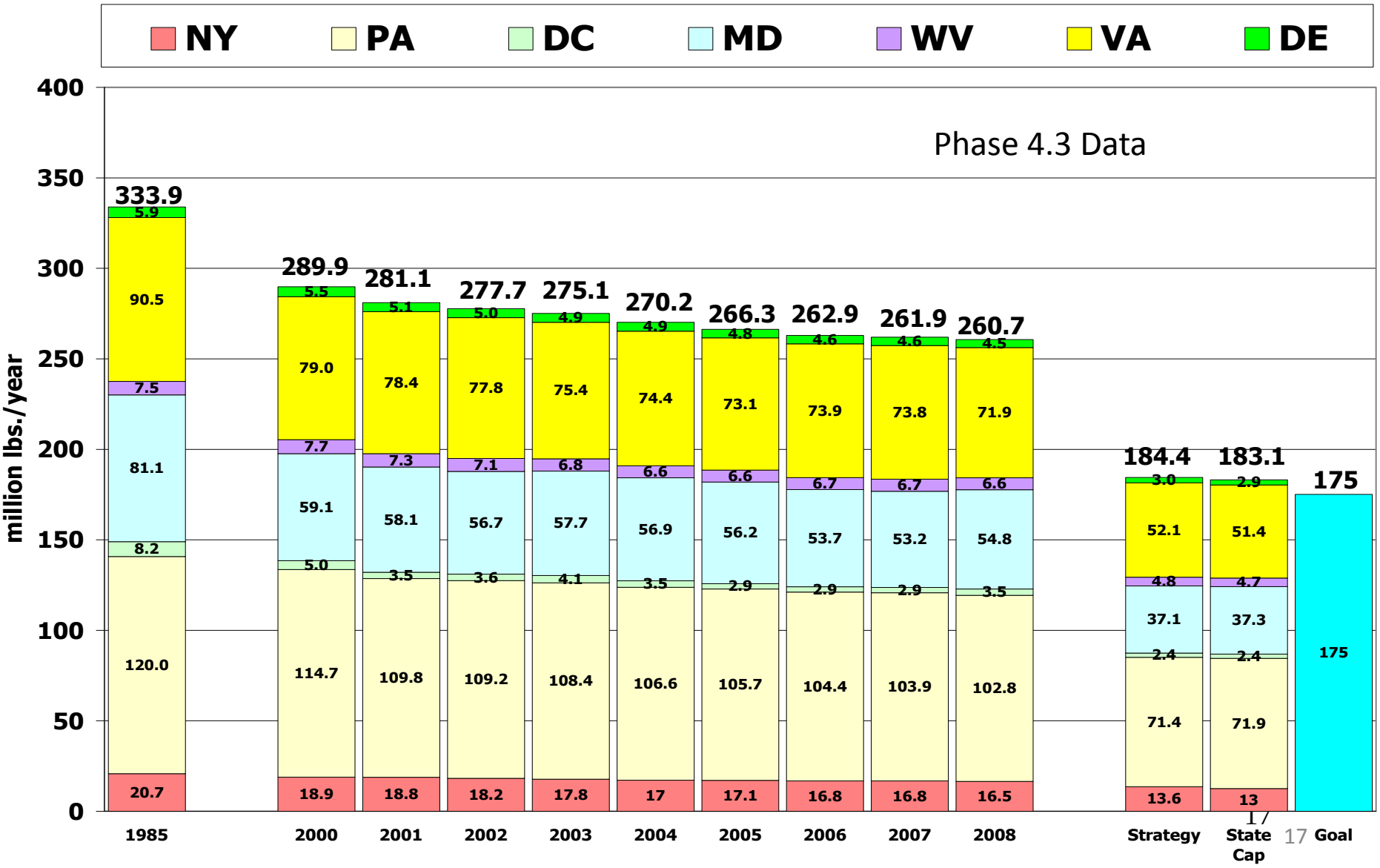
Constant values of anthropogenic factors:

Land Use Acreage
BMPs
Fertilizer
Manure
Tillage
Crop types
Atmospheric deposition
Waste water treatment
Septic loads

Run for 1984-2000
Average 1991-2000
For 'flow-normalized average annual loads'

Nitrogen Loads Delivered to the Chesapeake Bay By Jurisdiction

Point source loads reflect measured discharges while
nonpoint source loads are based on an average-hydrology year



- BMP Type and location (NEIEN/State supplied)
- Land acres
- Remote Sensing, NASS Crop land Data layer
- Crop acres
- Yield
- Animal Numbers (Ag Census or state supplied)
- Land applied biolsolids
- Septic system (#s)

Inputs

Parameters

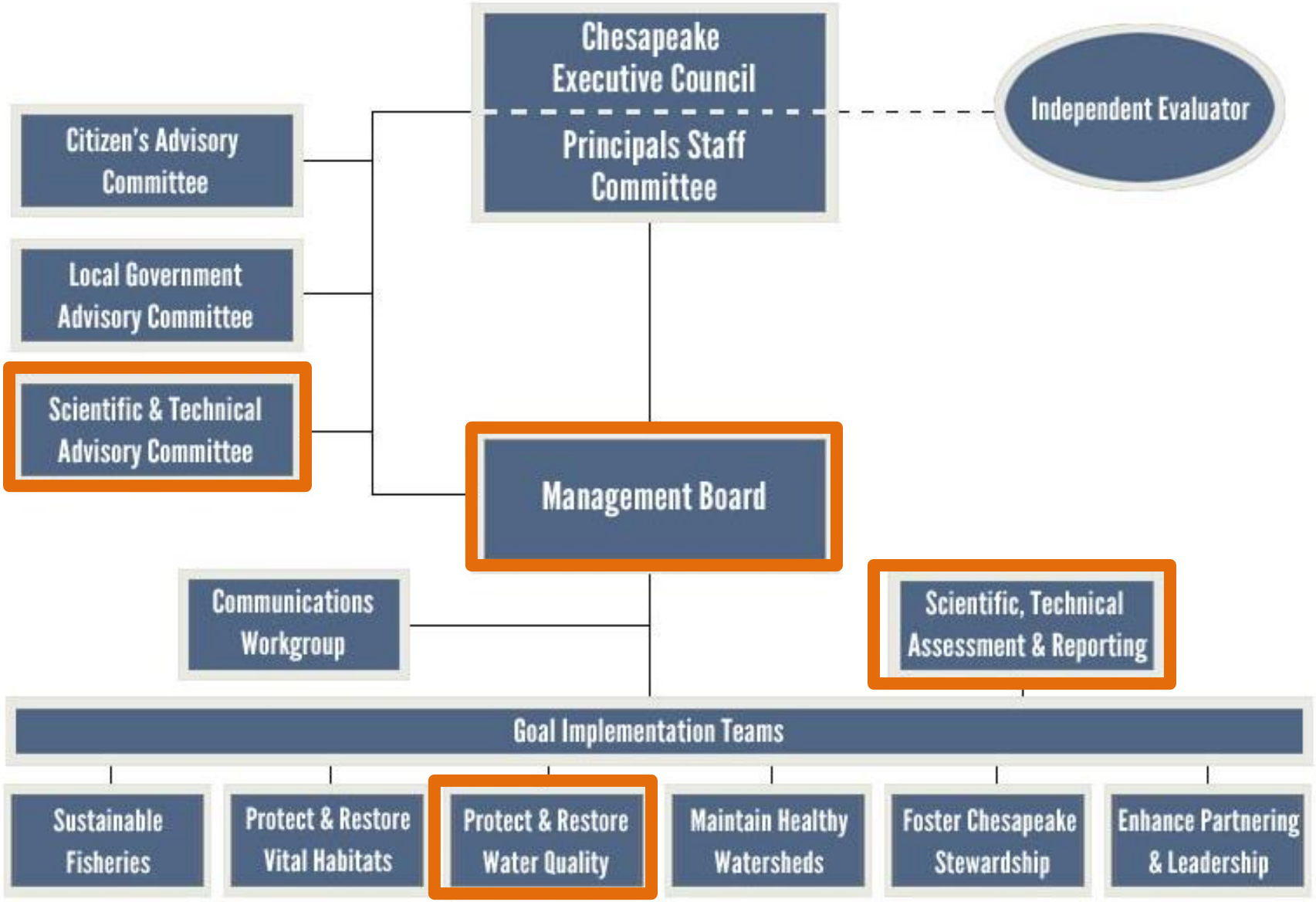
(Changeable by user)

- BMP types and efficiencies
- Land use change (BMPs, others)
- RUSLE2 Data: % Leaf area and residue cover
- Plant and Harvest dates
- Best potential yield
- Animal factors (weight, phytase feed, manure amount and composition)
- Crop application rates and timing
- Plant nutrient uptake
- Time in pasture
- Storage loss
- Volatilization
- Animal manure to crops
- N fixation
- Septic delivery factors

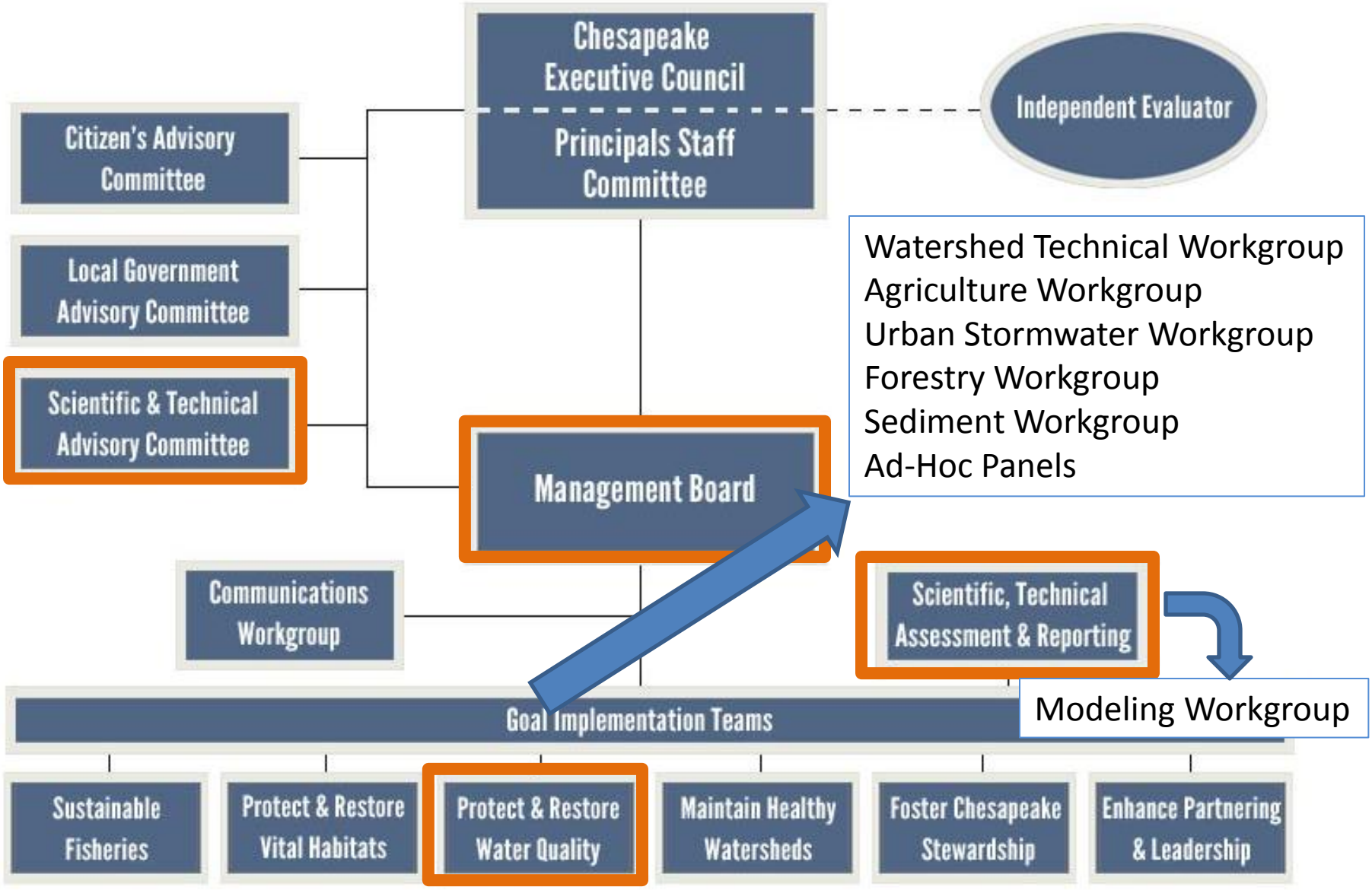
- BMPs, # and location
- Land use
- % Bare soil, available to erode
- Nutrient uptake
- Manure and chemical fertilizer (lb/segment)
- N fixation (lb/segment)
- Septic loads

