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Chesapeake Bay Watershed Model Evolution Over 30 Years

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Chesapeake Bay Watershed Model Evolution over 30 years

50 Years of Watershed Modeling Conference

September 24, 2012

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and Gary Shenk
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Program Office
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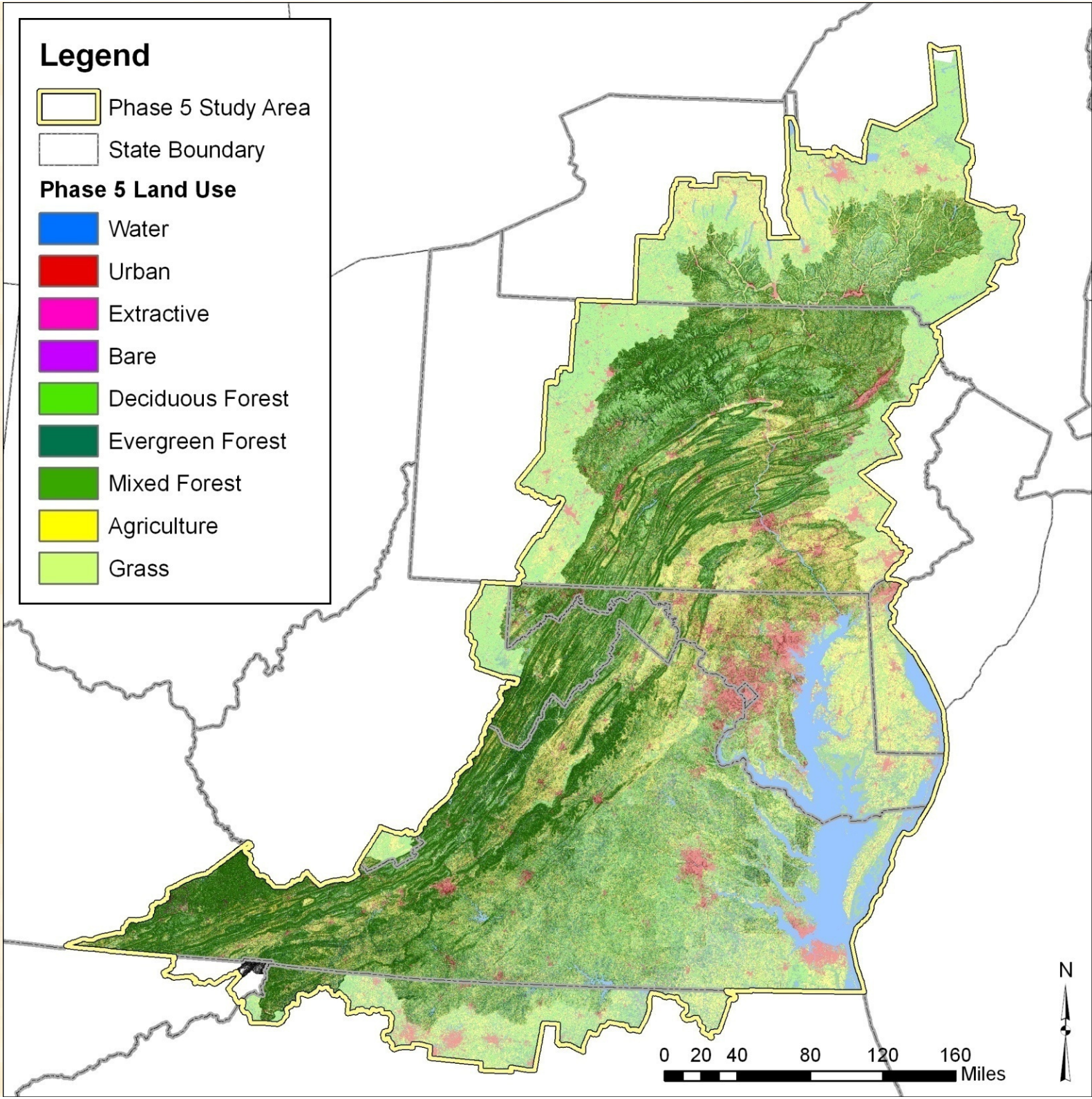
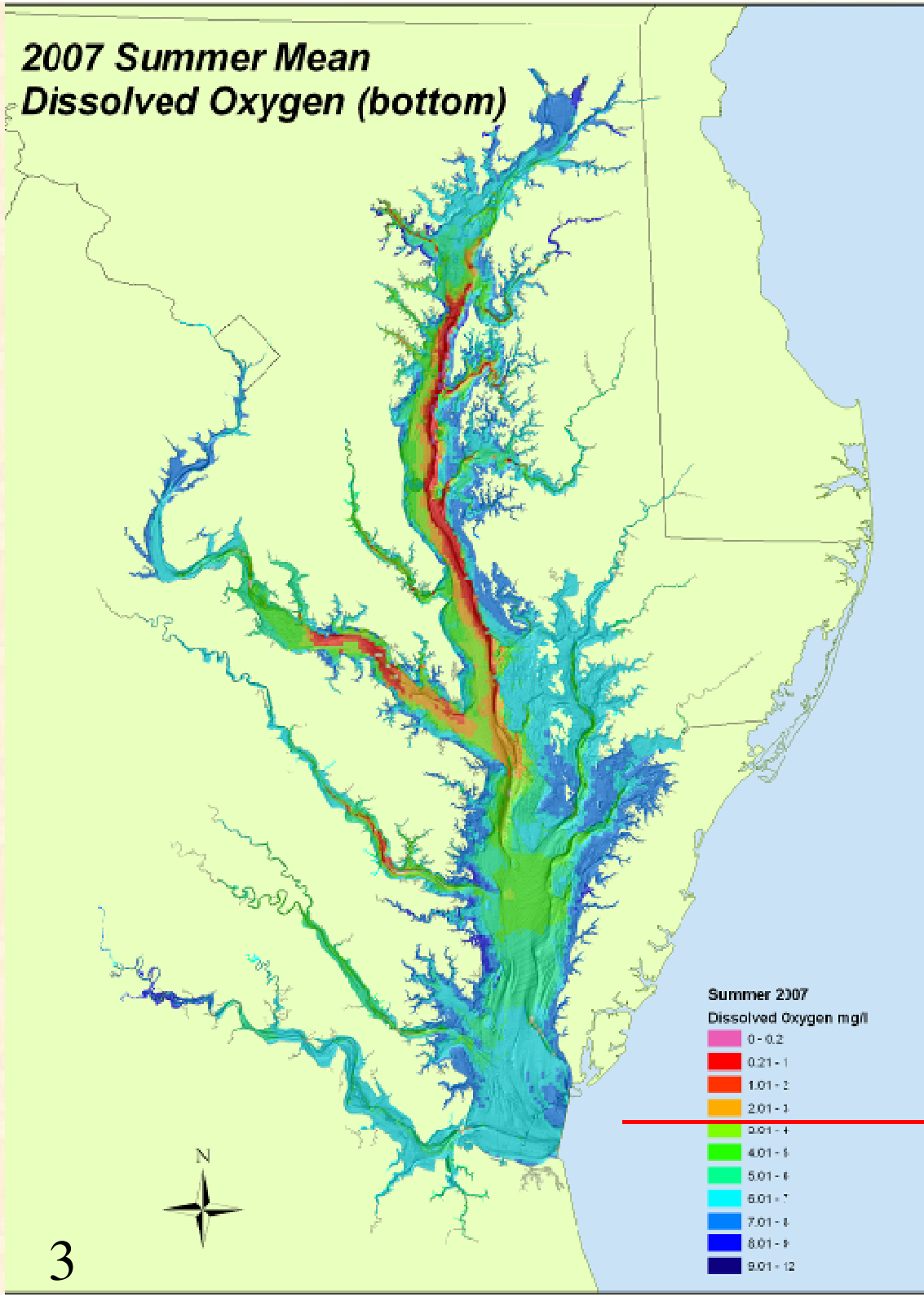
shenk.gary@epa.gov

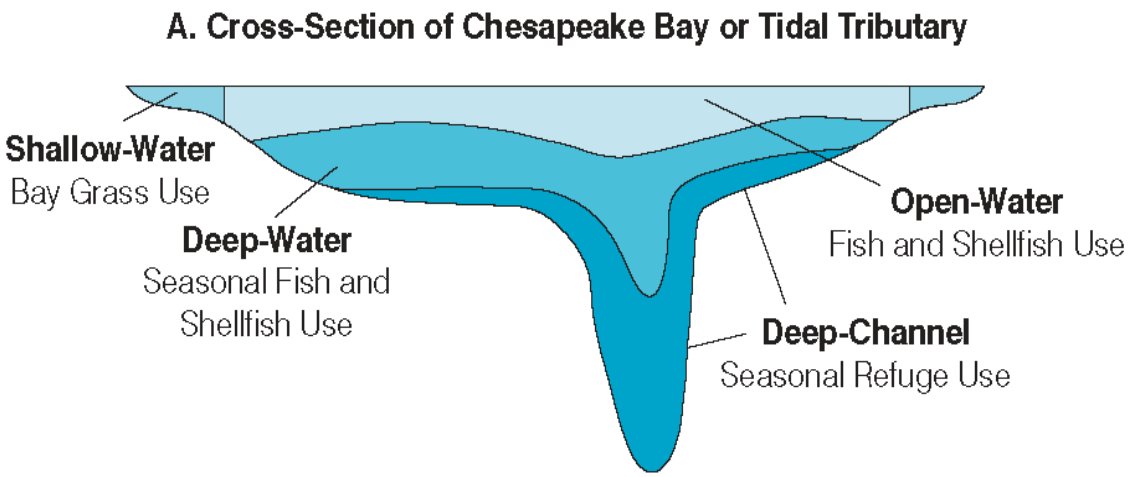
We need to view the CBP integrated models of the airshed, watershed, and tidal Bay models as a whole. Together they relate the watershed and airshed loads to water quality impairments in the Chesapeake.

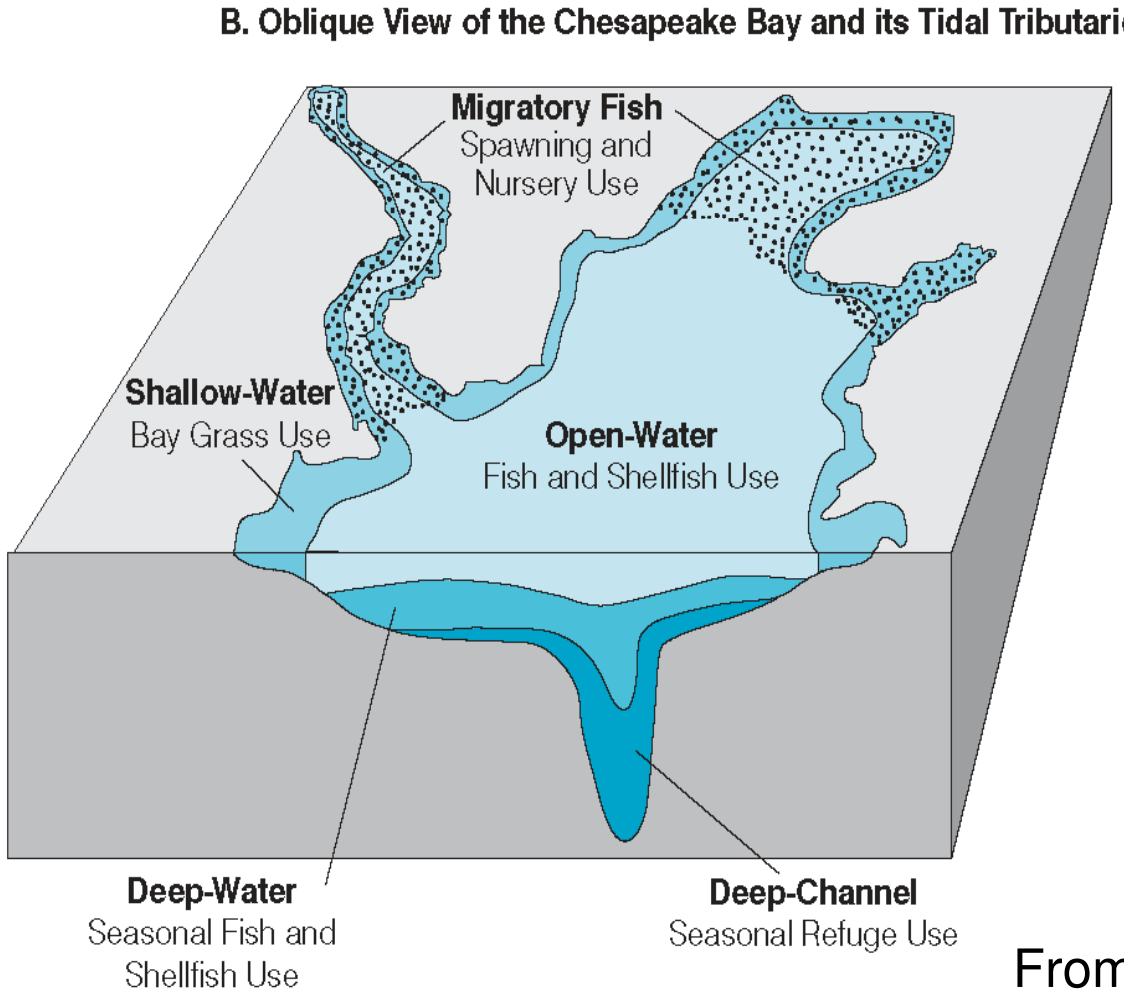


Low to no dissolved oxygen in the Bay and tidal rivers every summer



Water Quality Standards of Deep Water, Deep Channel, Open Water, and Shallow Water Dissolved Oxygen (DO) are key for protection of living resources. Chlorophyll and SAV/clarity standards are also designed to protect living resources.