Outputs

Chesapeake Bay Program Partnership



Chesapeake Bay Program Partnership



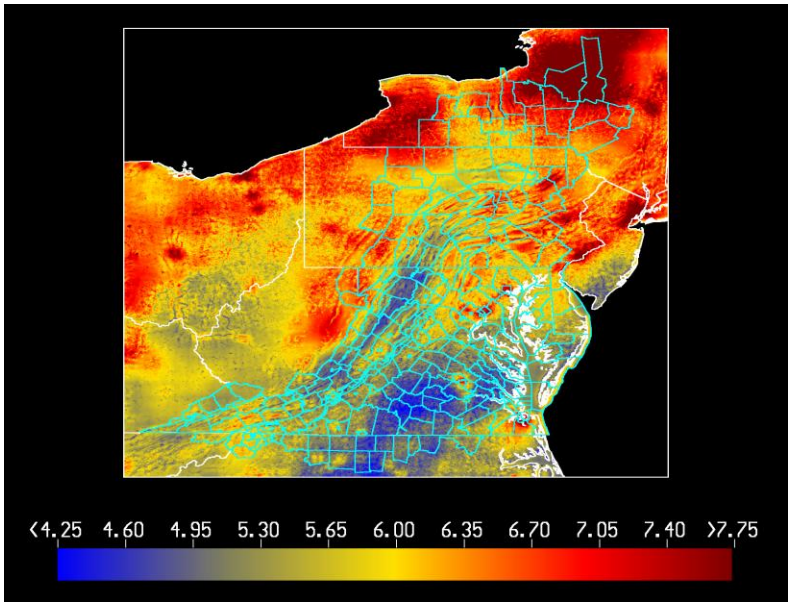
Agricultural Workgroup

- **Federal**
  - USDA, EPA
- **State**
  - Chesapeake Bay Commission, Delaware Department of Agriculture, Maryland Department of Agriculture, NY DEC, PA Department of Environmental Protection, Pennsylvania Department of Environmental Protection, Pennsylvania State Conservation Commission, VA DCR, VA DEQ, West Virginia Department of Agriculture, WV DEP
- **University**
  - Chesapeake Research Consortium, Cornell University, Penn State University, University of Delaware, University of Maryland, West Virginia University
- **Industry Groups**
  - Delaware Maryland Agribusiness Association, Delaware Pork Producers Association, Delmarva Poultry Industry, Inc., MD Farm Bureau, VA Farm Bureau, VA Grain Producers Producers Association, Virginia Agribusiness Council, Virginia Poultry Association, U.S. Poultry & Egg Association,
- **Local organizations**
  - Cortland County Soil and Water Conservation District, Lancaster County Conservation District, Madison Co. SWCD, Upper Susquehanna Coalition
- **NGOs**
  - American Farmland Trust, Environmental Defense Fund, Keith Campbell Foundation for the Environment, MidAtlantic Farm Credit, PA NoTill Alliance

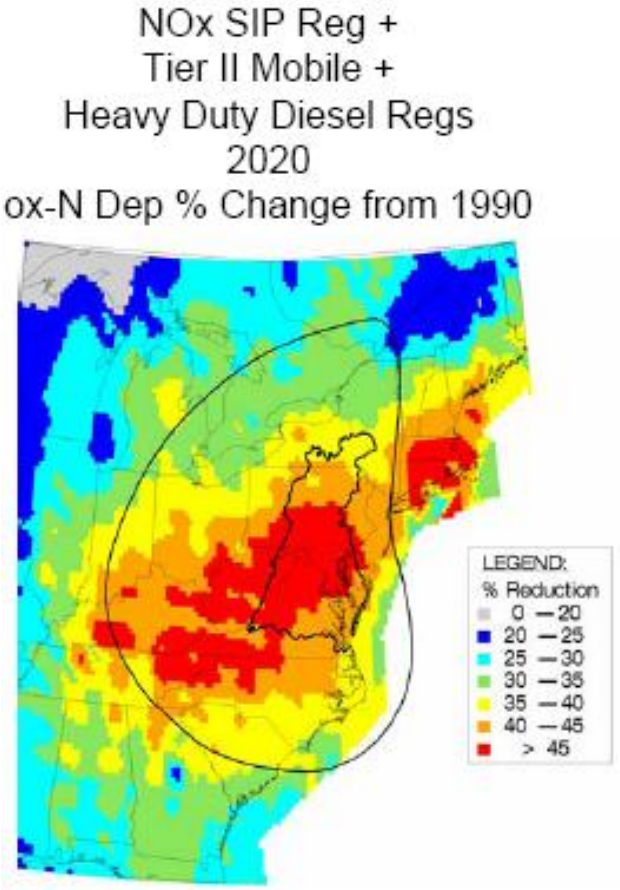
One Ad-Hoc Subgroup of the Agricultural Workgroup

Mid-Atlantic Water Program, U.S. Department of Agriculture-Natural Resources Conservation Service, Virginia Department of Conservation and Recreation, Virginia Department of Forestry, Pennsylvania State Conservation Commission, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Environmental Protection, Maryland Department of Agriculture, Maryland Department of Natural Resources, Maryland Department of the Environment, University of Maryland Cooperative Extension, University of Maryland-College Park, Delaware Department of Agriculture, Delaware Department of Natural Resources and Environmental Control, Delaware Maryland Agribusiness Association, West Virginia Department of Agriculture, West Virginia Department of Environmental Protection, Cacapon Institute - West Virginia, New York Department of Environmental Conservation, Upper Susquehanna Coalition, American Farmland Trust, Chesapeake Bay Commission, U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Environmental Protection Agency, Keith Campbell Foundation for the Environment, Pinchot Institute, Piedmont Environmental Council

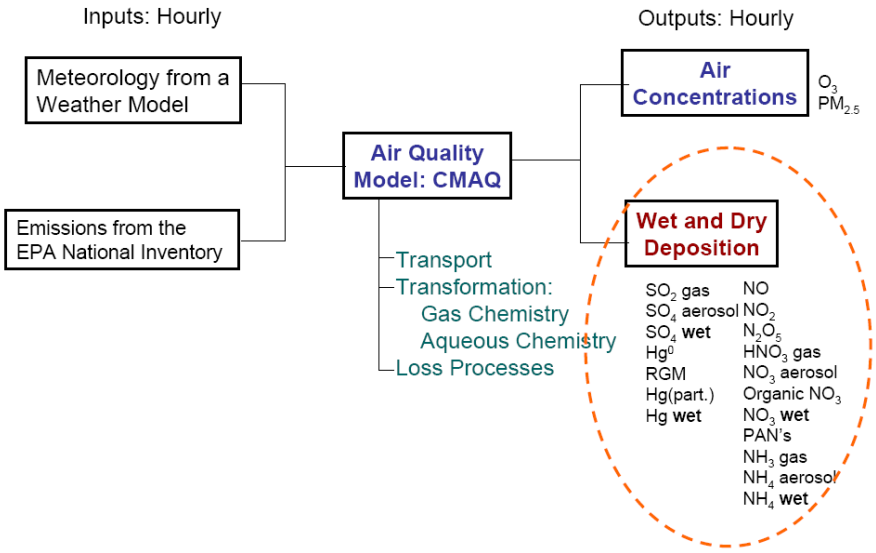
Atmospheric Deposition Estimates



Combining a regression model of wetfall deposition...



…with CMAQ estimates of dry deposition for the base…



…and using the power of the CMAQ model for scenarios.

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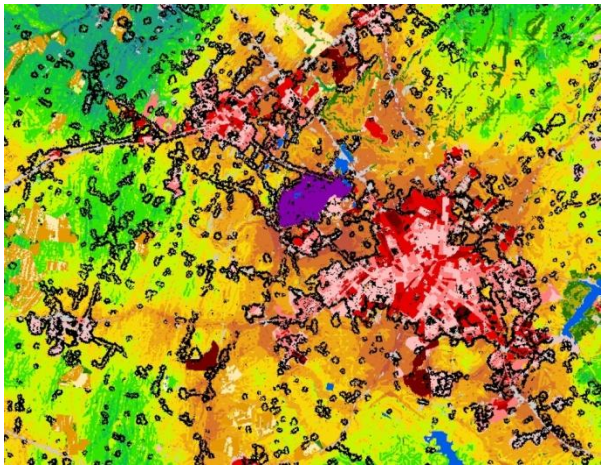
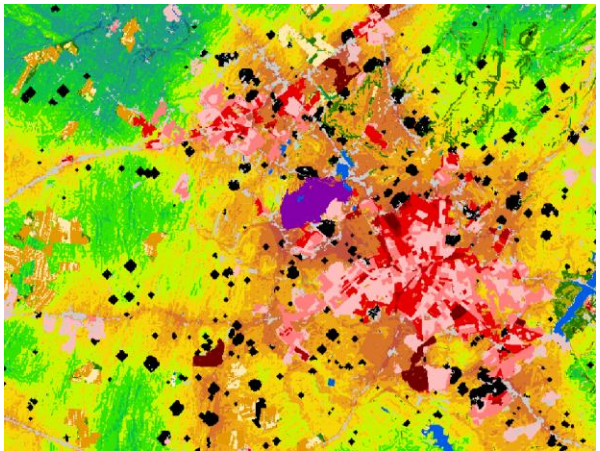
Land Change Modeling at the CBP

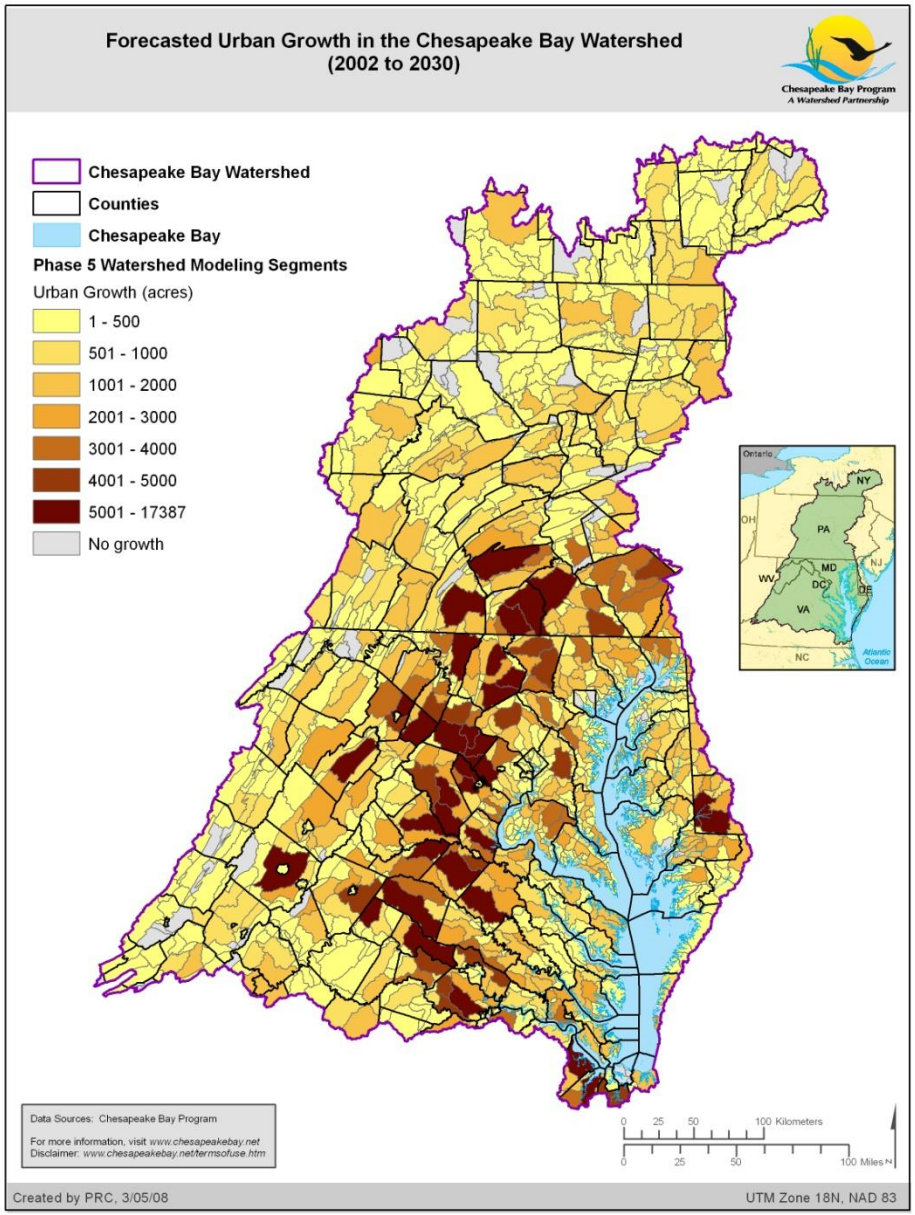
- 1980s – 1990s – simple empirical relationships
- CBLCM
  - v1 – Sleuth
  - V2 –empirical relationships
  - V3 – Patch-based growth
    - Existing Lu/Lc
    - Topographic/Geologic data
    - Population Projections