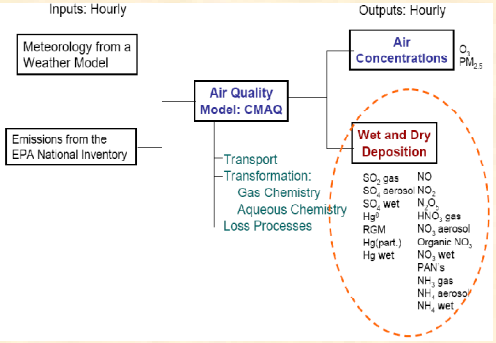


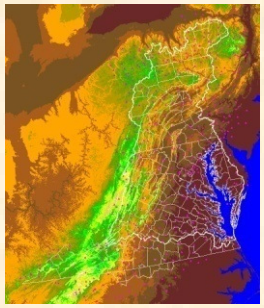


From Batiuk (2003)

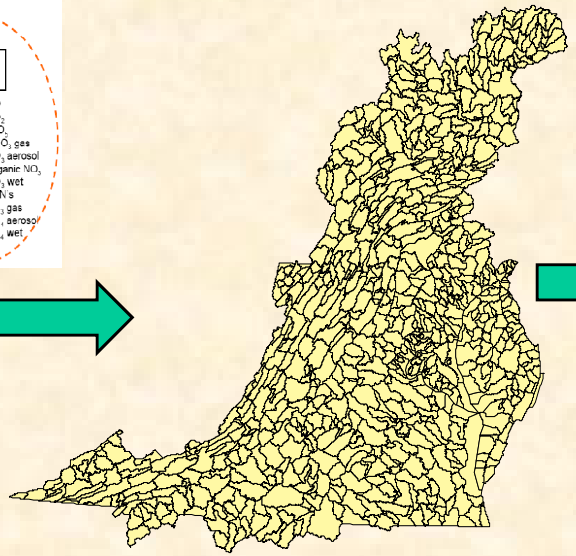
Nutrient Allocation Decision Support System