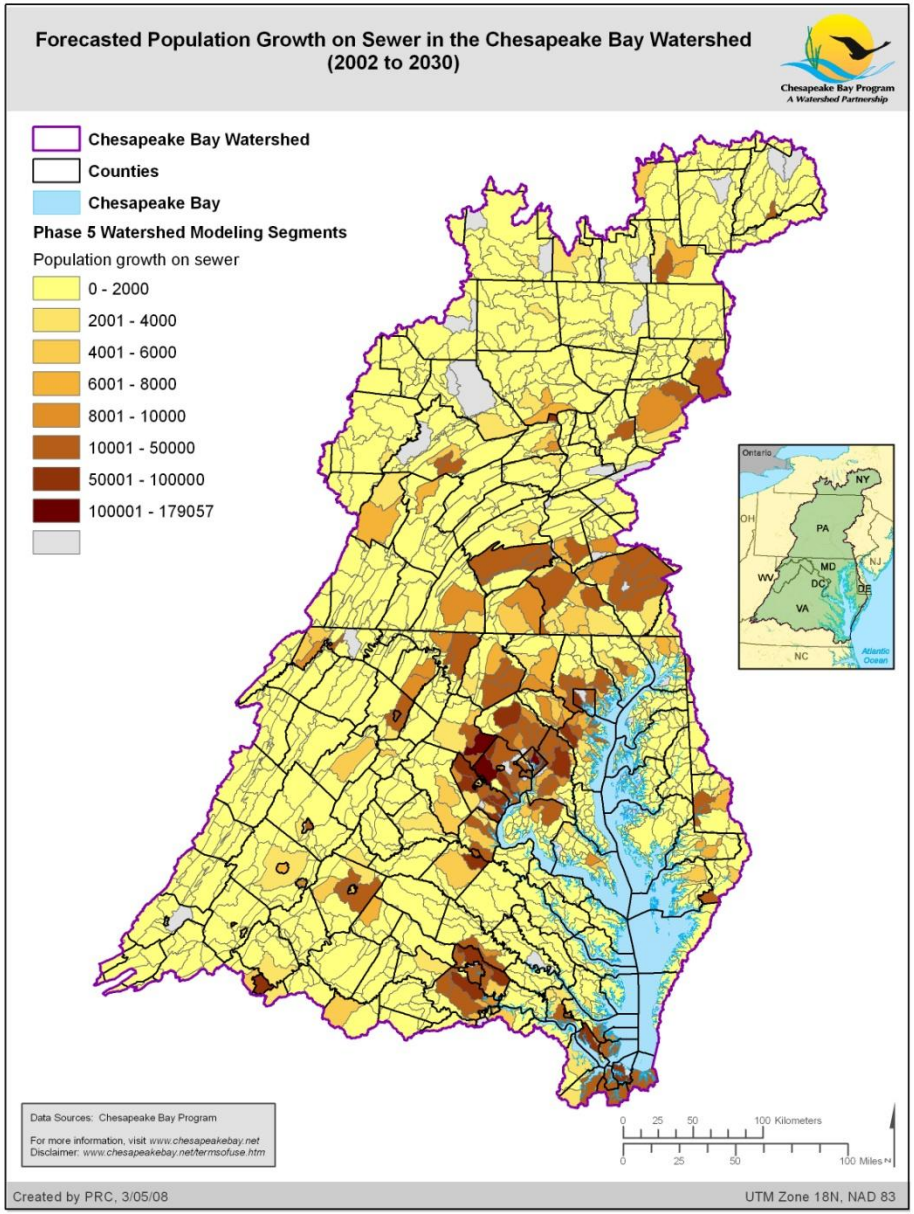


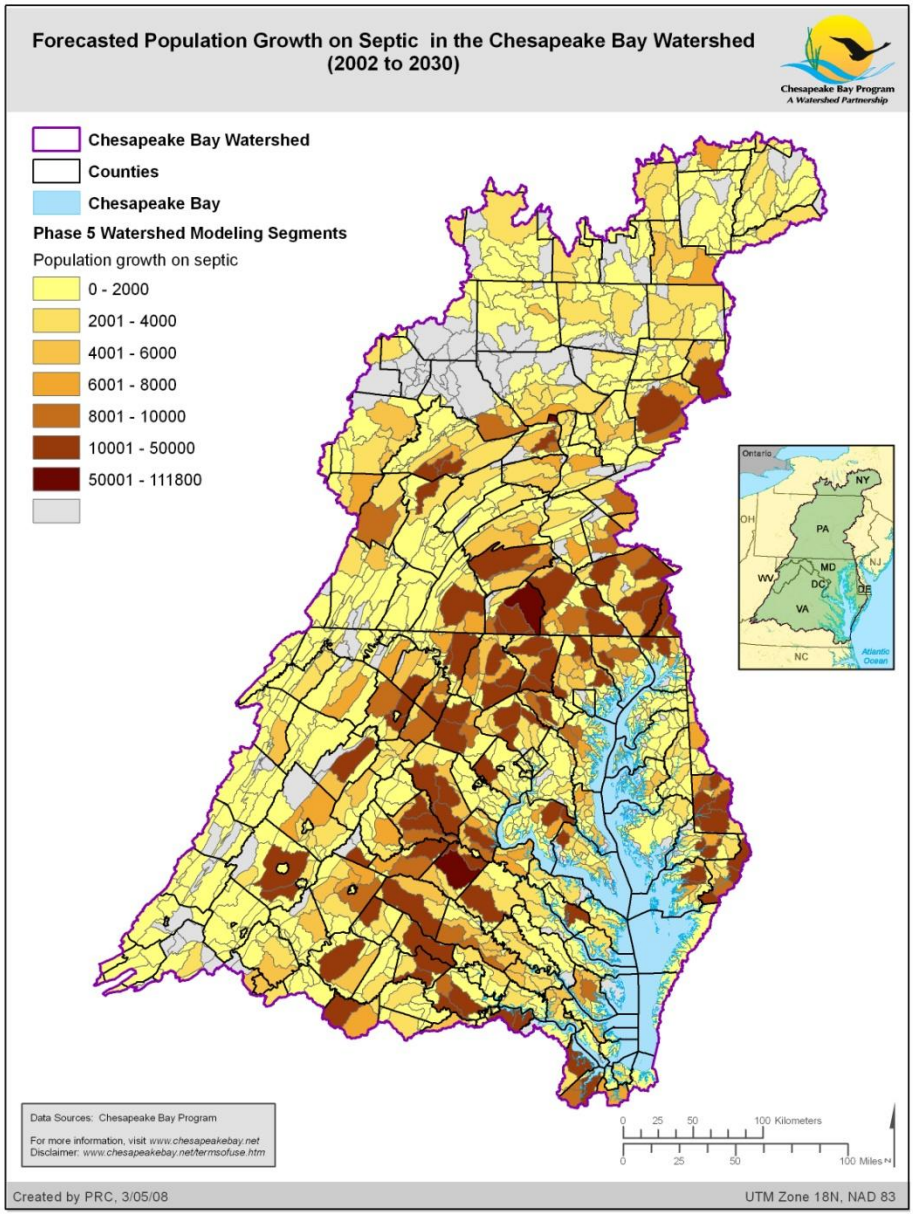
Probability surface

Forecasted Urban Growth (2000 to 2030)

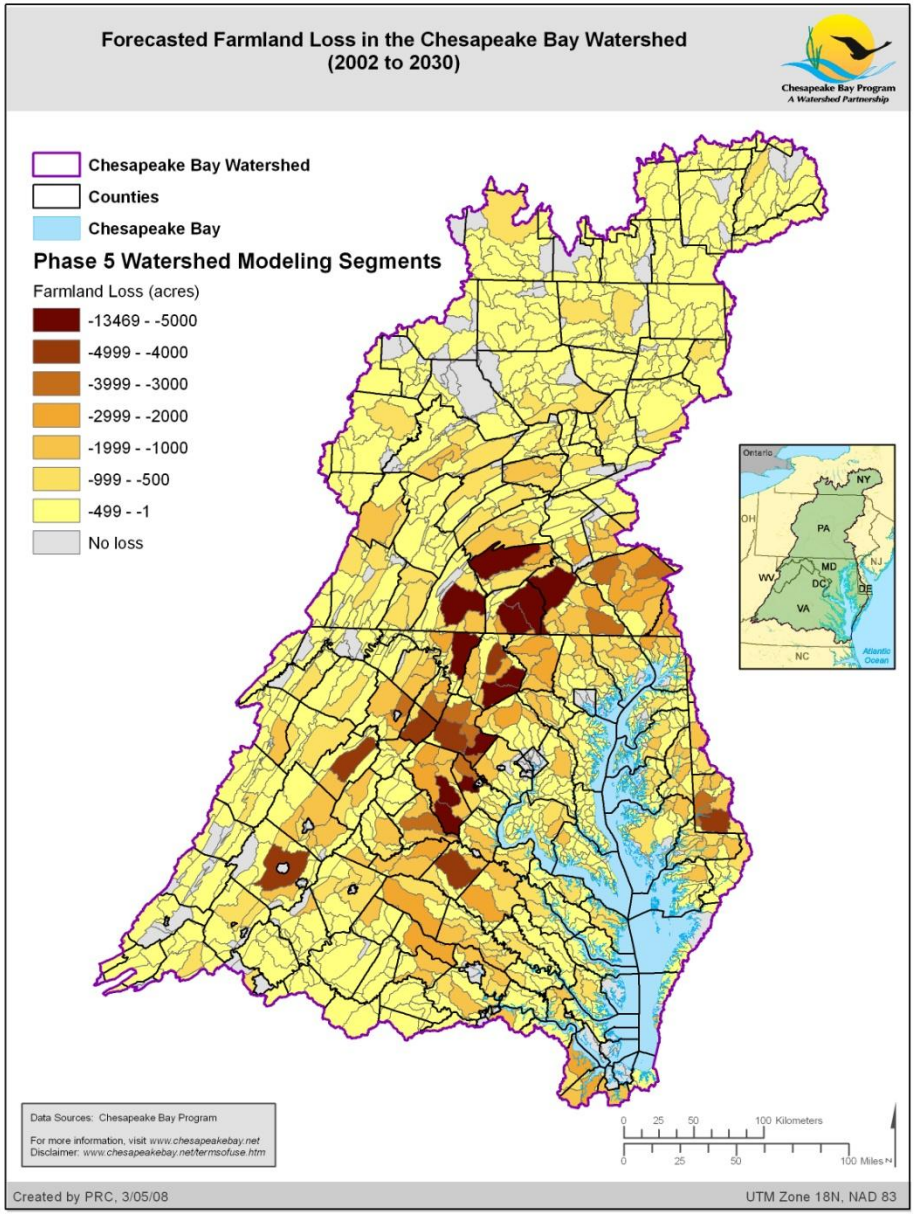


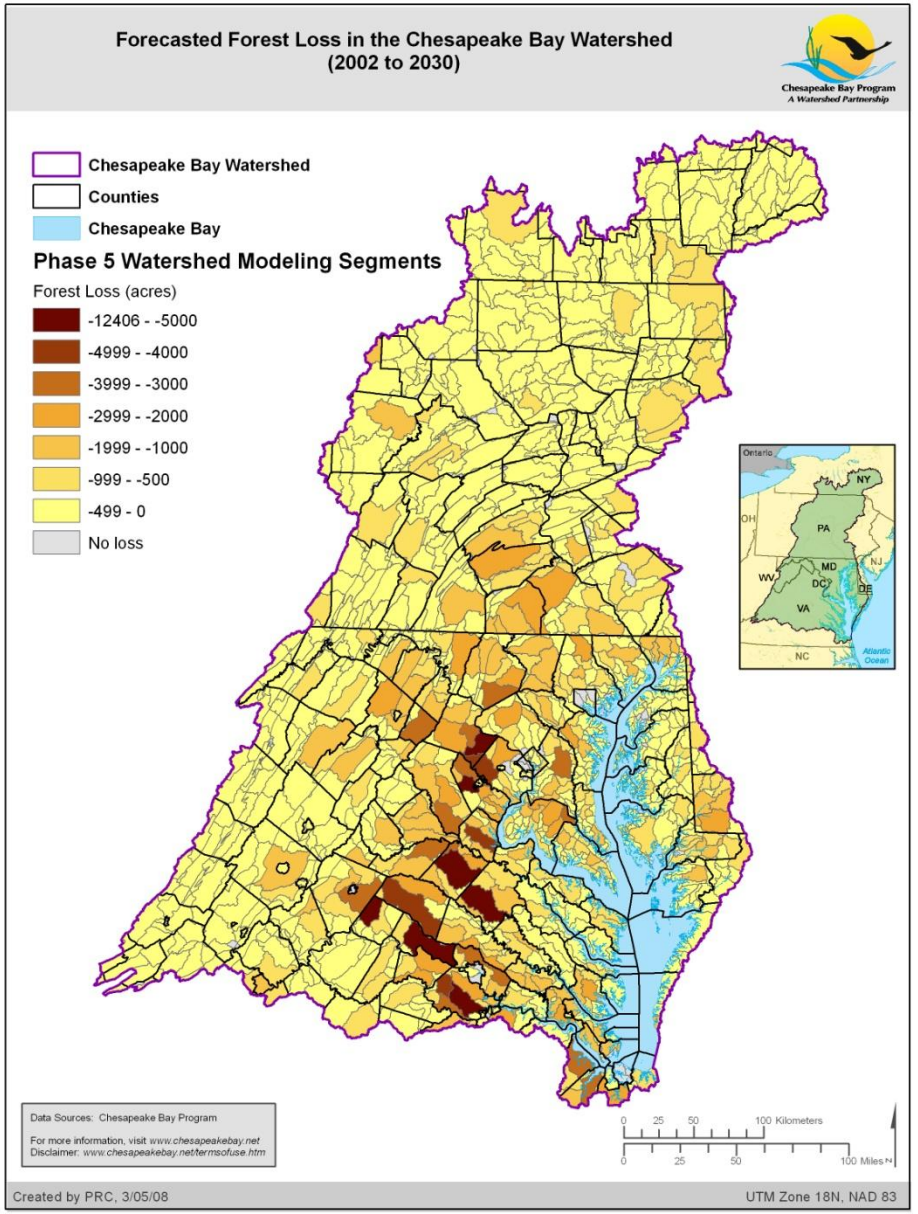
Forecasted Population Growth on Sewer vs. Septic (2000 to 2030)