Airshed Model

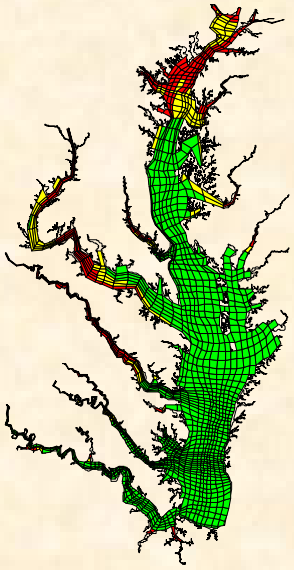




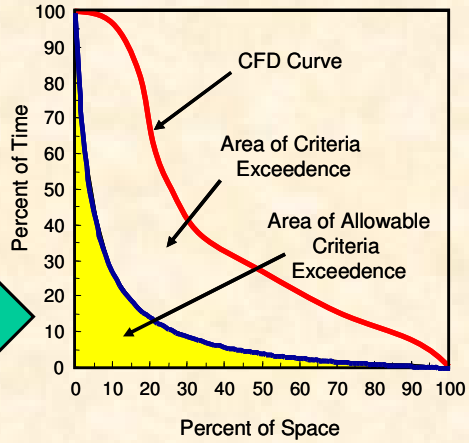
Watershed Model



Bay Model



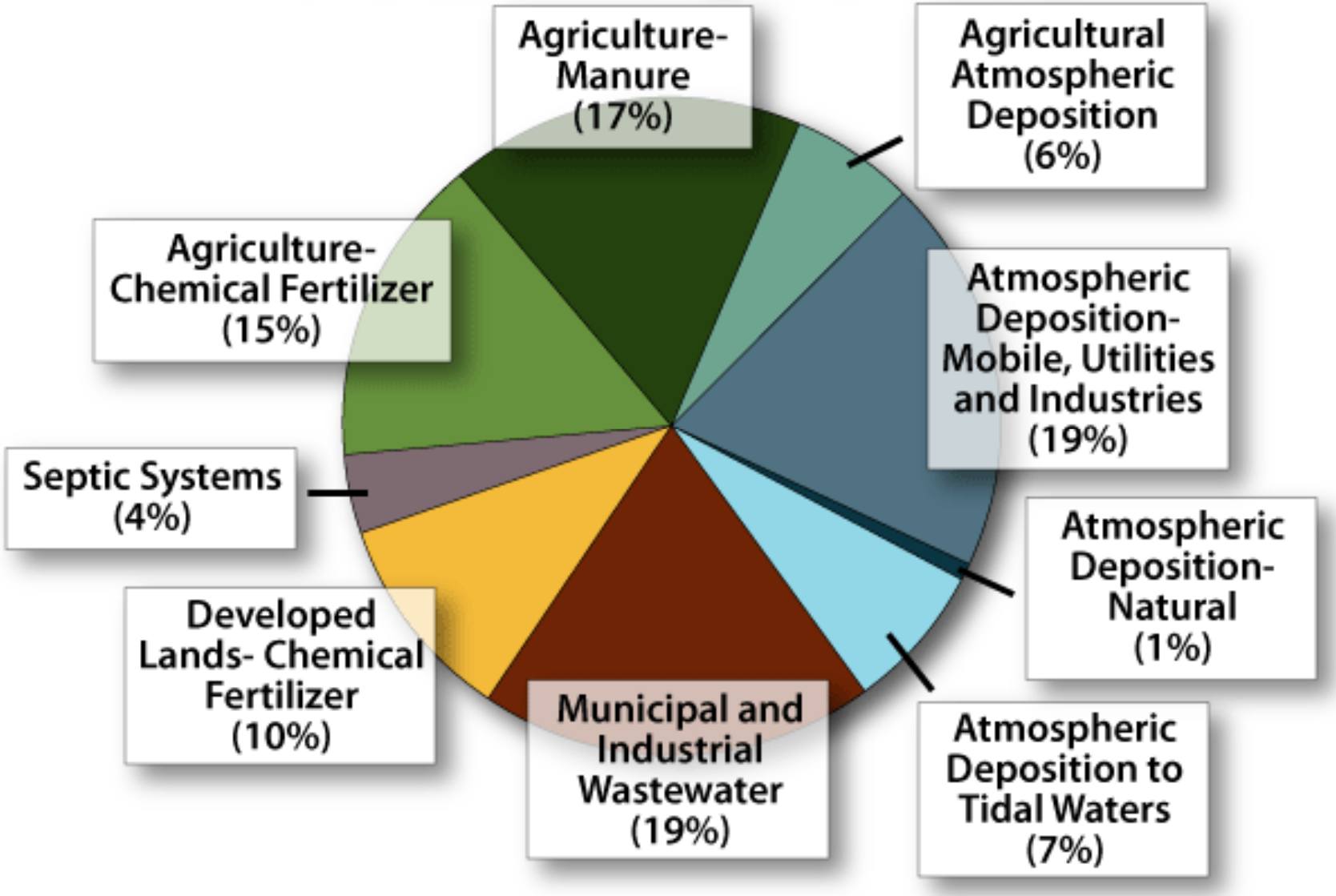
Criteria Assessment Procedures



Effects

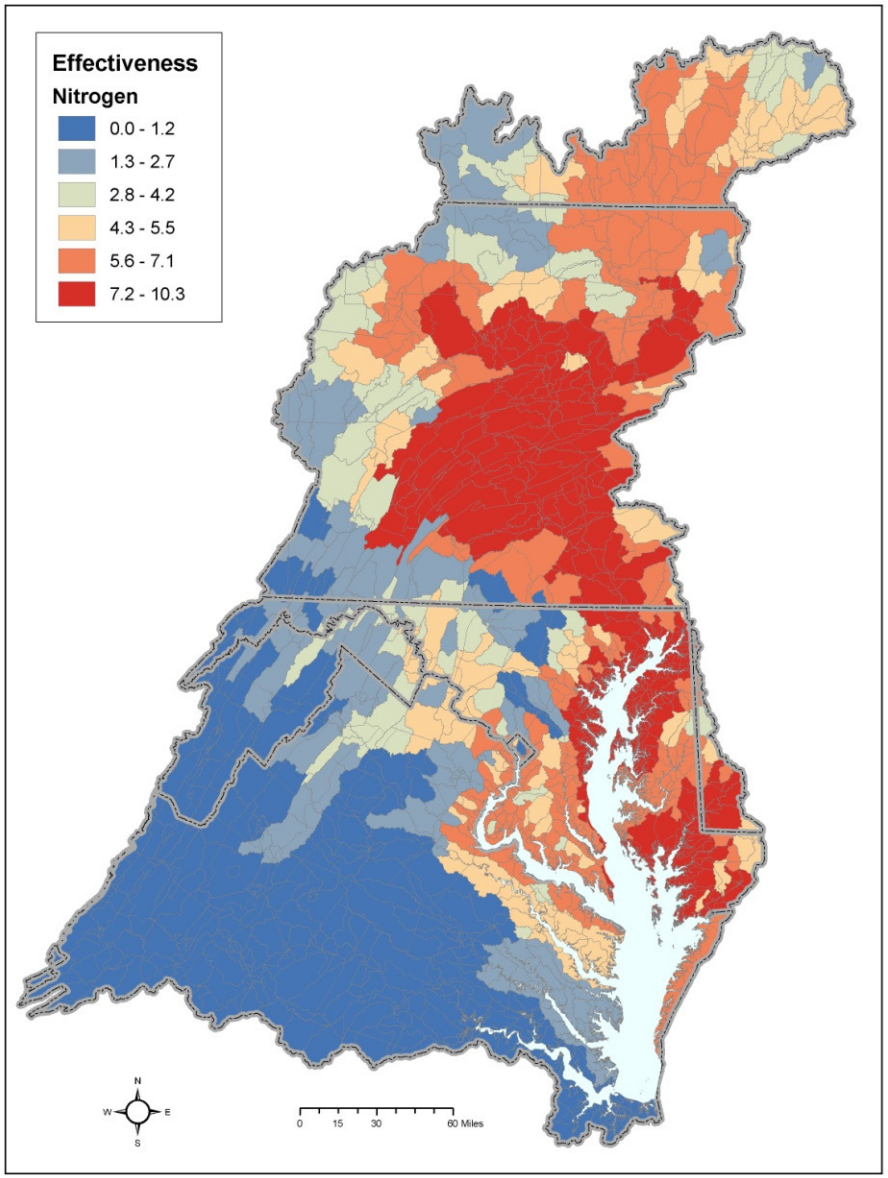
Allocations

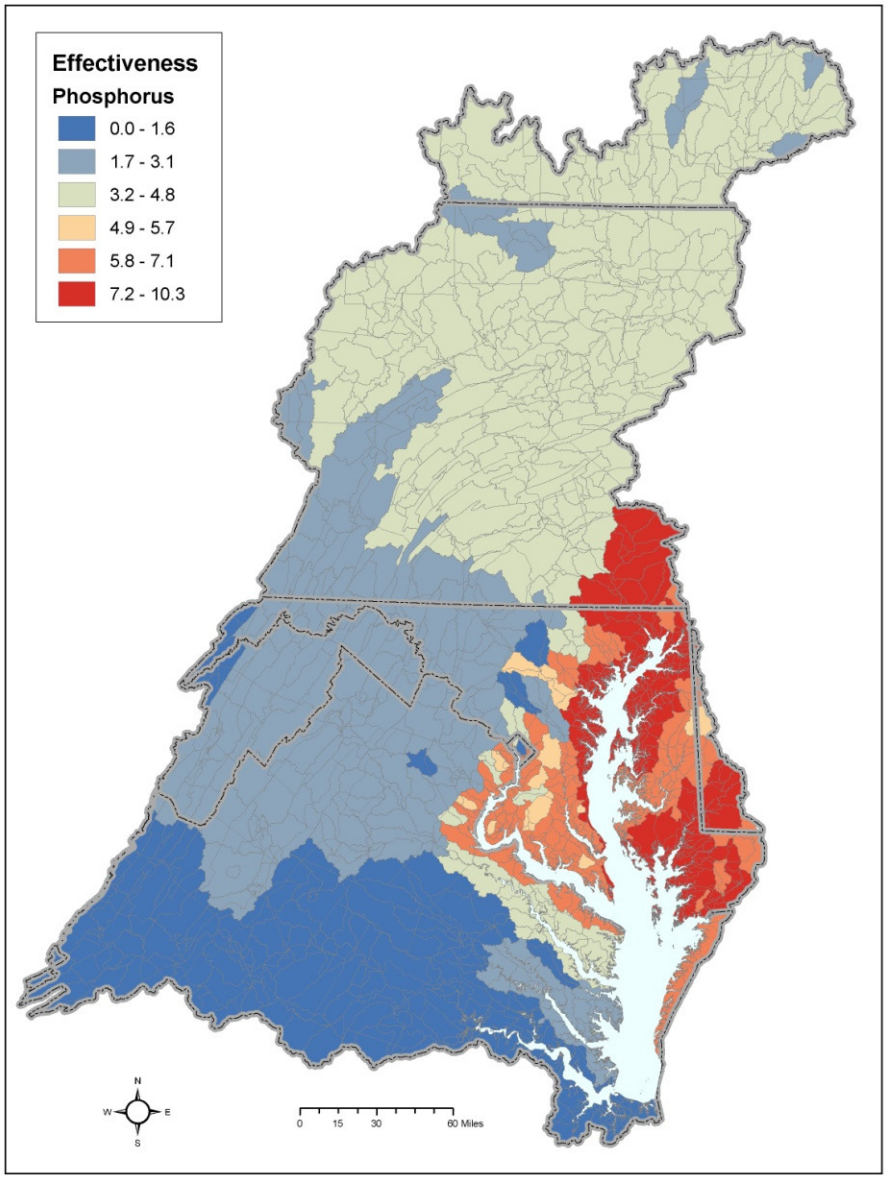
Sources of Nitrogen to the Bay

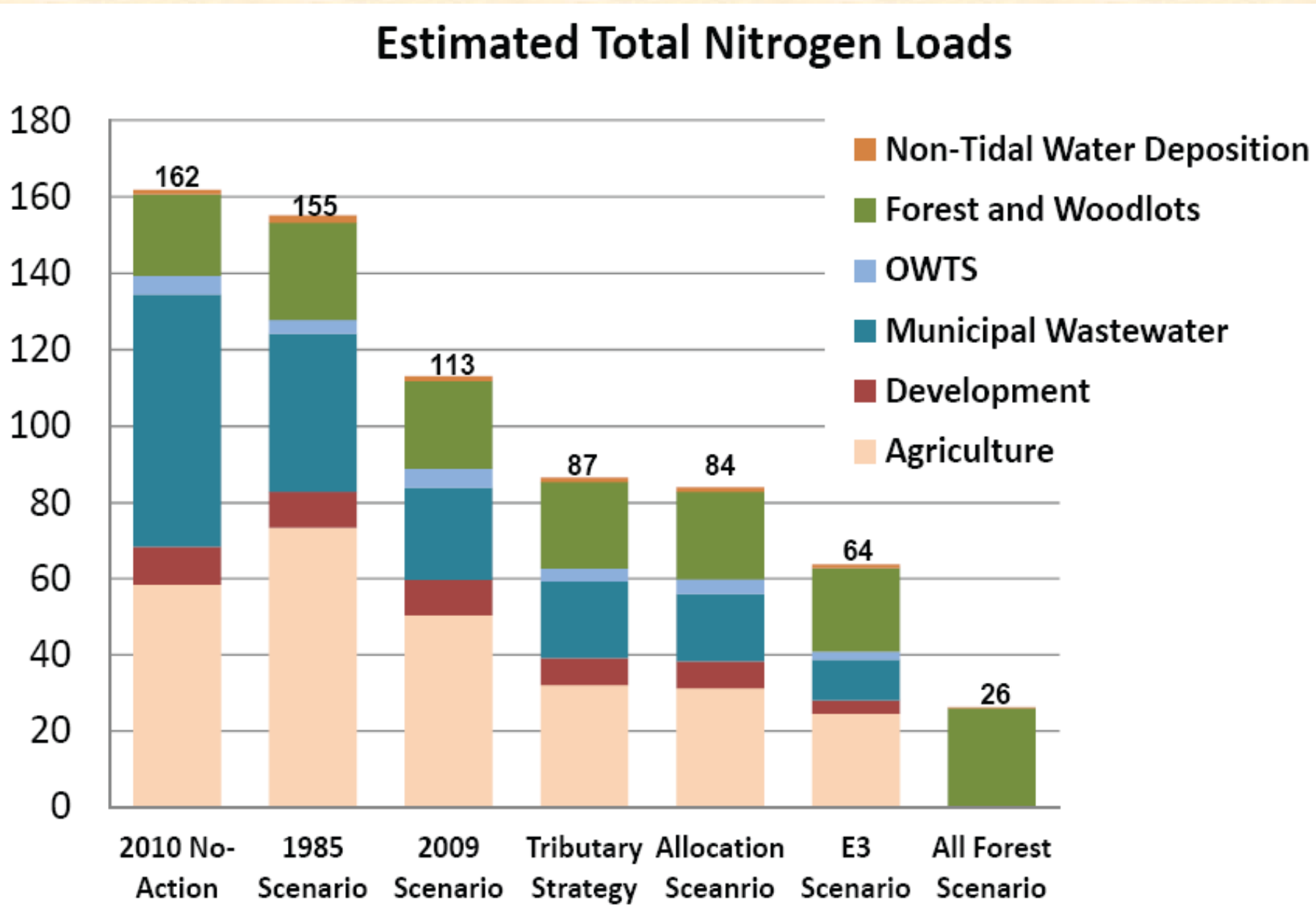


Note: Does not include loads from the ocean or tidal shoreline erosion. Wastewater loads are based on measured discharges; other loads are based on an average-hydrology year using the Chesapeake Bay Program Watershed Model Phase 4.3 (Chesapeake Bay Program Office, 2009). Values do not add up to 100% due to rounding.

Relative Effect of a Pound of Pollution on Bay Water Quality







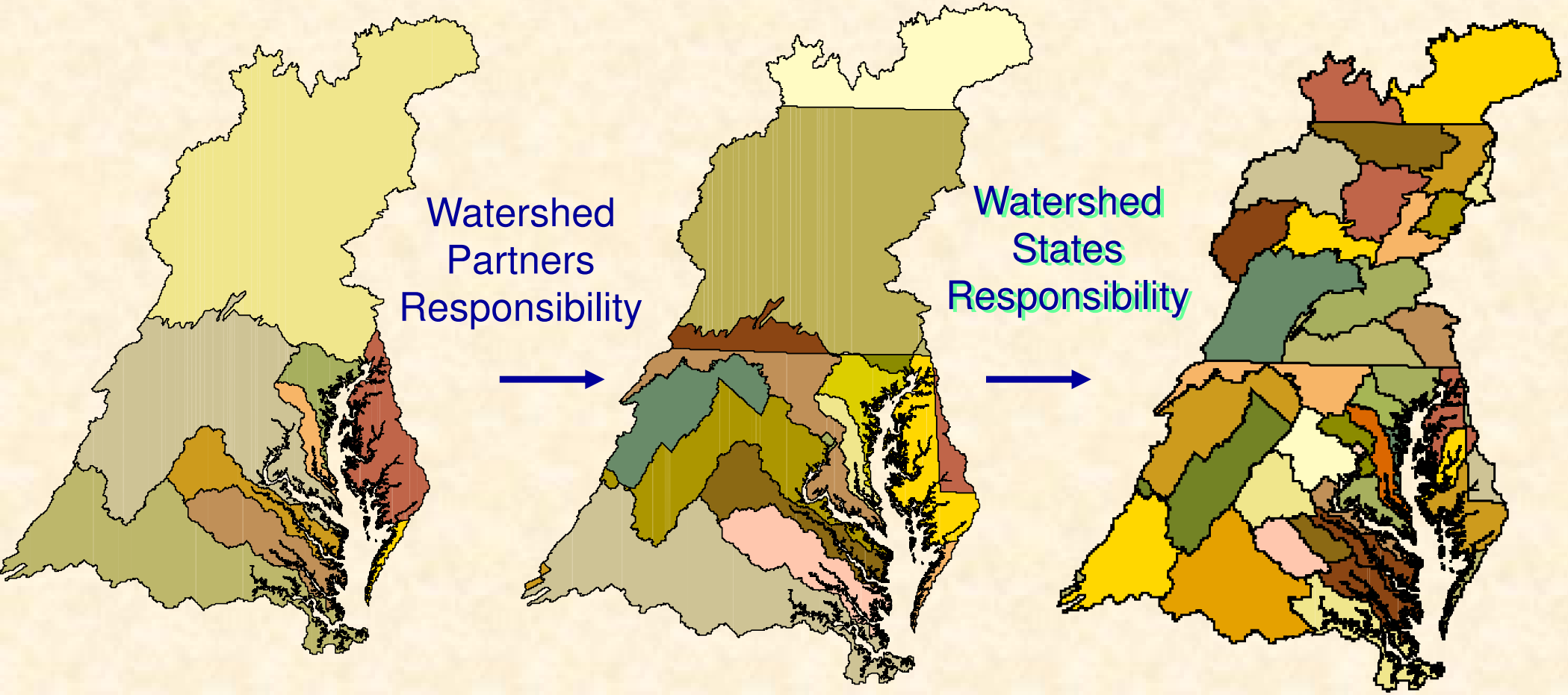
Estimated total nitrogen loads from key scenarios. Loads in millions of kilograms.