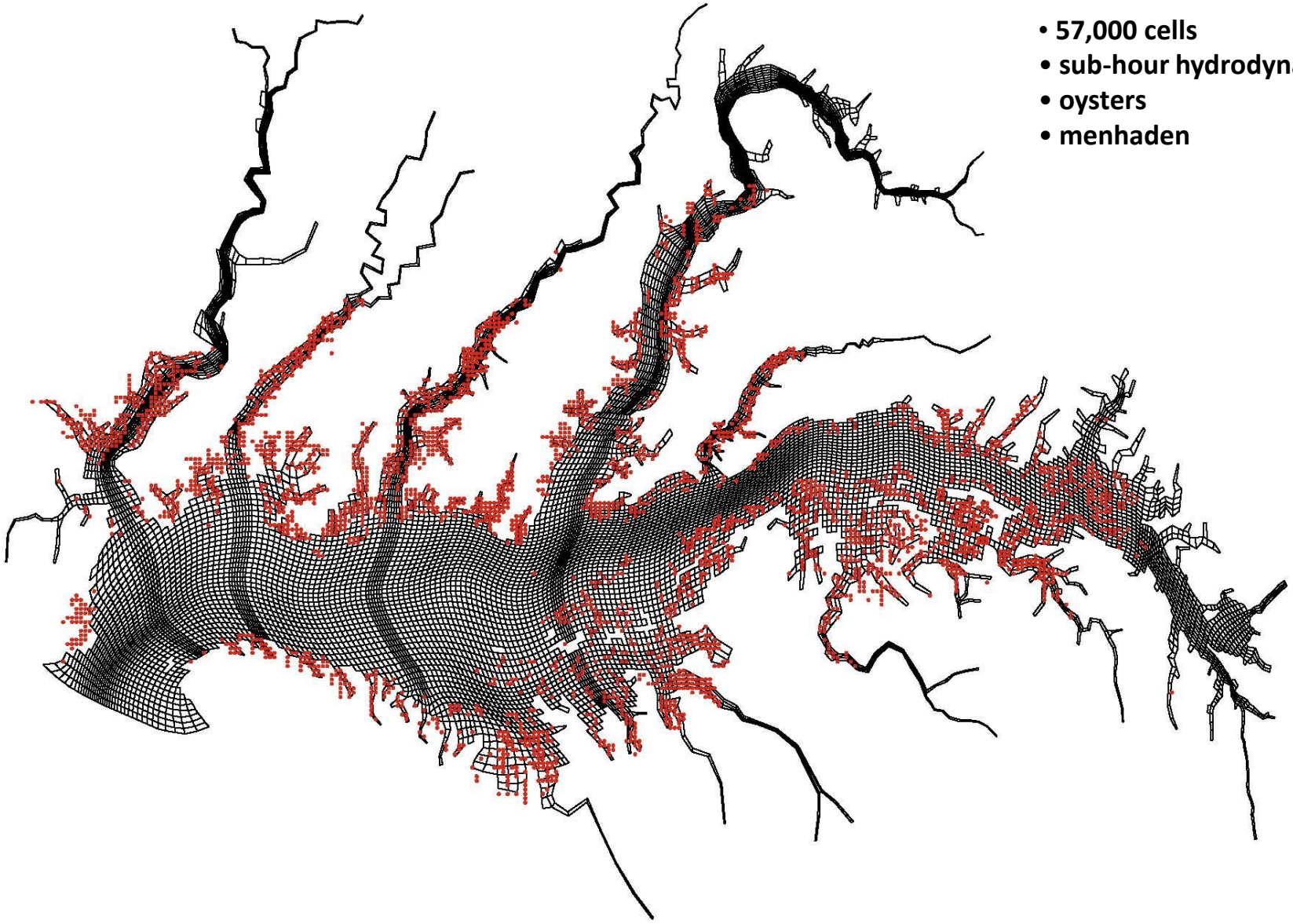


Farmland and Forest Land Loss (2000 to 2030)



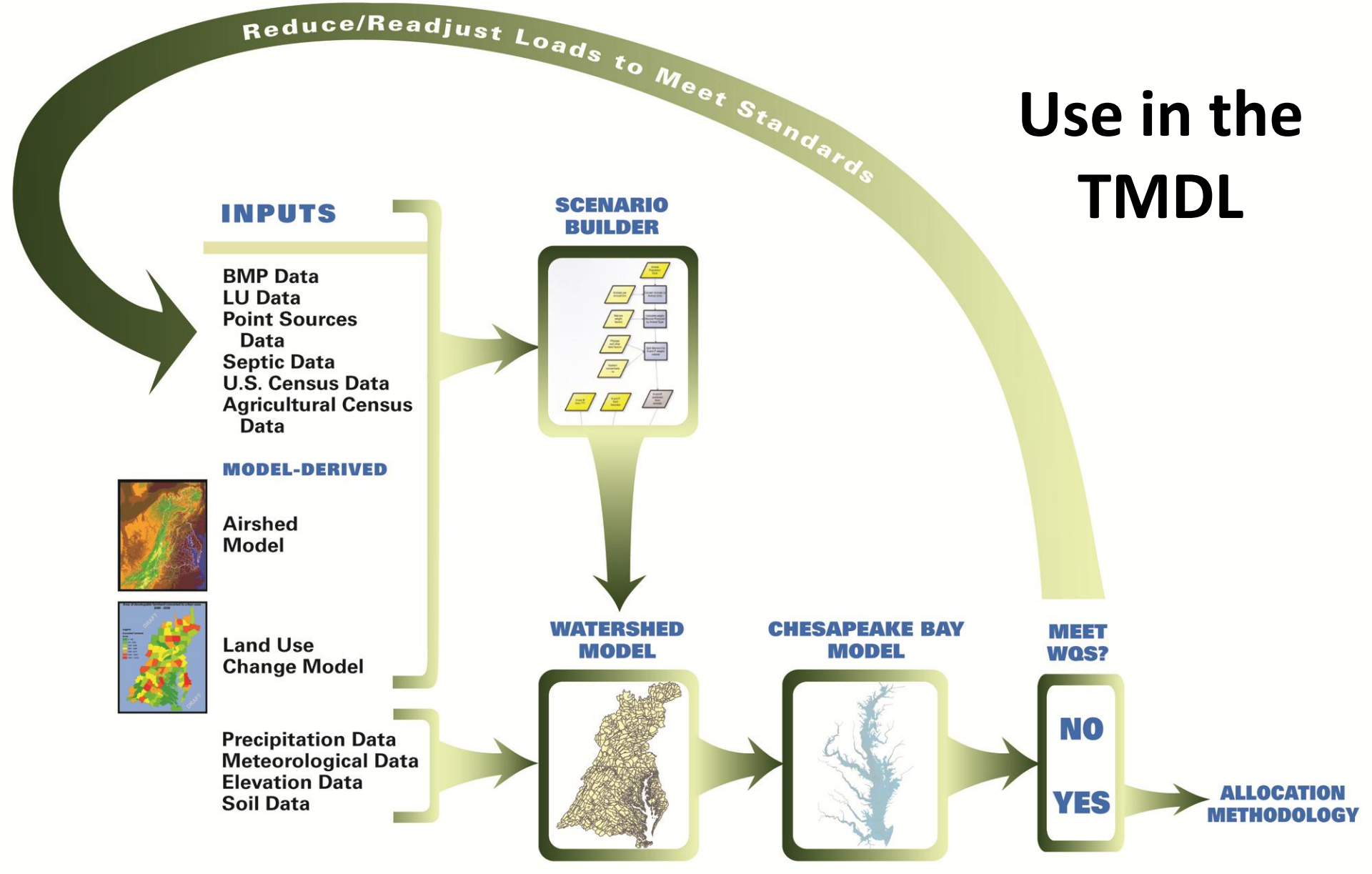


Estuarine Model



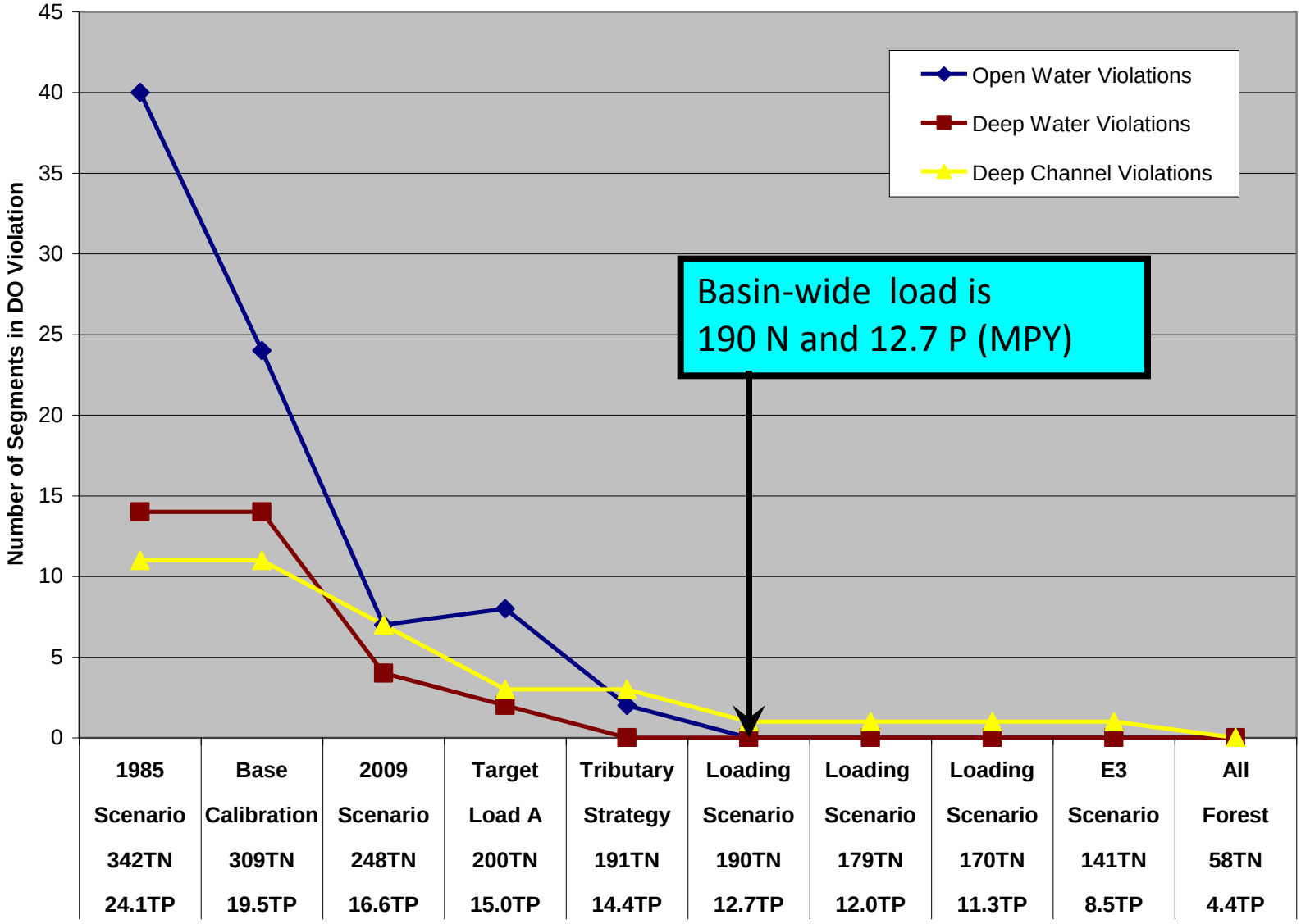
- 57,000 cells
- sub-hour hydrodynamics
- oysters
- menhaden