Load Allocation Process

By **9** major river basins

...then by **20** major tributary basins by jurisdiction

…then by **44** state-defined tributary strategy subbasins



Long-Term Flow-Adjusted Trends for Total Nitrogen for 32 Sites in the Chesapeake Bay Watershed, 1985-2009

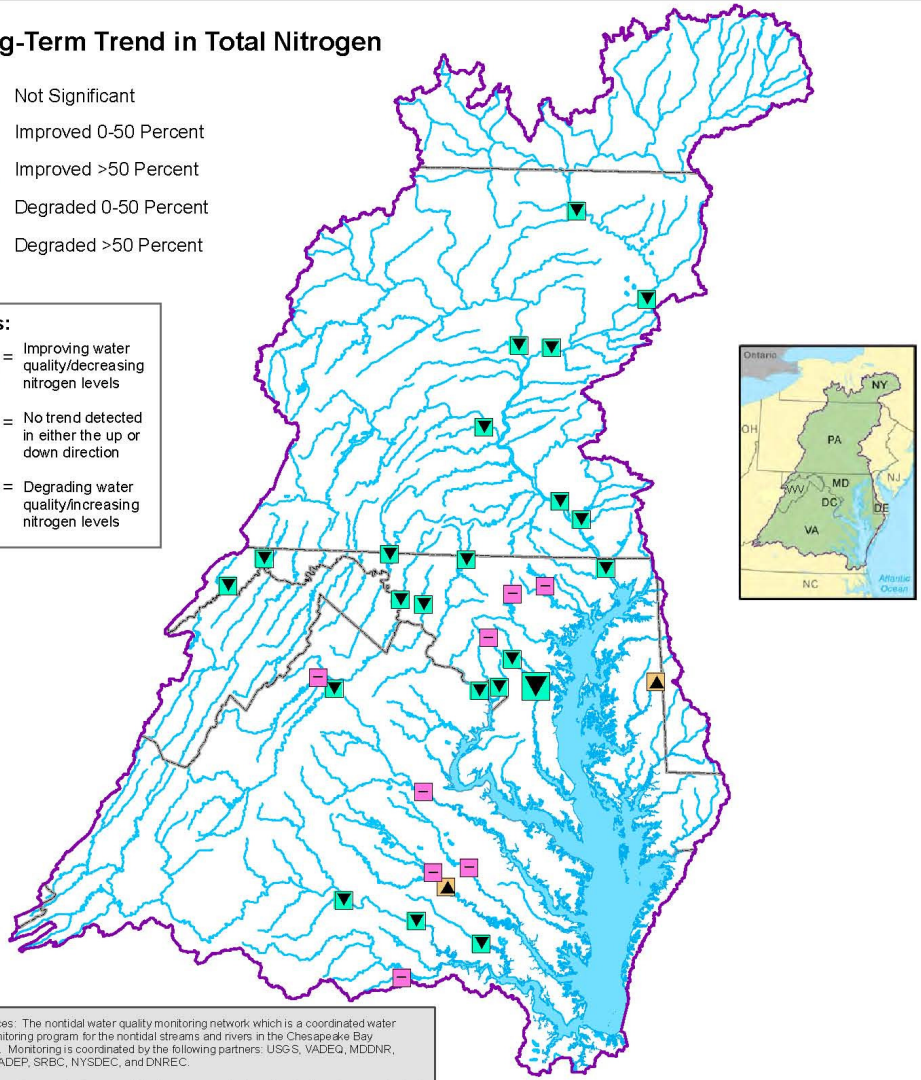
Chesapeake Bay Program
A Watershed Partnership

Long-Term Trend in Total Nitrogen

- Not Significant
- Improved 0-50 Percent
- Improved >50 Percent
- Degraded 0-50 Percent
- Degraded >50 Percent

Notes:

- = Improving water quality/decreasing nitrogen levels
- = No trend detected in either the up or down direction
- = Degrading water quality/increasing nitrogen levels



Data Sources: The nontidal water quality monitoring network which is a coordinated water quality monitoring program for the nontidal streams and rivers in the Chesapeake Bay Watershed. Monitoring is coordinated by the following partners: USGS, VADEQ, MDDNR, WVDEP, PADEP, SRBC, NYSDEC, and DNREC.

Trends in the Chesapeake Bay may differ from measured values due to downstream ecological processes. For more information on nitrogen trends in the Bay see http://www.chesapeakebay.net/status_pollutants.aspx

For more information, visit *www.chesapeakebay.net*
Disclaimer: *www.chesapeakebay.net/termsofuse.htm*

0 15 30 60 Kilometers
0 20 40 80 Miles

Created by JW, 3/11/11

UTM Zone 18N, NAD 83

Long-Term Flow-Adjusted Trends for Total Phosphorus for 32 Sites in the Chesapeake Bay Watershed, 1985-2009

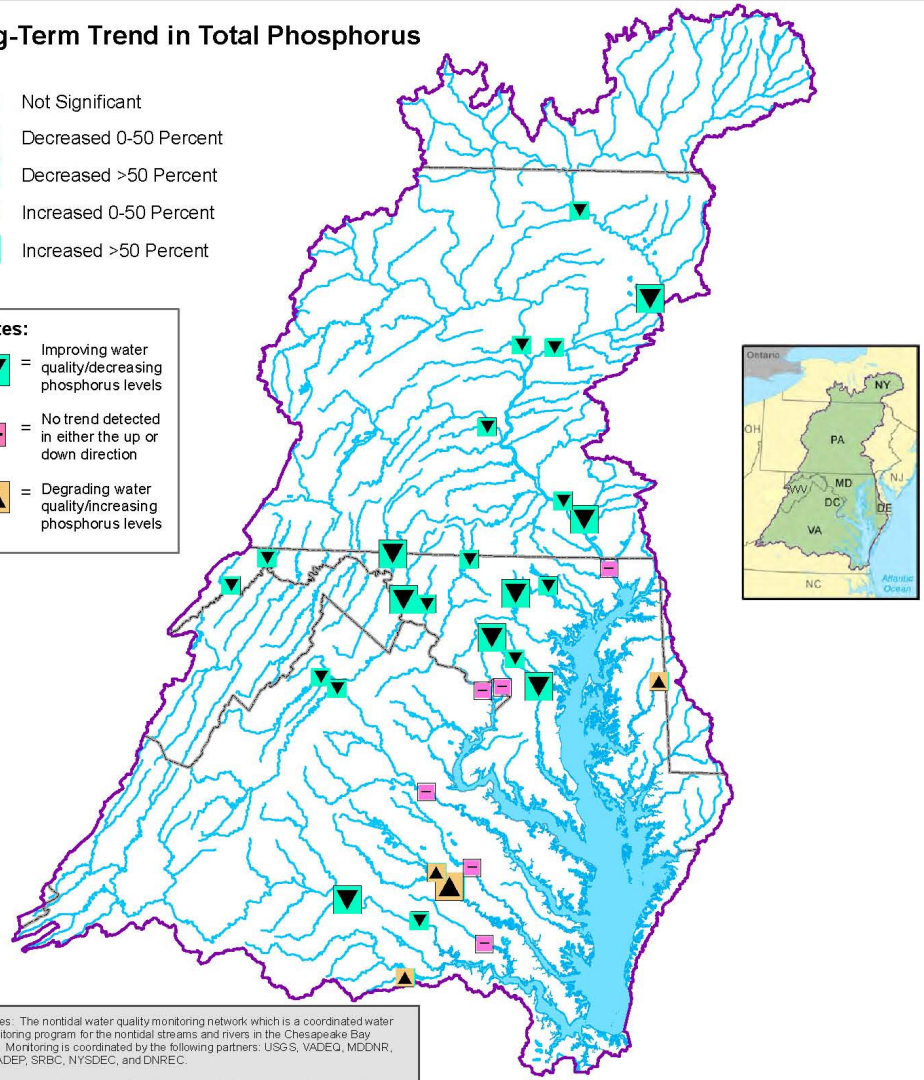
Chesapeake Bay Program
A Watershed Partnership

Long-Term Trend in Total Phosphorus

- Not Significant
- Decreased 0-50 Percent
- Decreased >50 Percent
- Increased 0-50 Percent
- Increased >50 Percent

Notes:

- = Improving water quality/decreasing phosphorus levels
- = No trend detected in either the up or down direction
- = Degrading water quality/increasing phosphorus levels



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Disclaimer: *www.chesapeakebay.net/termsofuse.htm*

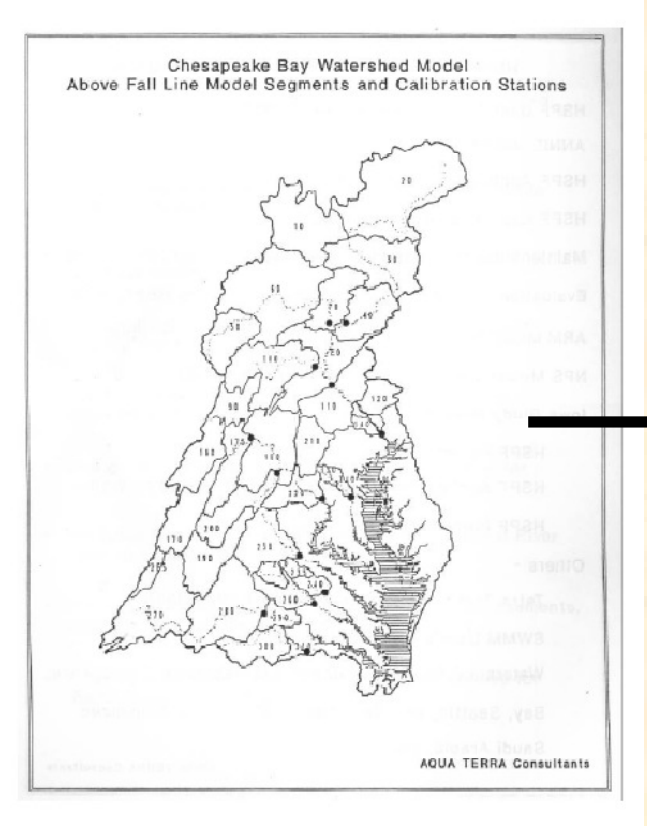
0 15 30 60 Kilometers
0 20 40 80 Miles

Created by JW, 3/11/11

UTM Zone 18N, NAD 83

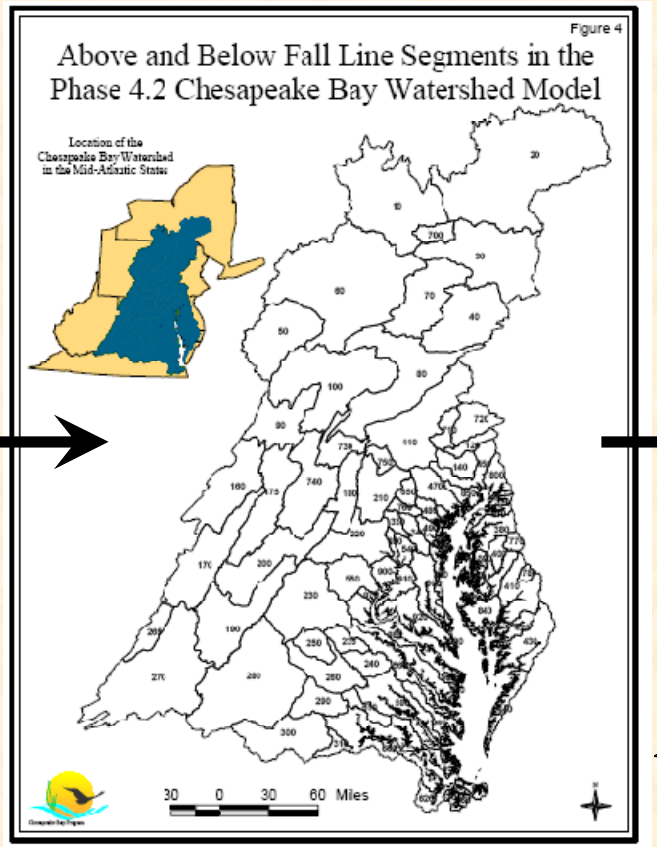
A Quarter Century of Watershed Model Development

Phase 1



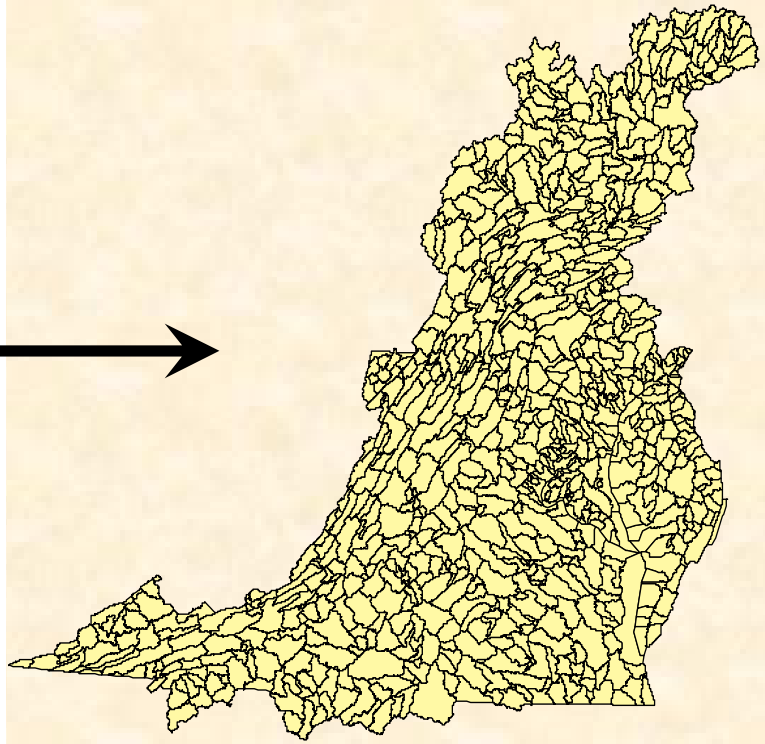
- Completed in 1982.
- 63 model segments.
- 2 year calibration period (Mar.- Oct.).
- 5 land uses.

Phase 4



- Completed in 1998.
- 94 model segments.
- 9 land uses.
- 14 year calibration period (1984-97) using automated input and output model processors.

Phase 5



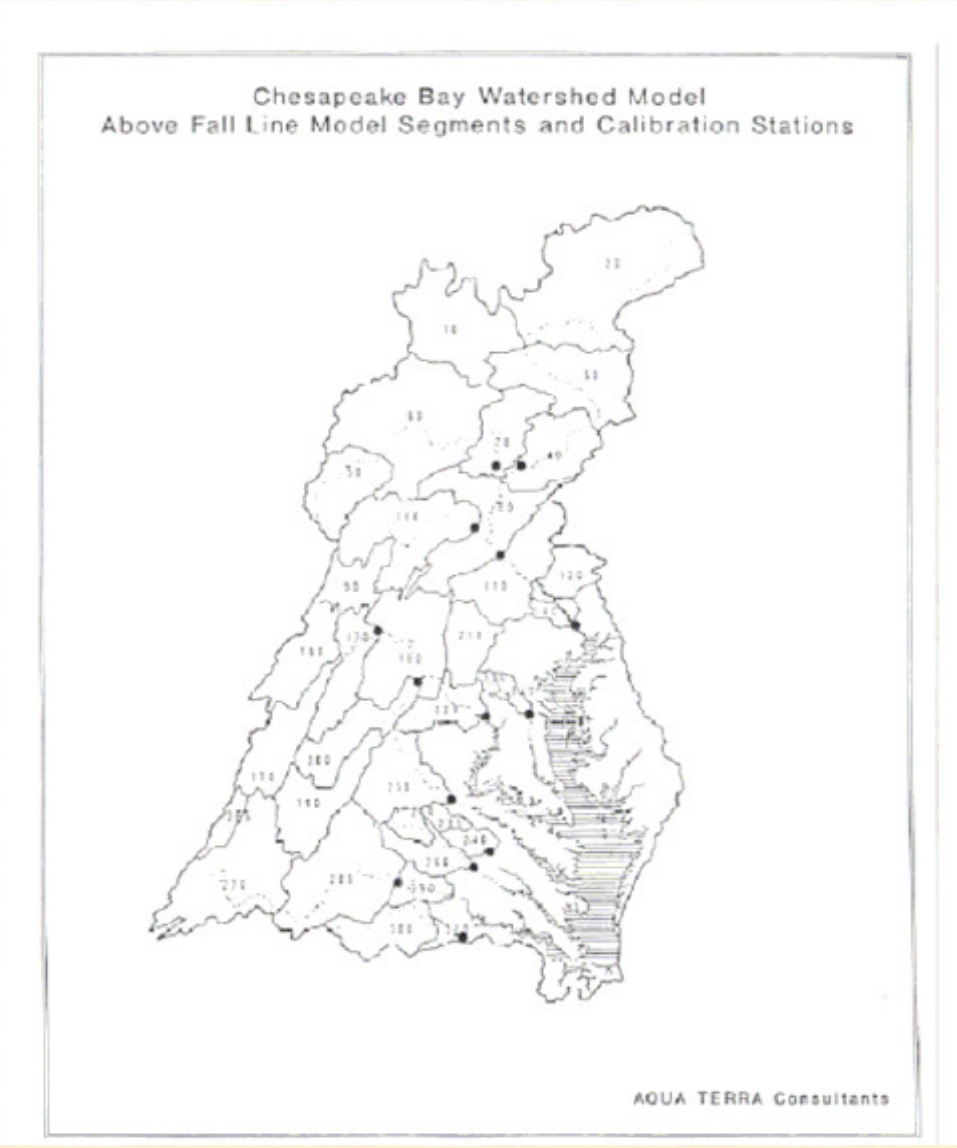
- May 2009 roll-out
- ~ 1,000 model segments.
- 21 year calibration period (‘85-’05).
- ~ 25 land uses using time-varying land use & BMPs.

Trends From 1982 to 2012 in Chesapeake Bay Modeling:

- Expansion of spatial detail/segmentation and simulation periods.
- More simulation detail. Example - BMP performance in different physiographic regions.
- Increased web-based distribution of open source public domain model code, data, results, documentation and support of community modeling.
- Integration with other key modeling efforts such as CMAQ and climate models.

First Version of the Watershed Model:

- Completed in 1982.
- 63 model segments.
- 2 year calibration period (Mar.- Oct.).
- 5 land uses.
- IBM mainframe platform.



Primary Products of the First Version of the Watershed Model:

First estimate of relative point source and NPS loads for each major basin.

Demonstration of the importance of controlling NPS loads in the Chesapeake.

"Framework for Action" report, the first basin by basin assessment of Chesapeake nutrient loads.

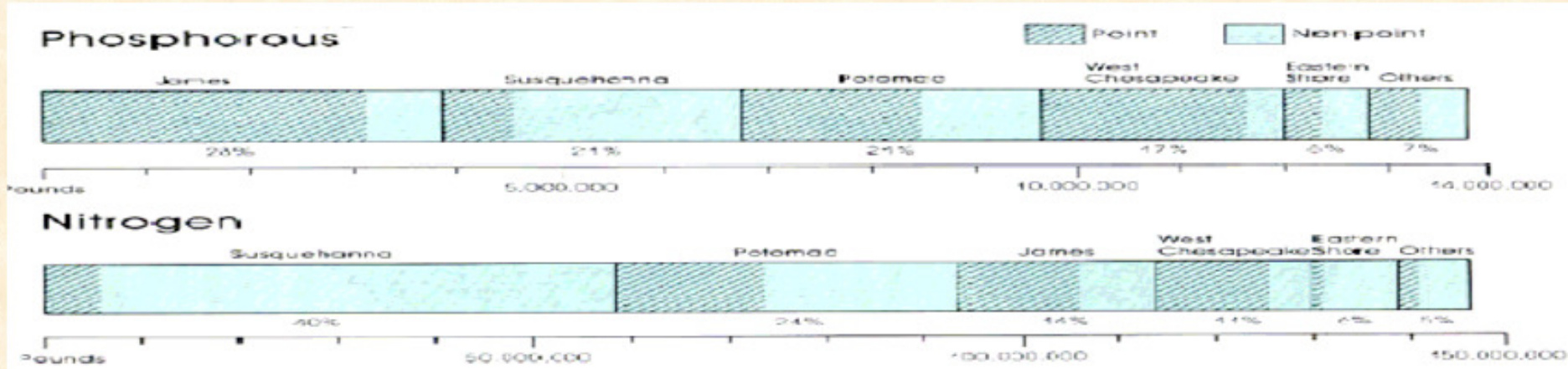
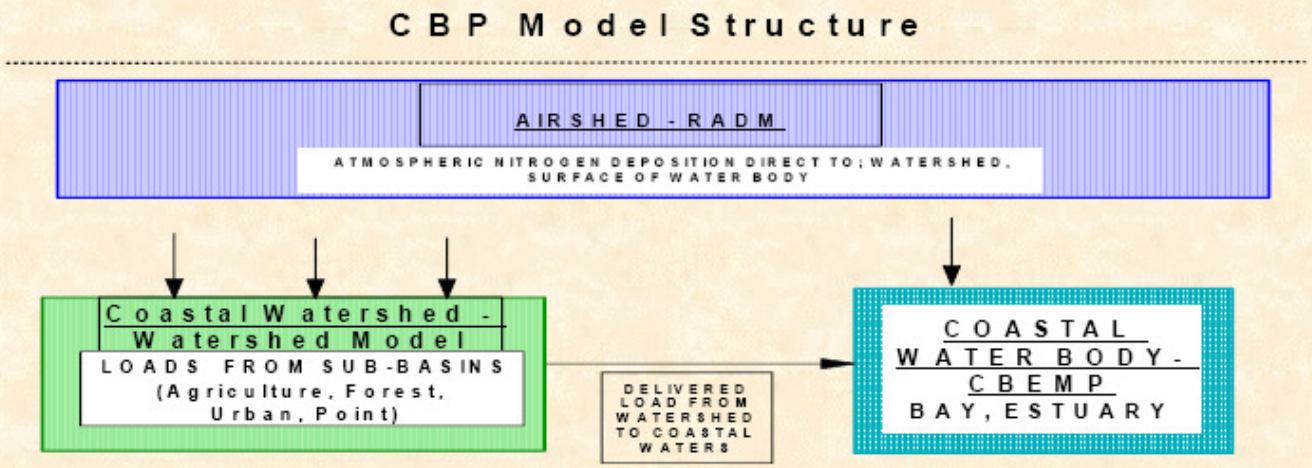


FIGURE 20. Nutrient loadings (March to October) by major basin under average rainfall conditions.

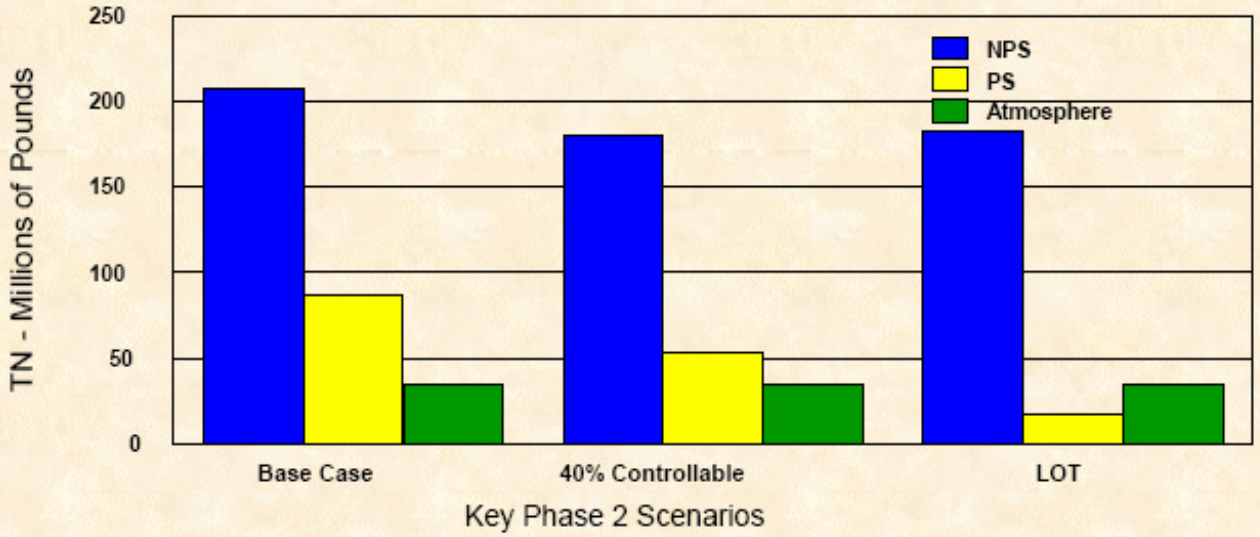
Watershed Model - Phase 2:

- Completed in 1992.
- 63 model segments.
- 4 year calibration period (1984-87).
- 9 land uses.
- DEC VAX mainframe platform.