Chesapeake Bay Partnership Models

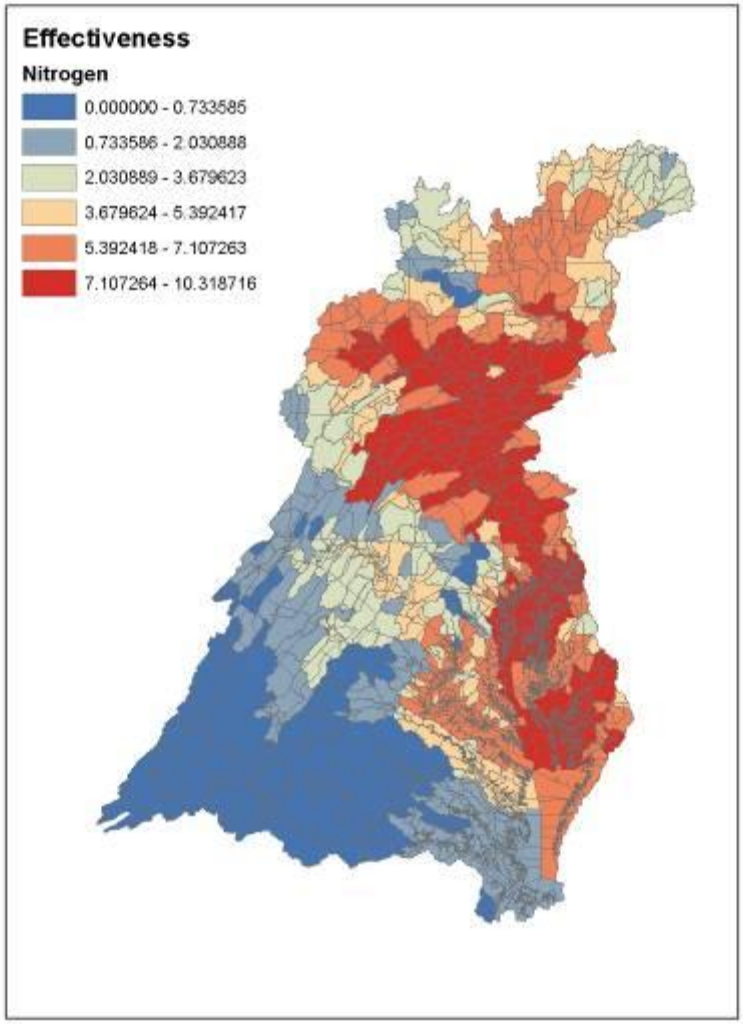


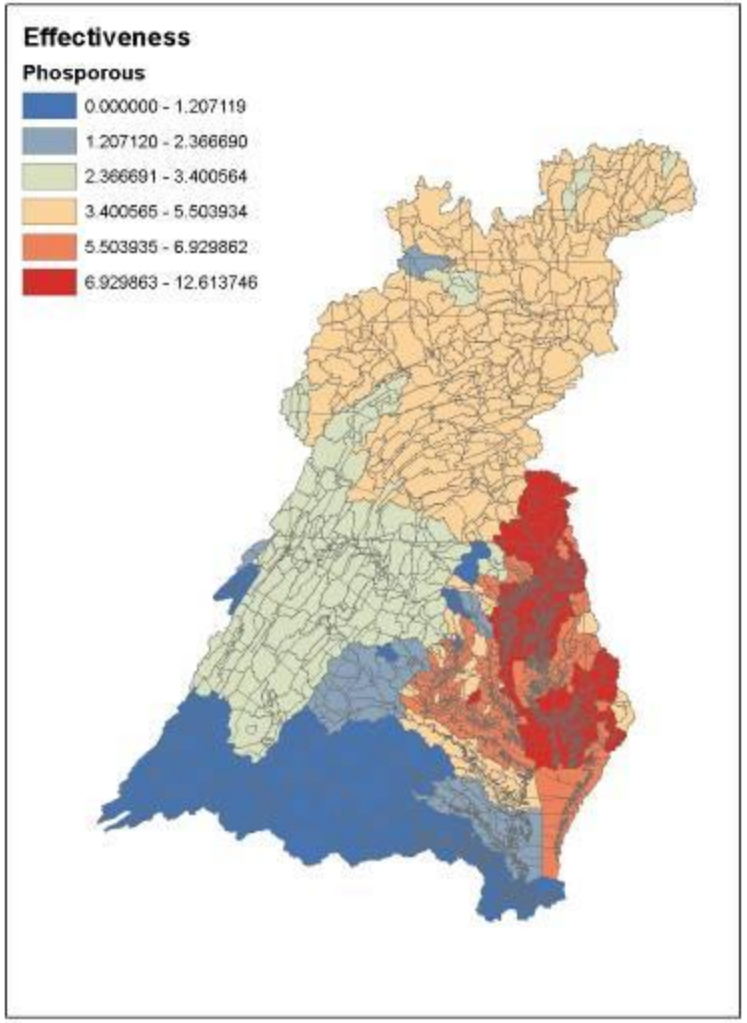
Use in the TMDL

Use of modeling suite in the Chesapeake TMDL

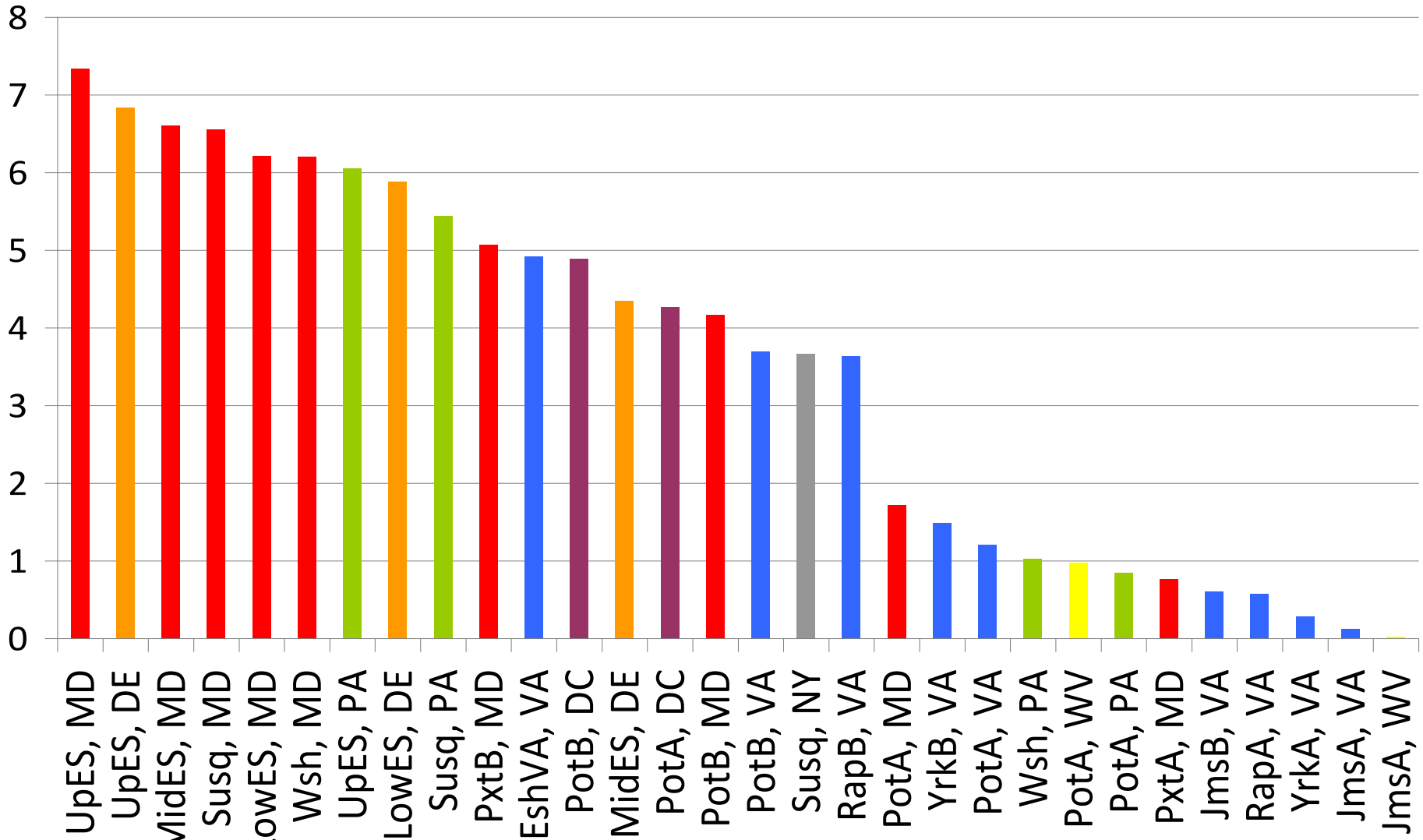


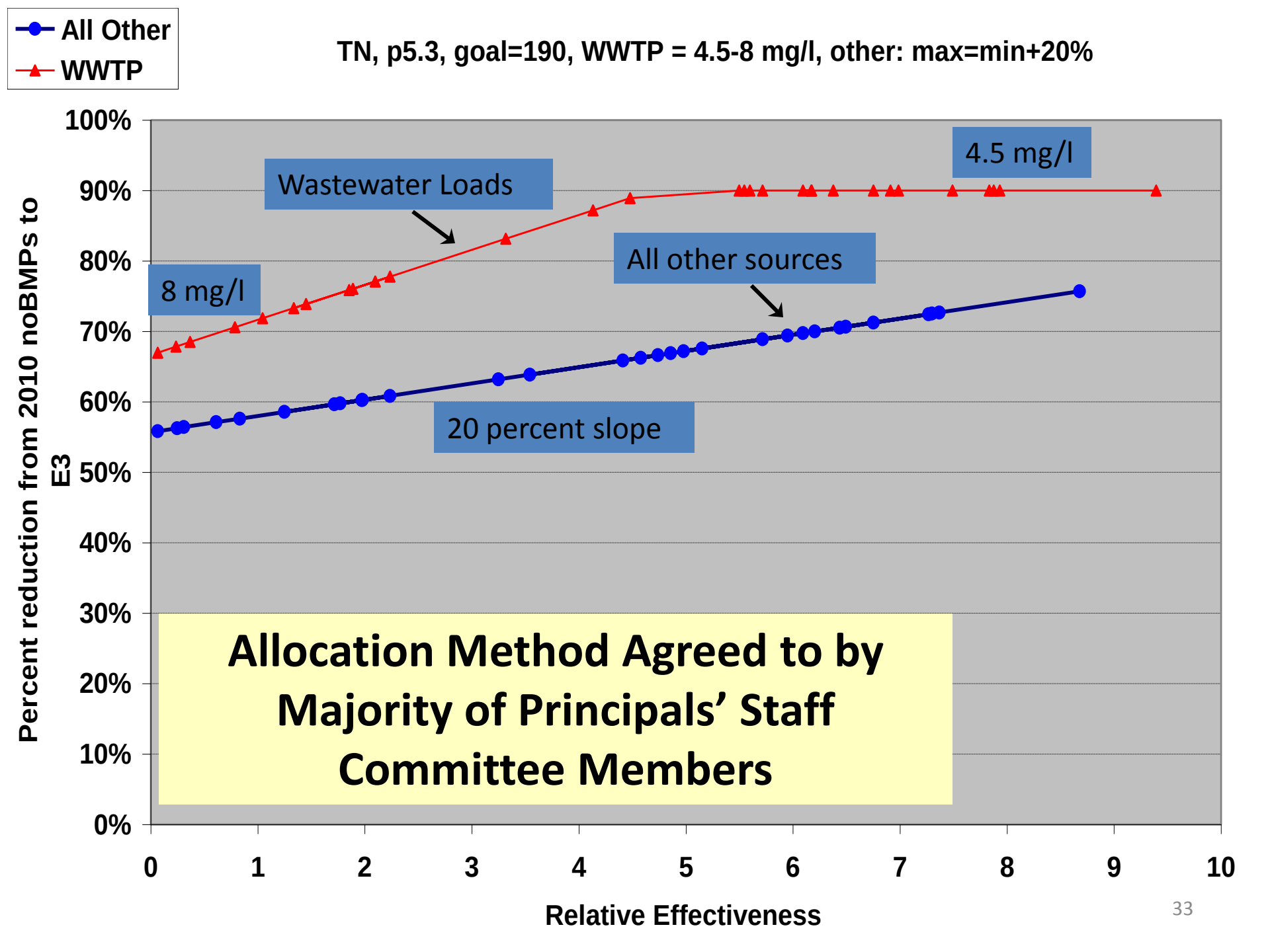
Nutrient Impacts on Bay WQ

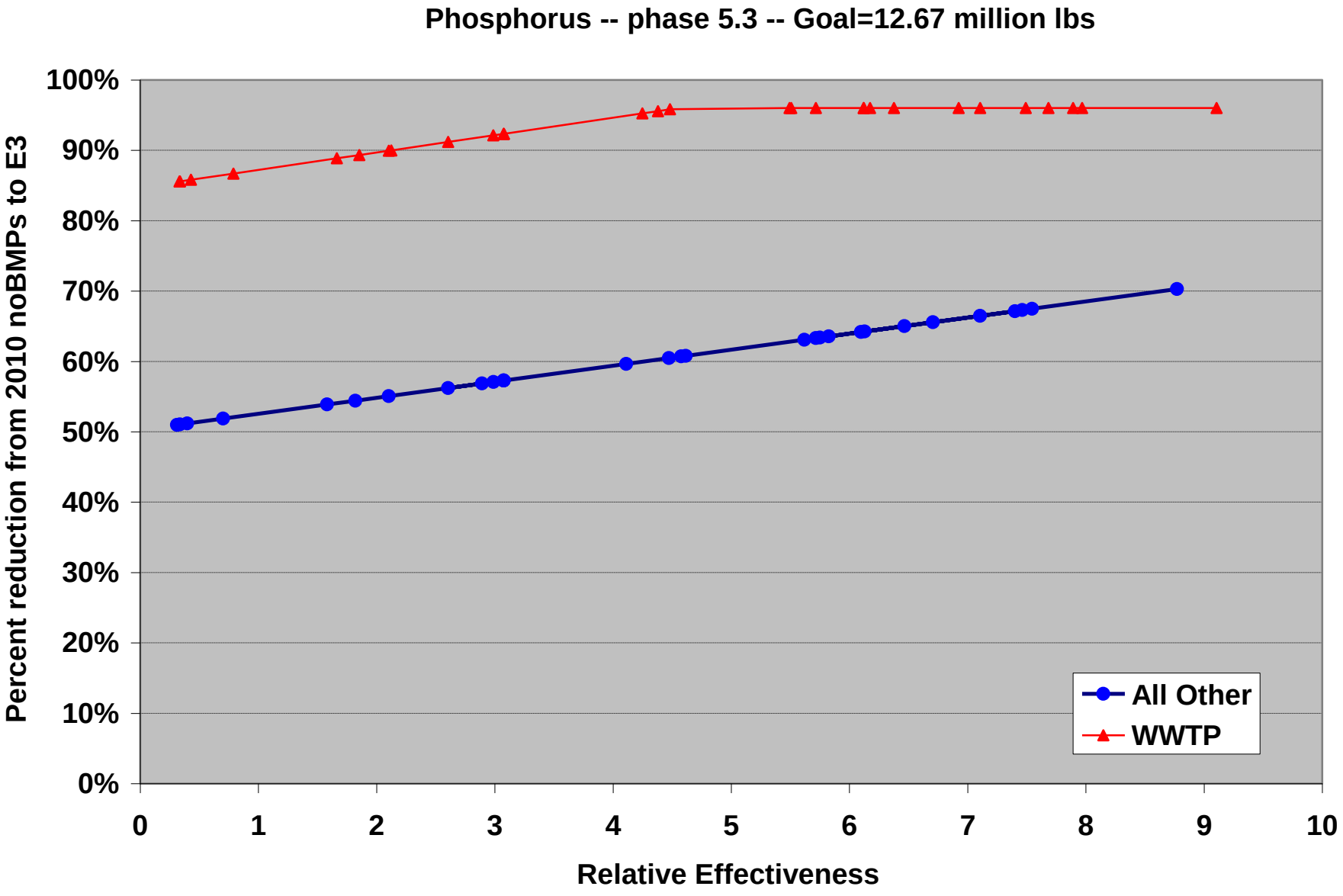




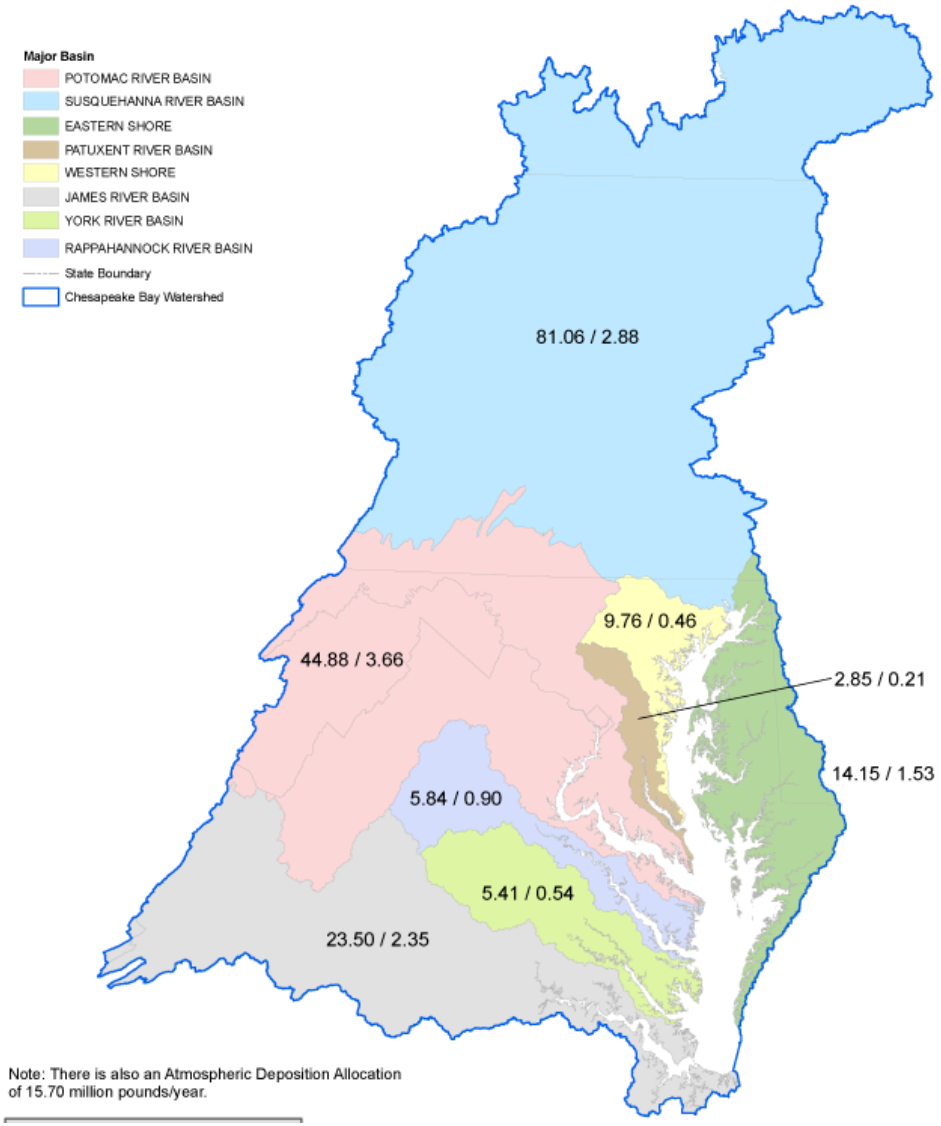
Major River Basin by Jurisdiction Relative Impact on Bay Water Quality