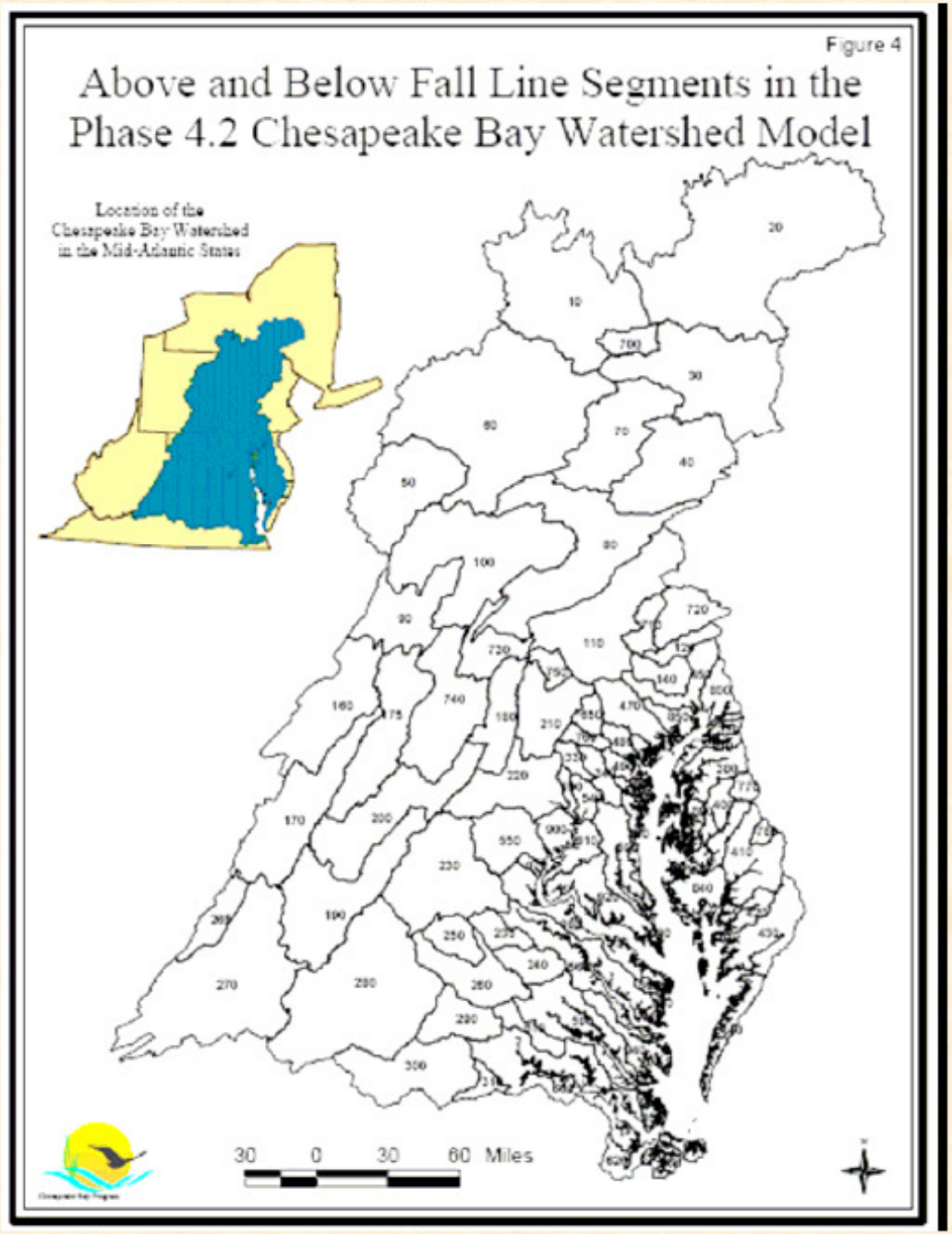
Primary Products of Phase 2:

- First nitrogen and phosphorous allocations for each major basin.
- First linkage to water quality model of the estuary.
- First linkage to the airshed model (RADM) and estimates of atmospheric loads for each major basin.



Watershed Model - Phase 4:

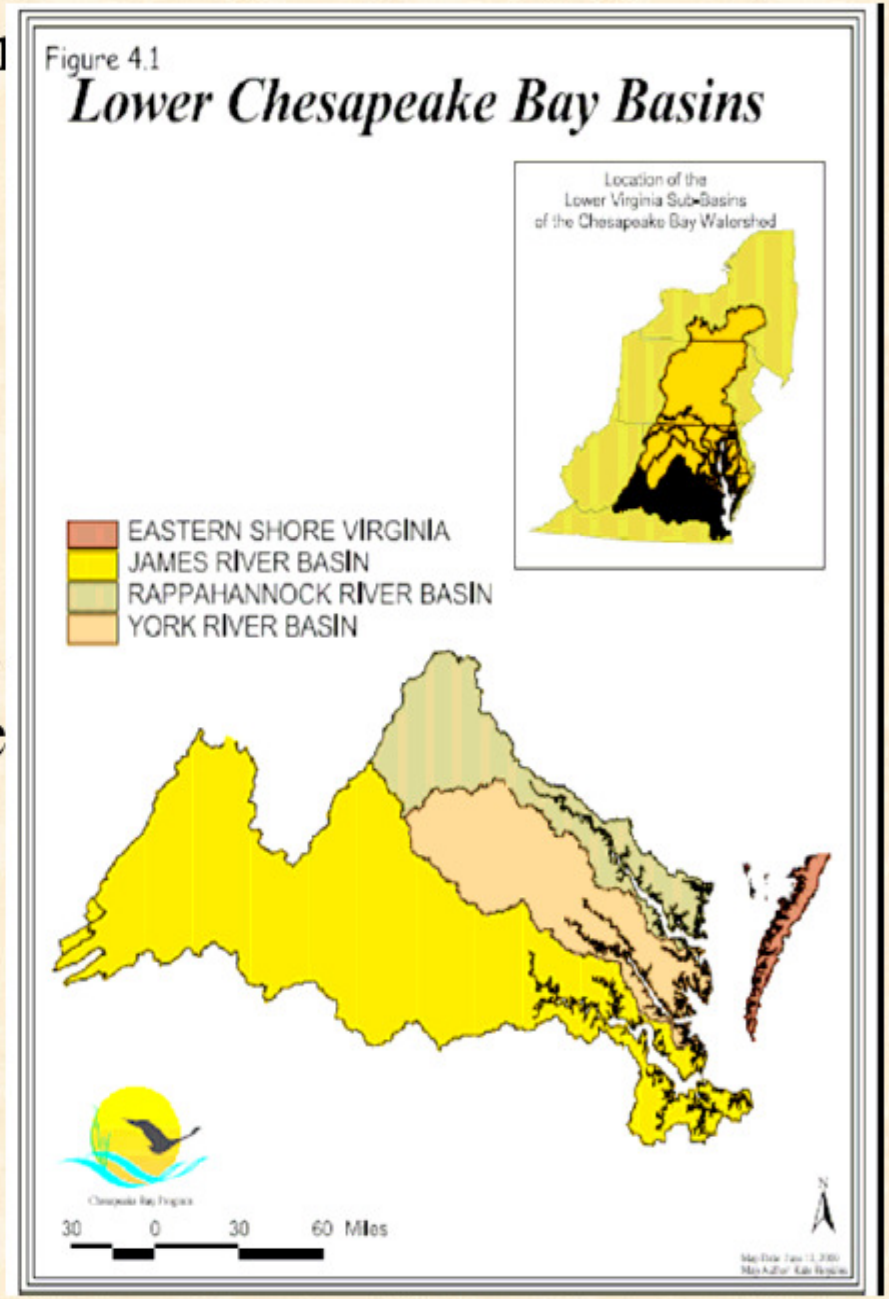
- Completed in 1998.
- 94 model segments.
- 9 land uses.
- 14 year calibration period (1984-97) using automated input and output model processors.
- Sun (UNIX) workstation platform.



Primary Products of Phase 4:

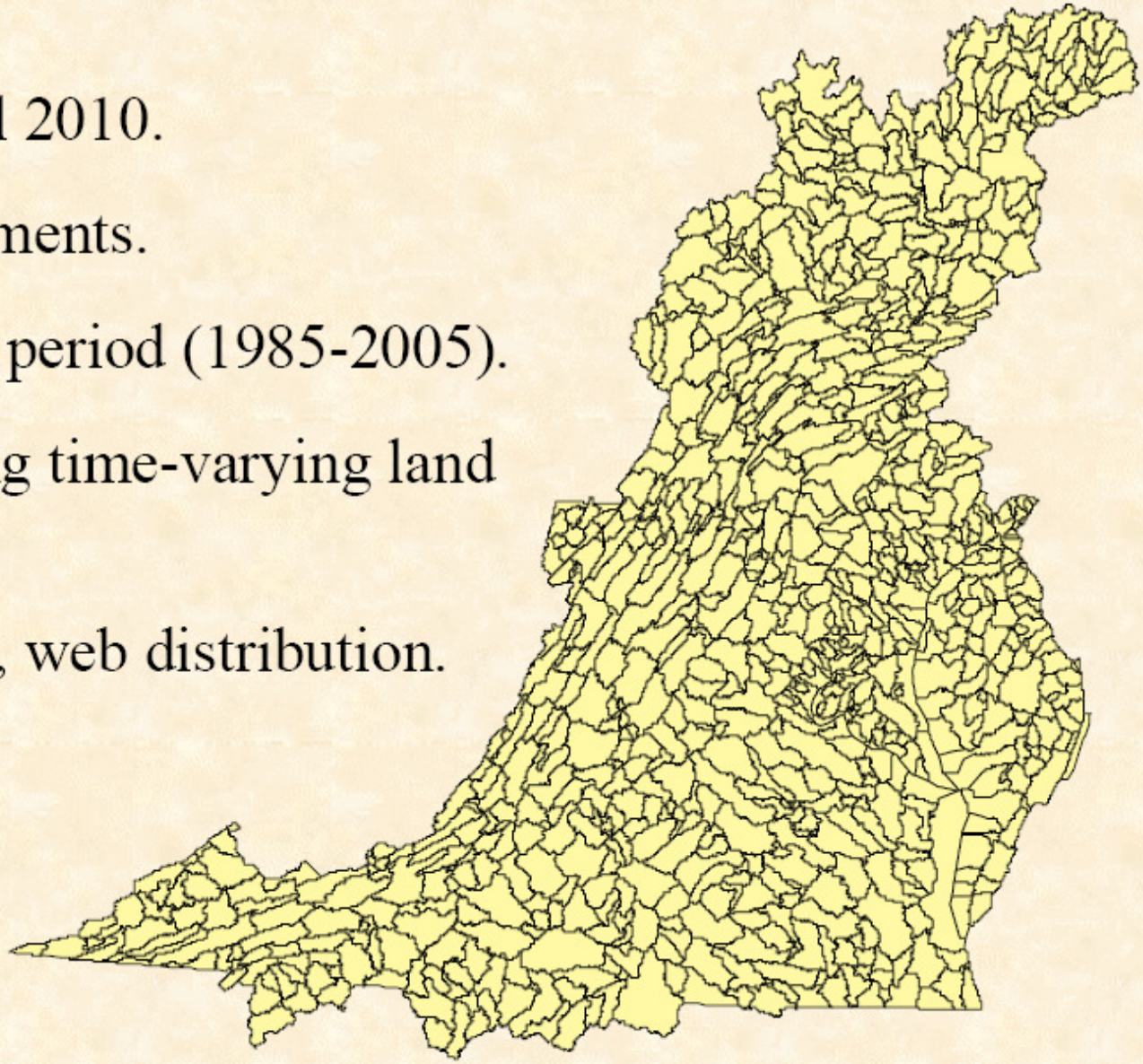
- Tributary allocations for the lower tributaries of the Rappahannock, York, and James (2000) and for all basins in the 2003 Allocation.