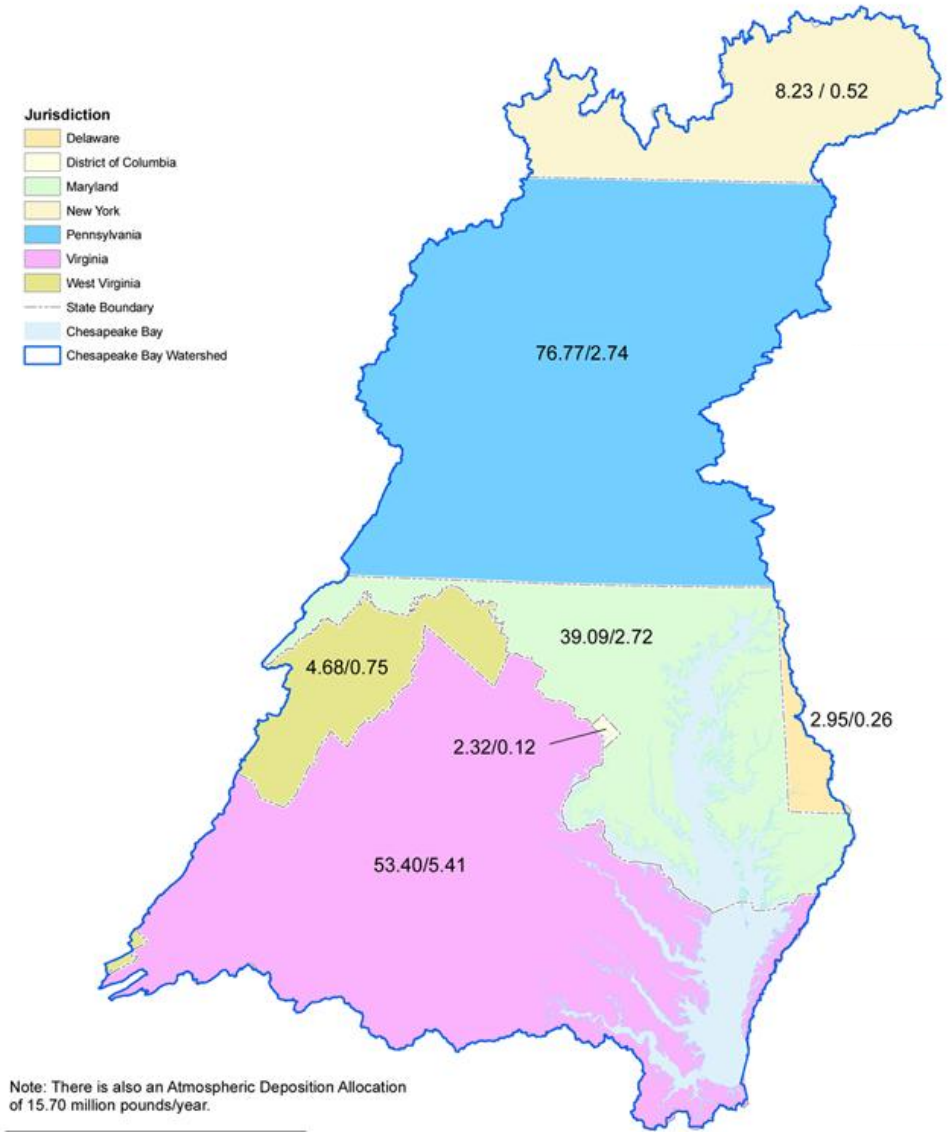

All Other
WWTP
TN, p5.3, goal=190, WWTP = 4.5-8 mg/l, other: max=min+20%
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness
Wastewater Loads
4.5 mg/l
All other sources
8 mg/l
20 percent slope
Allocation Method Agreed to by Majority of Principals' Staff Committee Members


Phosphorus -- phase 5.3 -- Goal=12.67 million lbs
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness
All Other
WWTP

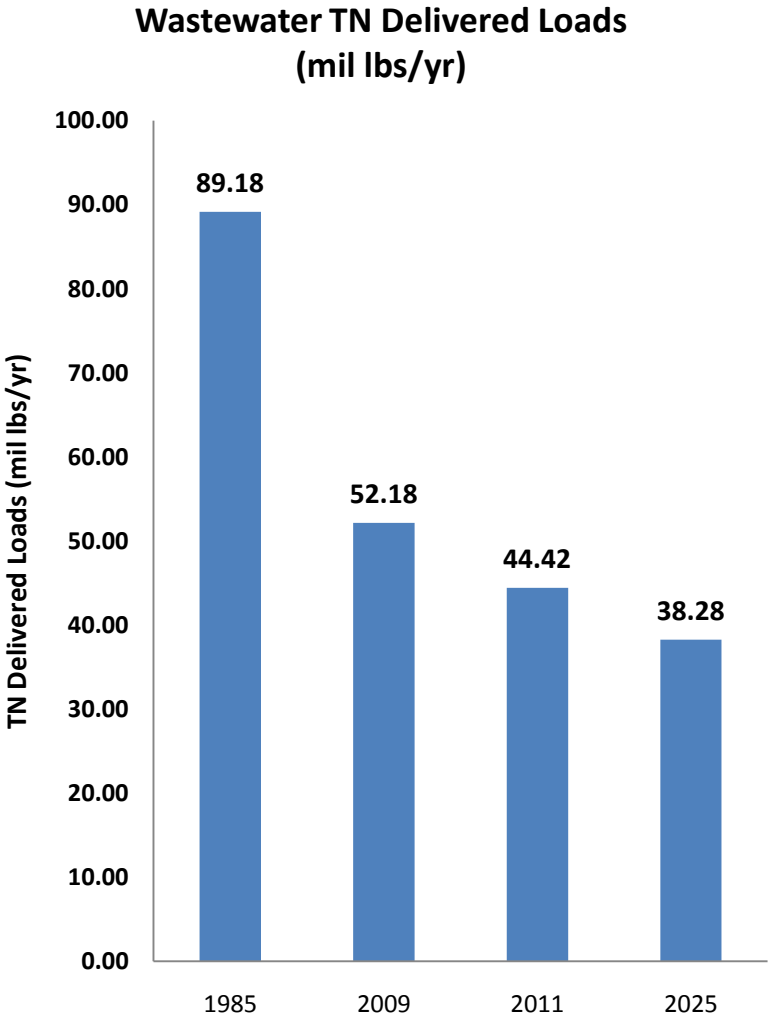
Pollution Diet by River

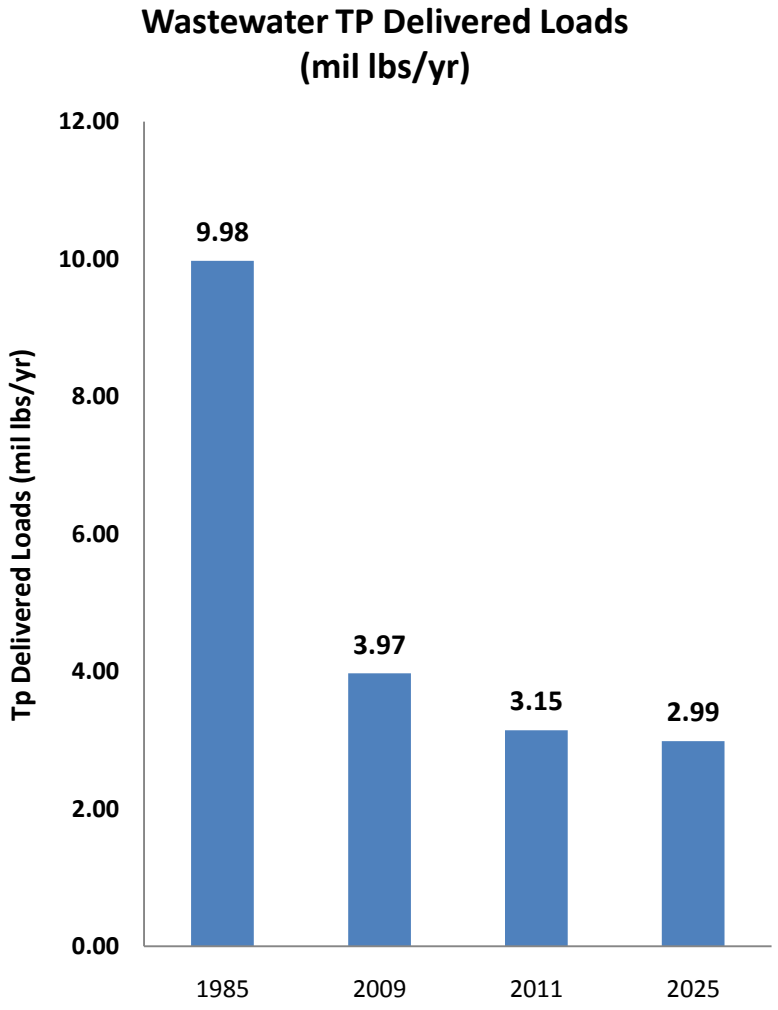


Pollution Diet by State

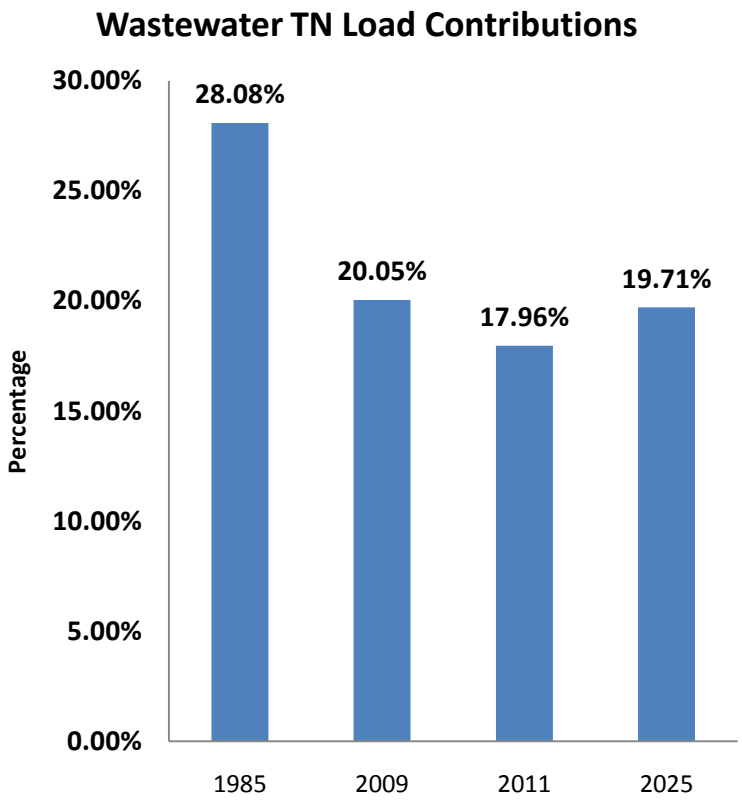


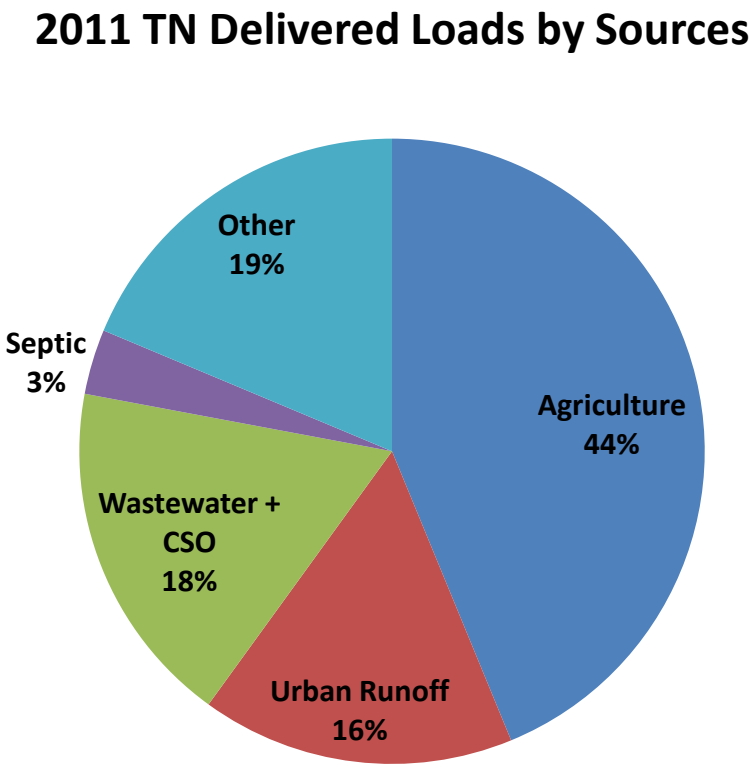
Chesapeake Bay WWTP +CSO Loading Trends and WIP Loads



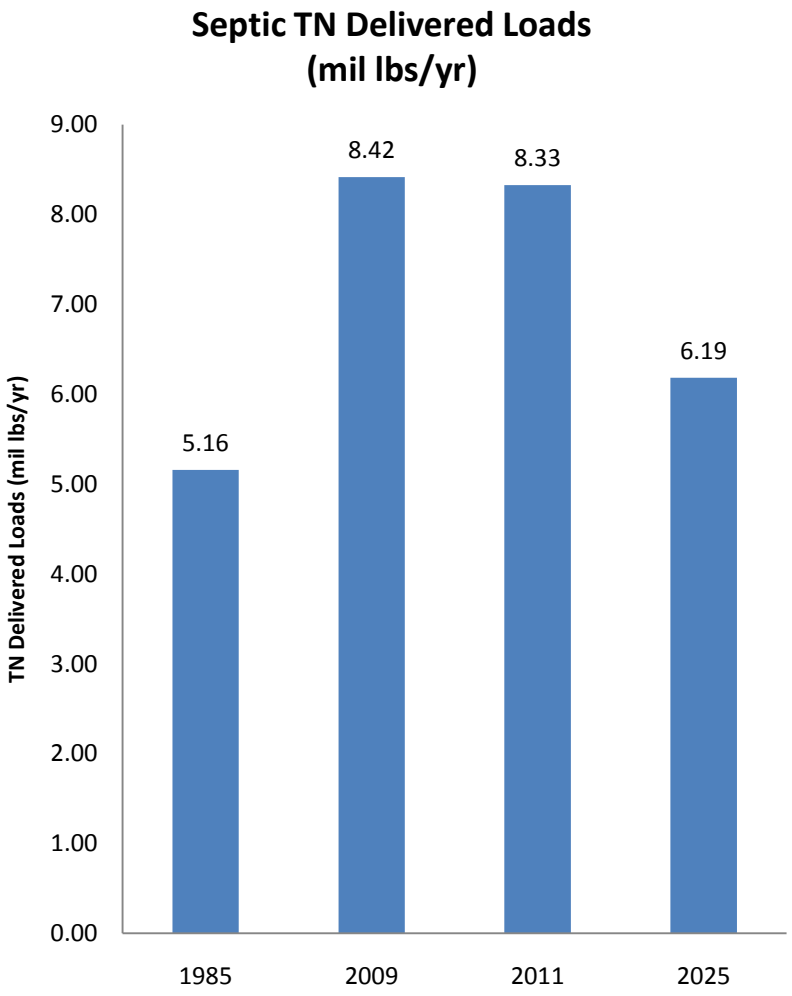


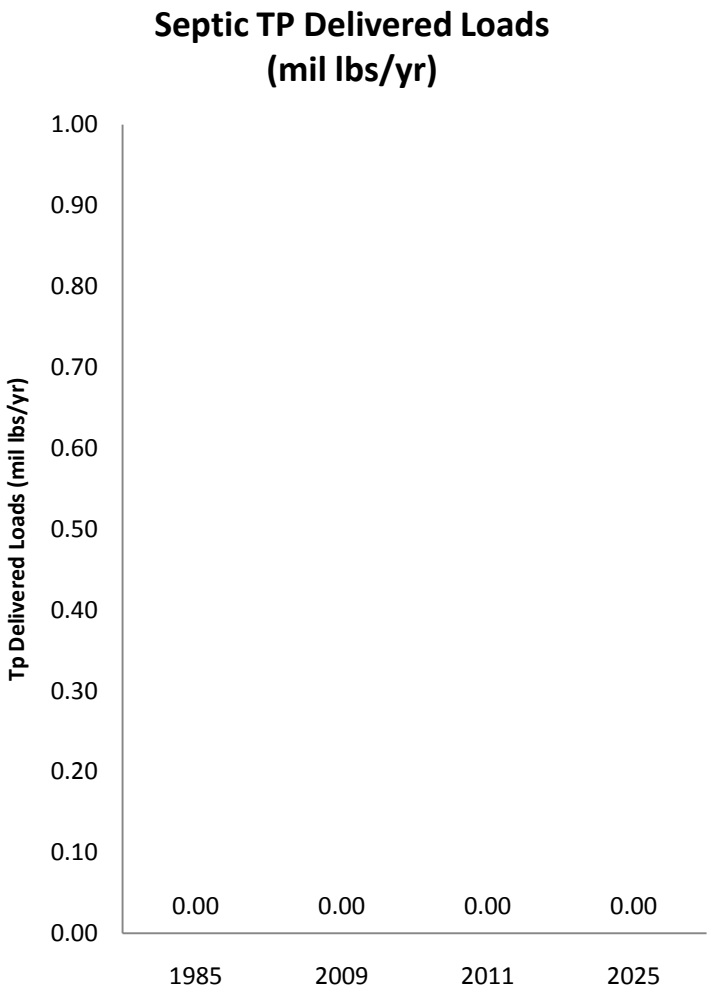
Wastewater + CSO TN Load Contributions Among All Sources



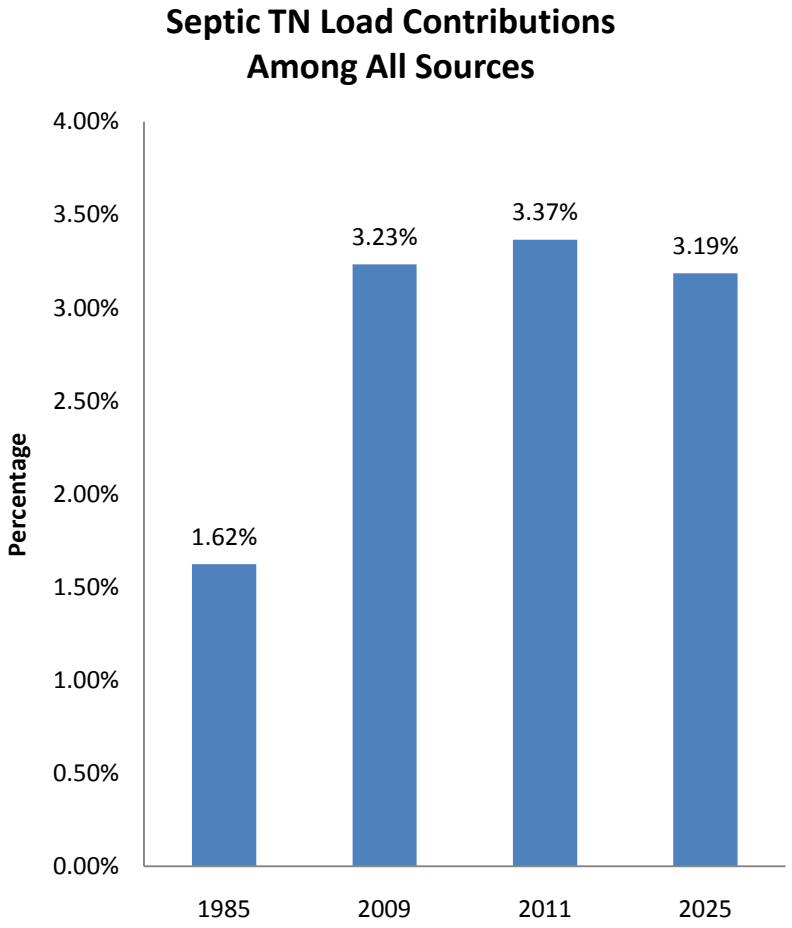


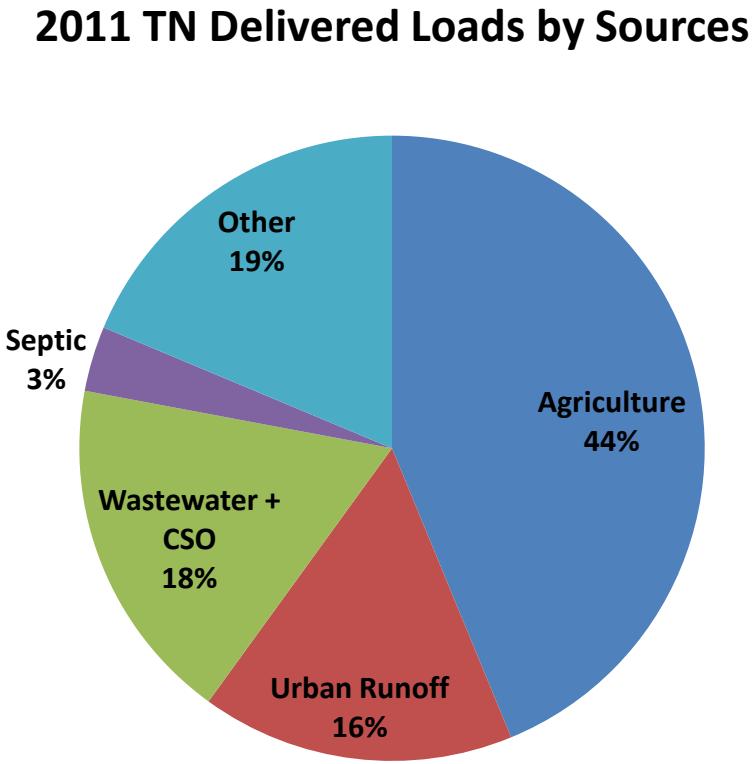
Chesapeake Bay Septic System Nutrient Loading Trends and WIP Loads