- Began open source, public domain, web distribution of preprocessors, post processors, and open source code. Begin broad use in the community for research, TMDLs, and analysis.

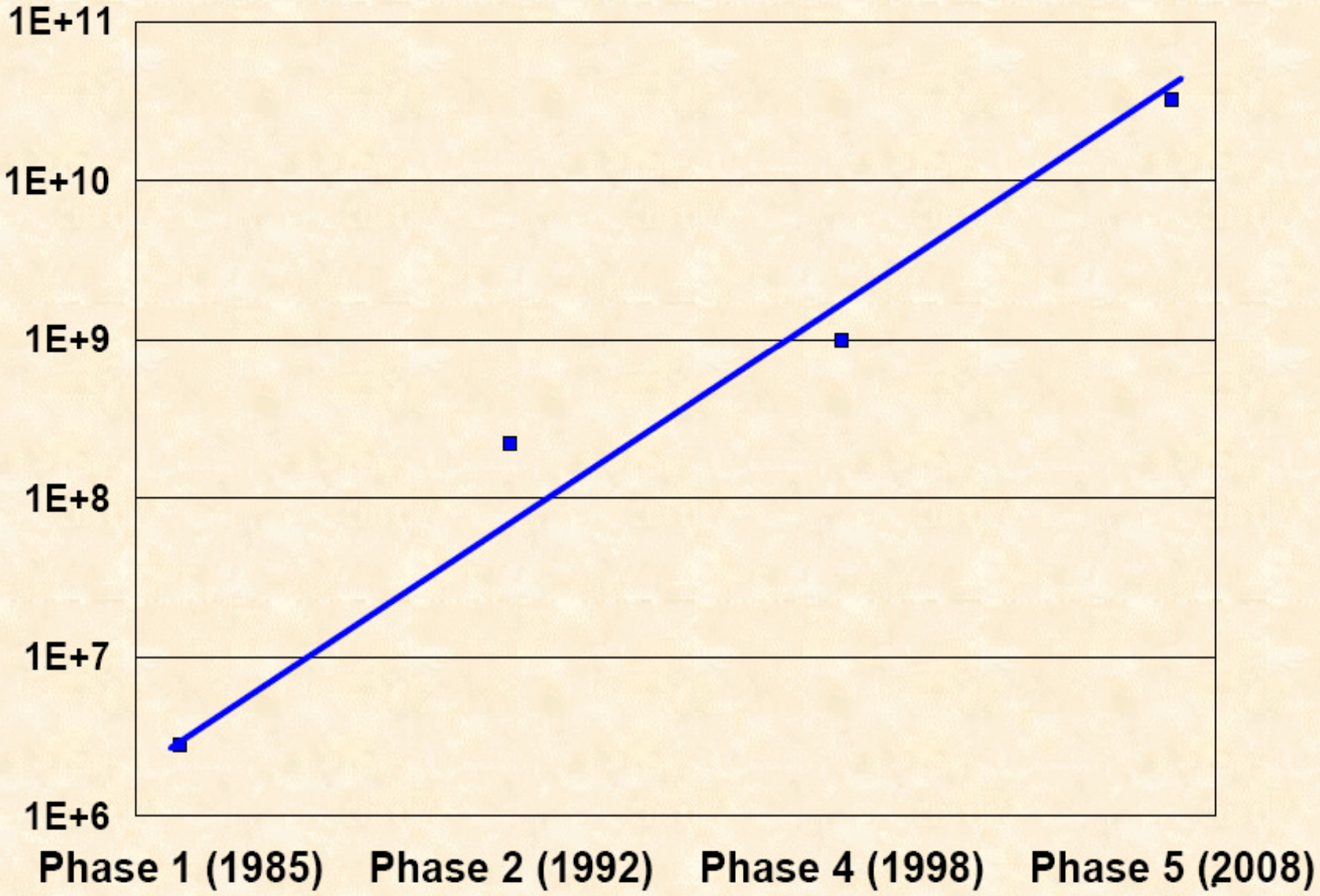


Watershed Model - Phase 5:

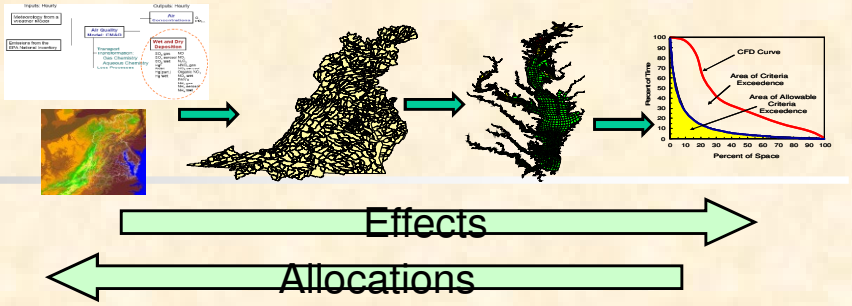
- Completed in April 2010.
- > 1,000 model segments.
- 21 year calibration period (1985-2005).
- ~20 land uses using time-varying land use & BMPs.
- Multiple platforms, web distribution.



History of Watershed Model Operations:
[LU x parameters x (segments + reaches) x time steps]



Conclusions:

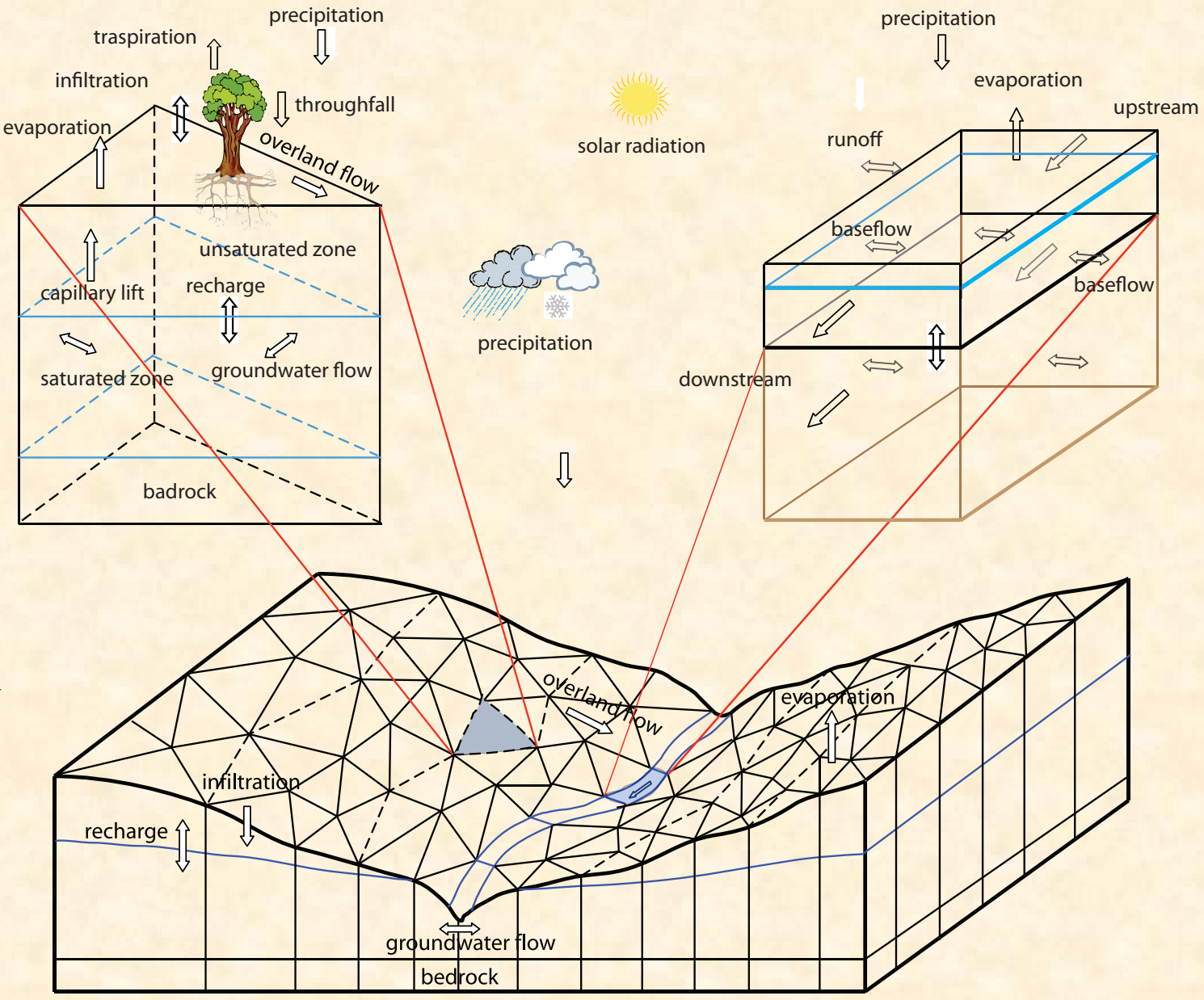


Future Directions of Watershed Modeling

- Distributed watershed models at the Chesapeake watershed scale.
- Greater integration with airshed, coastal, living resource, and climate change models.

Penn State Integrated Hydrologic Model (PIHM)

Now have a working hydrology model of Juniata basin (1/20th CB watershed operational on 87,000 partitions and running 1 year in 1 hour.



The future of CBP Modeling…2010 and beyond:

"**Never bow to precedent**. As the pace of change accelerates, the value of precedent will continue to wane. A healthy disrespect for precedent is the ultimate advantage in a world where the future is less and less an extrapolation of the past."

Gary Hamel

Lessons Learned
Management Models in the Chesapeake

- **Too much stakeholder input is not enough**
- KISS
- Agility is key

Empower the community to create, understand, and use the model.

Chesapeake Bay Program Partners

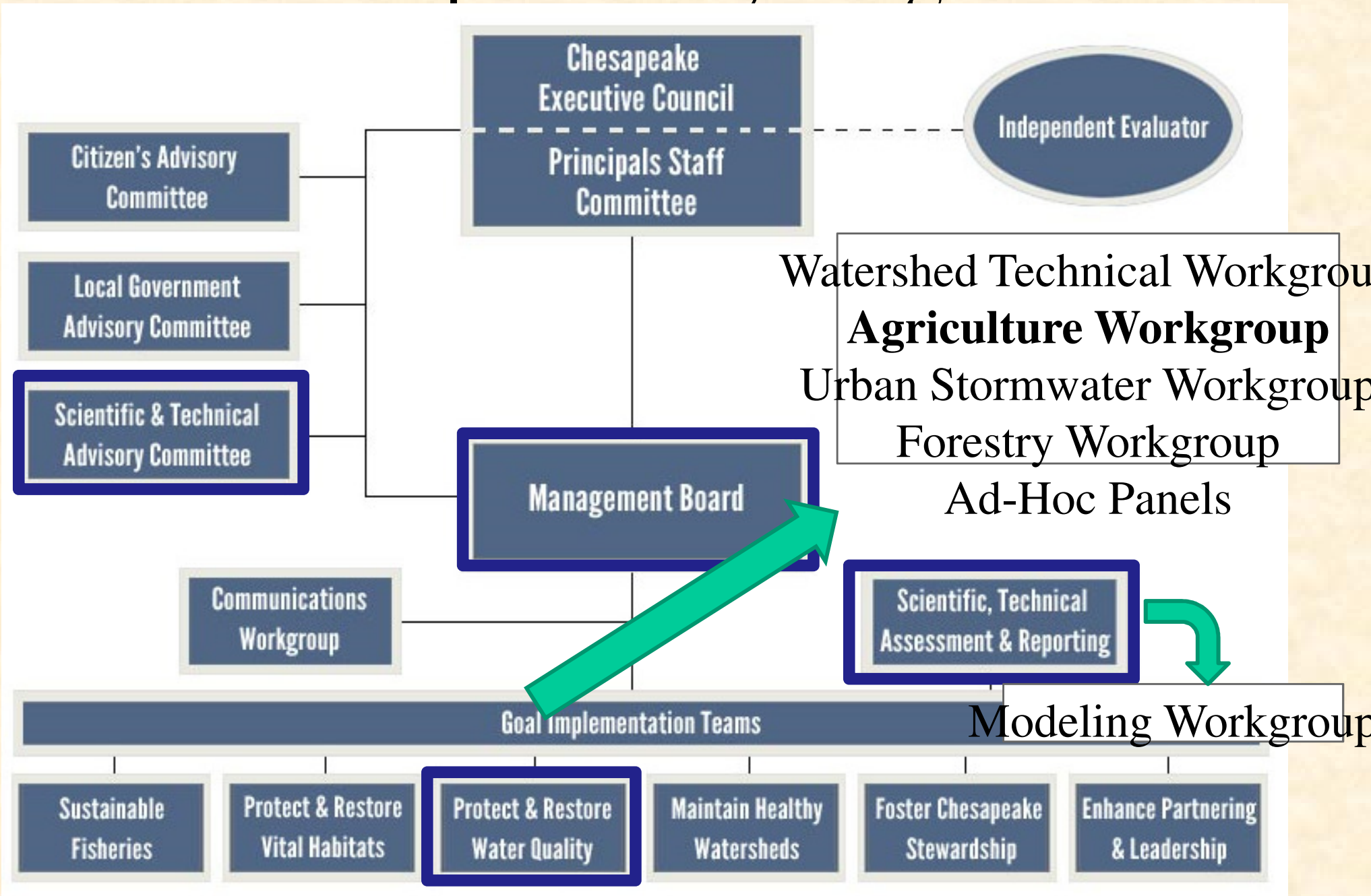
- Signatories to the Chesapeake Bay Agreement
  - PA, MD, VA, DC
  - CBC
  - EPA
- Headwater States
  - DE, NY, WV
- Federal Agencies
  - NOAA
  - USDA
  - USGS
  - NPS
  - USFW
  - DOD
  - NASA
  - NCPC
  - D.Ed.
  - USPS
  - GSA