Septic System TN Load Contributions Among All Sources





Septic Nitrogen Load Calculation

Septic N Load (lbs/yr) at the edge of drain field
= Pop *8.91586 (lbs/person, yr) *BMP Efficiency (%)

Septic N Load (lbs/yr) at the edge of stream
= Pop *8.91586 *BMP Efficiency (%) * Pass-through rate (%)

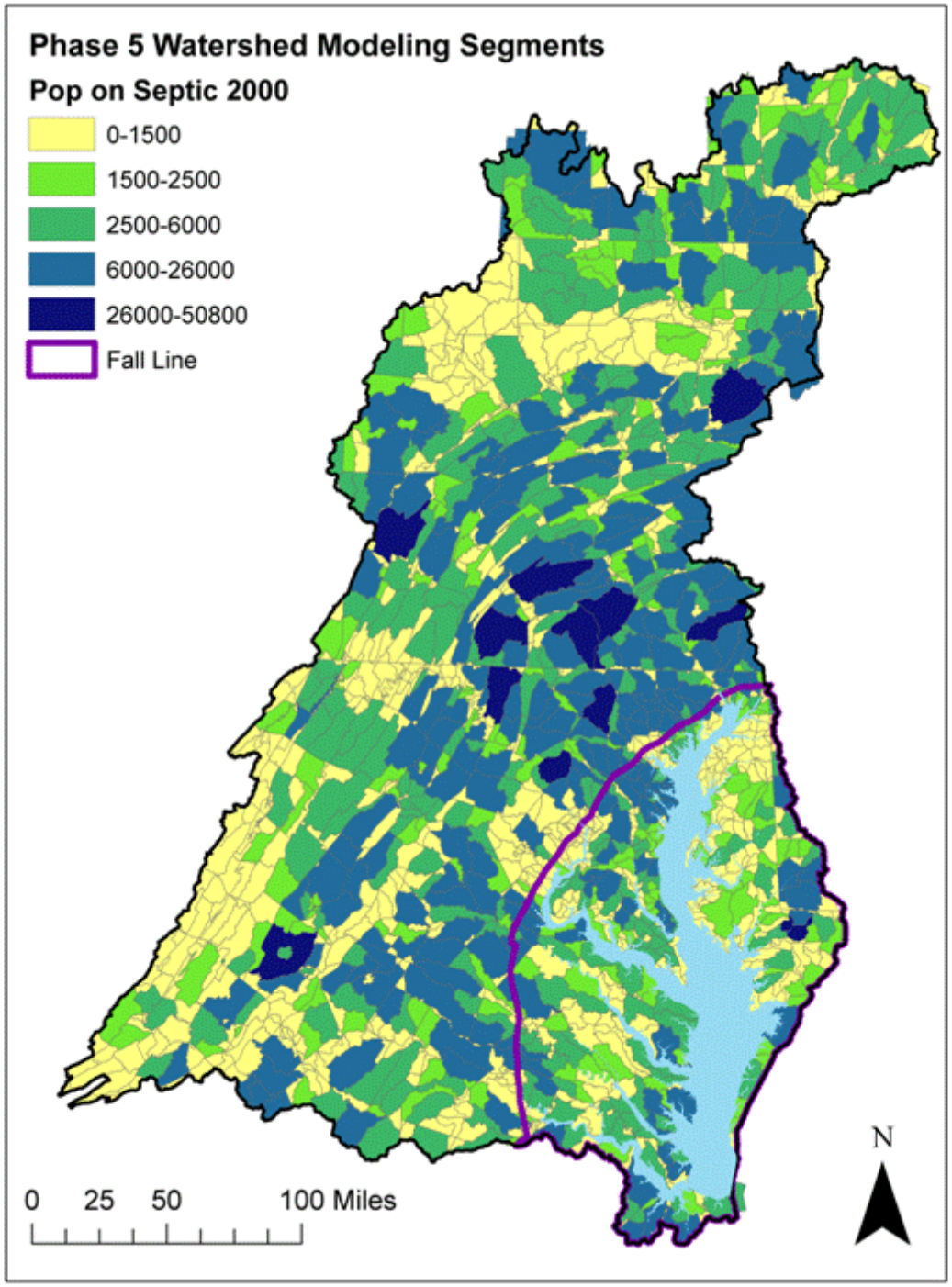
Phosphorus is assumed to be 100% attenuated by soil.

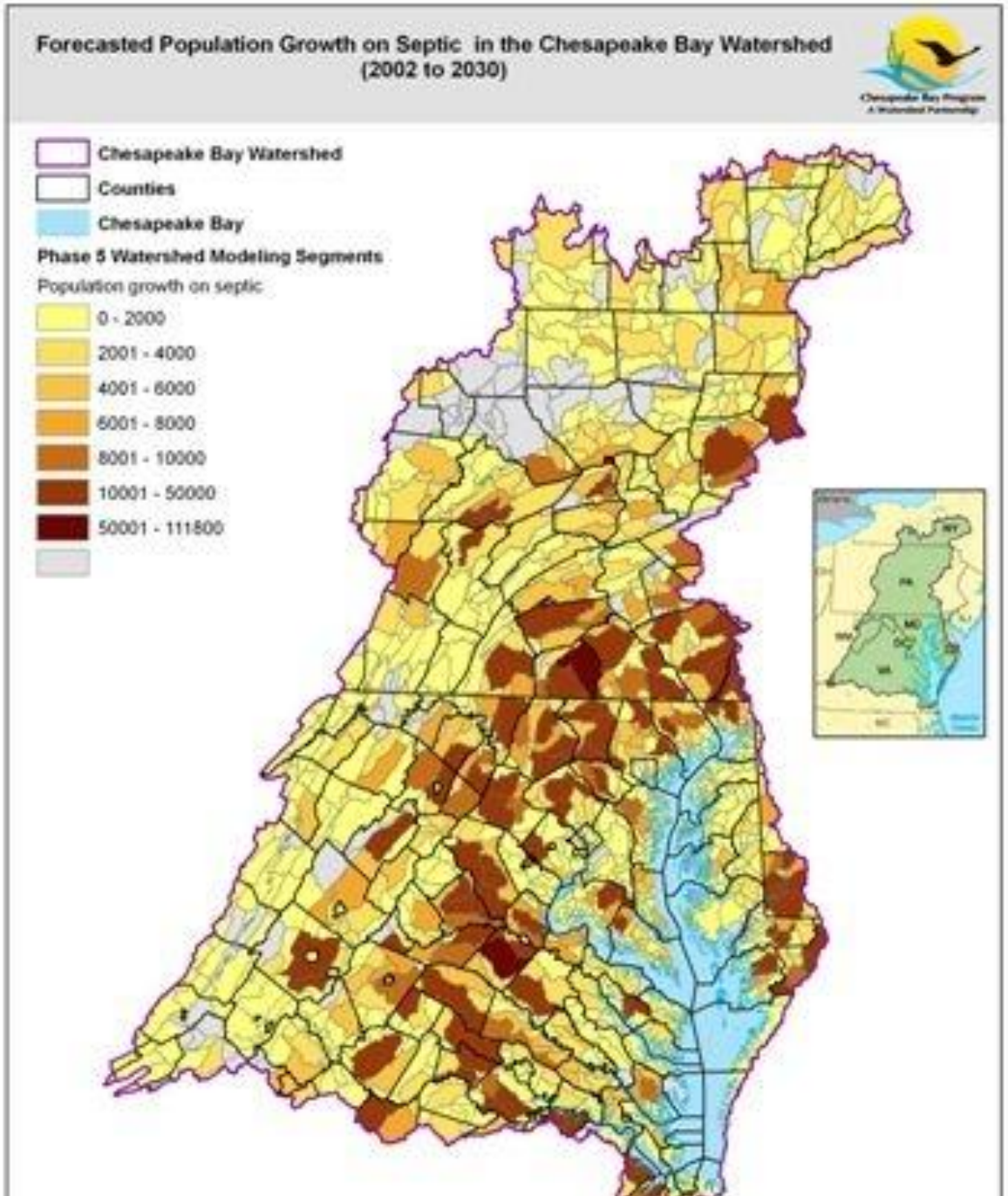
Septic BMP load reductions

Connection	100%
Denitrification	50%
Pumping	5%

Septic Nitrogen Pass-Through Rate

State	Pass-Through Rate	2011_# Systems
DE	40%	21,735
DC	40%	-
MD	30%	241,893
MD	50%	159,783
MD	80%	48,630
NY	40%	96,810
PA	40%	526,721
VA	40%	535,351
WV	40%	62,695

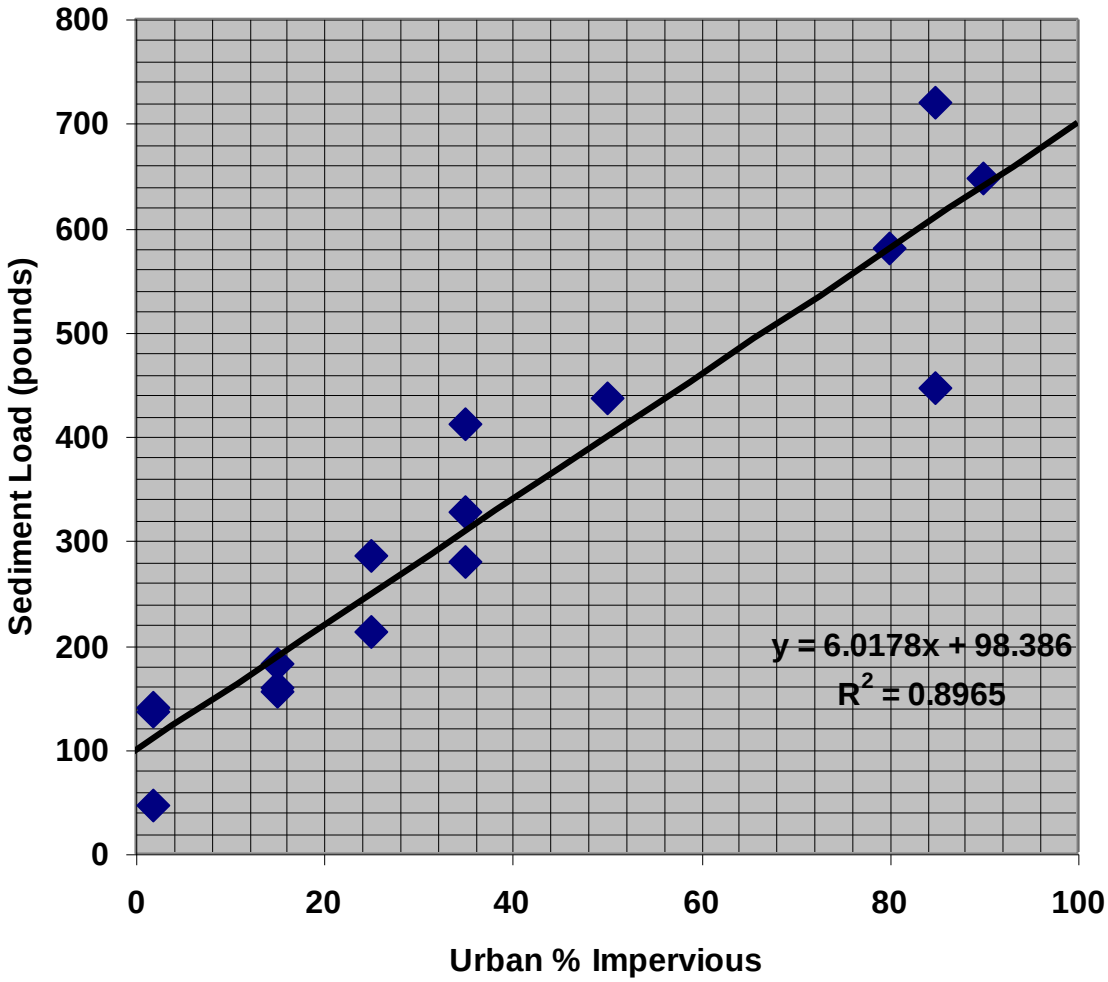

Phase 5 Watershed Modeling Segments
Pop on Septic 2000
0-1500
1500-2500
2500-6000
6000-26000
26000-50800
Fall Line
0 25 50 100 Miles
N


Forecasted Population Growth on Septic in the Chesapeake Bay Watershed
(2002 to 2030)
Chesapeake Bay Watershed
Counties
Chesapeake Bay
Phase 5 Watershed Modeling Segments
Population growth on septic
0 - 2000
2001 - 4000
4001 - 6000
6001 - 8000
8001 - 10000
10001 - 50000
50001 - 111800

Urban Sediment Targets

Sediment load for several urban land use types were compiled for sites in the mid-Atlantic and Illinois. Langland and Cronin (2003)

When plotted against 'typical' impervious percents for those urban land use types, the relationship is striking.



By setting pervious urban at the intercept and impervious urban at the maximum, the land use division within each particular segment determines the overall load according to the above relationship.