How many meetings did it take to create the Chesapeake TMDL?

- TMDL on the agenda: about 375 since 2005
- TMDL a principal topic: about 450 since 2008
- Model development started in 1999

Stakeholder Input

Chesapeake Bay Program



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

Stakeholder Input

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

Expert Review Panels; Planned and Active

Stakeholder Input

Agriculture

- Nutrient Management
- Poultry Litter
- Conservation Tillage
- Cover Crop Panel
- Manure Treatment Technologies
- Animal Waste Storage Systems
- Manure Injection/Incorporation
- Cropland Irrigation Management

Urban

- Urban Retrofits
- Performance Based Management
- Stream Restoration
- LID and Runoff Reduction
- Urban Fertilizer Management
- Erosion and Sediment Control
- Illicit Discharge Elimination
- Impervious Disconnect
- Floating Wetlands
- MS4 Minimum Management Measures

Forestry

- Riparian Buffers
- Urban Tree Planting
- Forest Management
- Urban Filter Strips and Upgraded Stream Buffers

Too much is not enough

- Stakeholder input and access has helped the modeling and management processes

- But …
  - Increase in the stakes has increased scrutiny
  - Increase in understanding by the users has increased demand for more complexity
  - Management-driven complexity has created difficulty in understanding and opportunity for detractors

Lessons Learned
Management Models in the Chesapeake

- Too much stakeholder input is not enough
- **KISS**
- Agility is key

Empower the community to create, understand, and use the model.

KISS

Lessons Learned through TMDL

- The CBP Partnership wants
  - Simplicity
  - Scalability
  - Serviceability
  - Stability

- Quote from State Government Representative:

"***We*** *want to be able to explain the models to our stakeholders and have them be* relevant *at the local scale*."

Simulated BMPs vs Percent Reduction

- **Which Description Works Best for Management?**
- **What's my reduction from Nutrient Management?**
  - Well, based on the rules developed by the partnership and the data supplied by national sources and the states, the balance of inputs and outputs for your land use is such that there is an overabundance of manure in your county, as opposed to the next county over where nutrient management has almost no effect. Now when you apply nutrient management, that will attract manure to the nutrient management land use, so it will have a higher load, but since it's pulling manure from other land uses, the total segment load will usually decrease, however in some circumstances when nutrient management is applied to pasture, it can push so much manure back on to other land uses, that the marginal effect …
- **What's my reduction from Cover Crops?**
  - Based on the Cover Crop Panel, who based their decision on multiple referenced data sources and models, your reduction for Early Drilled Barley in the Valley and Ridge Carbonate region is 38%

KISS

Management vs Research Model

- Management models should integrate knowledge, rather than create knowledge.

- The Watershed model does not tell us anything we don't already know, it just puts all of the knowledge in one place and allows us to see how different sources, watershed processes, and management practices interrelate.

Lessons Learned
Management Models in the Chesapeake

- Too much stakeholder input is not enough
- KISS
- **Agility is key**

Empower the community to create, understand, and use the model.

Number of Scenarios

- Mid 1980s 0
- Early 1990s – phase 2 <10
- Late 1990s phase 4.1 37
- Early 2000s – phase 4.3 400+
- 2009-2010 – phase 5.3.0 300+
- 2011 - 2012 - phase 5.3.2 300 thru Sept

Scenario automation in the early 2000s greatly expanded the use of the watershed model

Data flows

Agility

Feds, States and DC

submit Non-Point Source Load, Practices/Verification

Wastewater Point Source /Data Direct Reporting

Final TMDL, Baseline Progress, Other data.

Practices

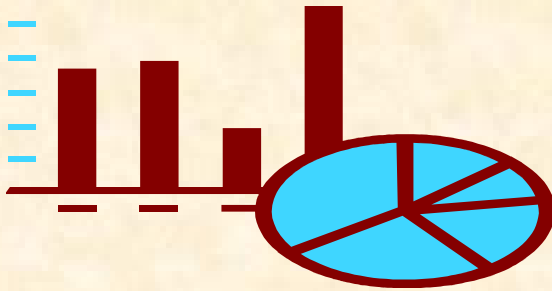
Scenario Builder

1/3 of this code is SPF

Watershed Model runs measure loadings progress.

Back-end – BayTAS O&M Team and State Access (QA, data entry, review etc.)

BayTAS (In CBPO IT Infrastructure)

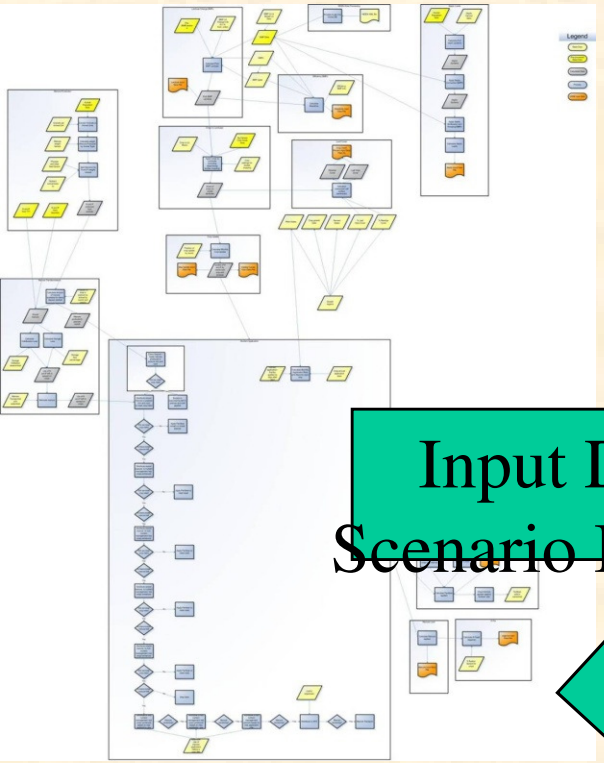


To Chesapeake Stat for Presentation

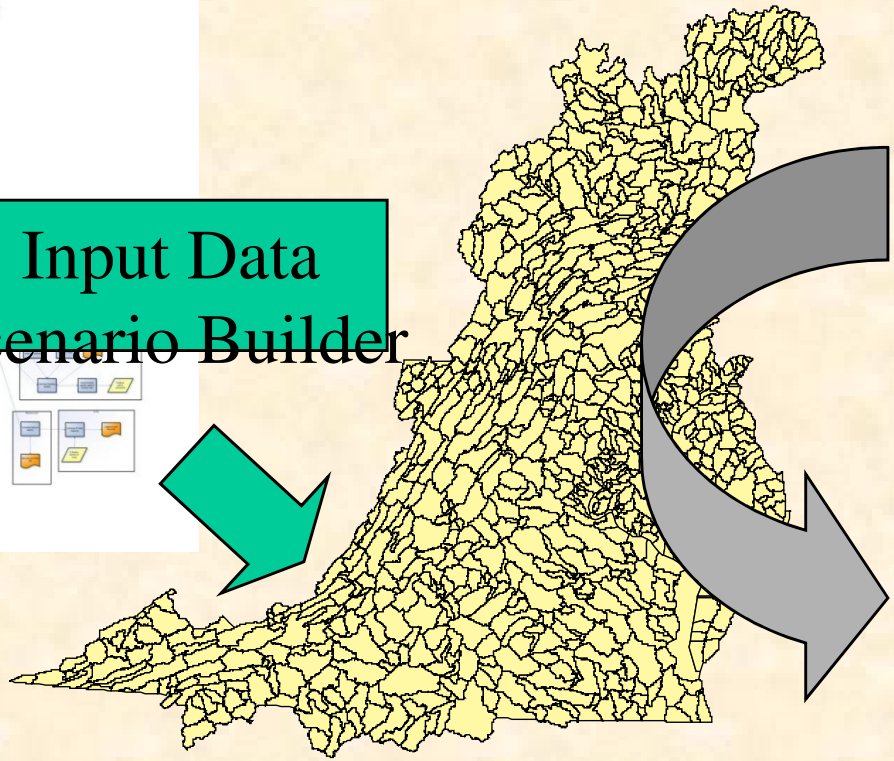
38

Automated Calibration

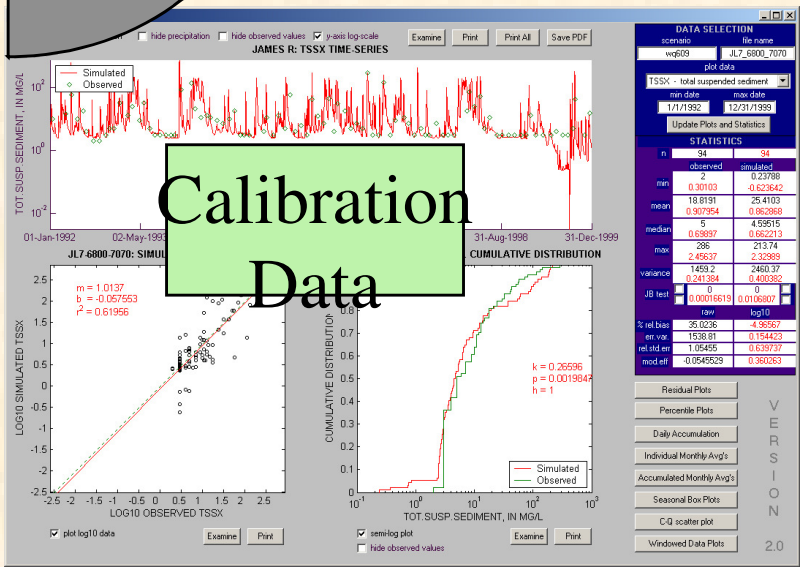
Agility



Input Data
Scenario Builder



Calibration
Procedures



Calibration
Data

Calibration automation made calibration possible

Automation will allow fast turnaround of model versions during the next development phase

Lessons Learned
Management Models in the Chesapeake

- Too much stakeholder input is not enough
- KISS
- Agility is key

Empower the community to create, understand, and use the model.

Management Modeling Maxims

- Absolute Rule #1
  - Always Improve and Never Change
- Absolute Rule #2
  - Include Everything and Keep it Simple