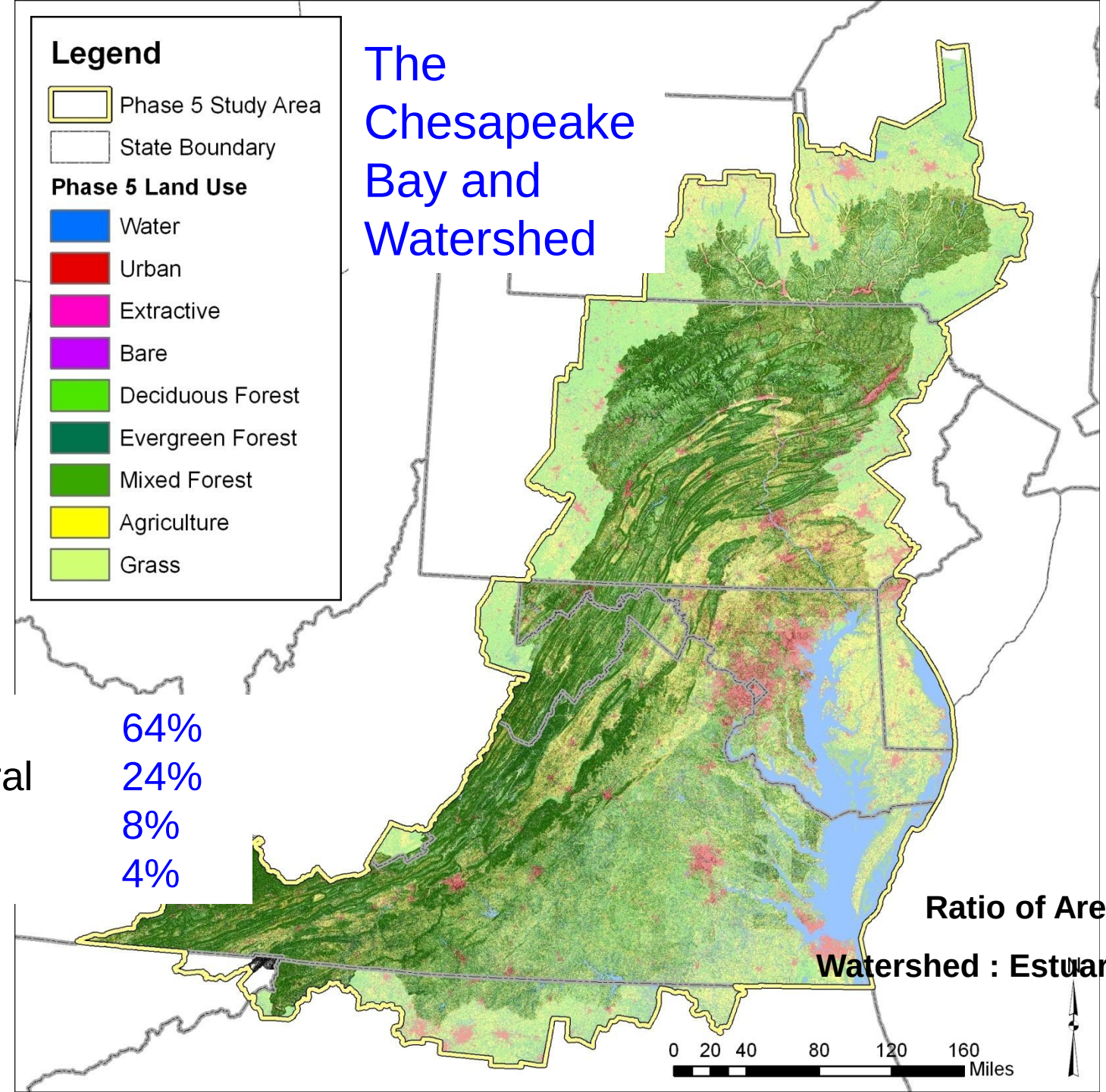
Chesapeake Bay Integrated Modeling and Decision Making

Gary Shenk

EPA / Chesapeake Bay Program



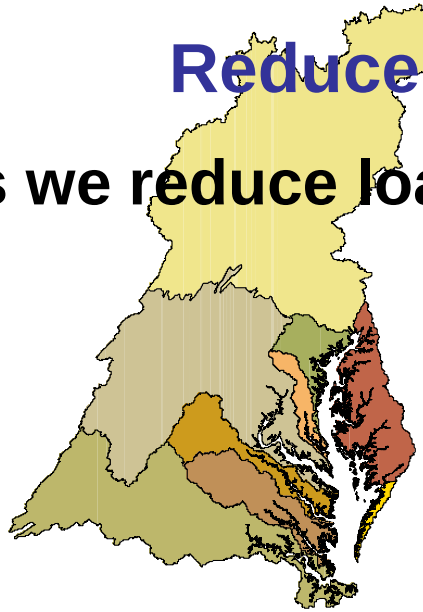
Forest	64%
Agricultural	24%
Urban	8%
Other	4%

Ratio of Areas

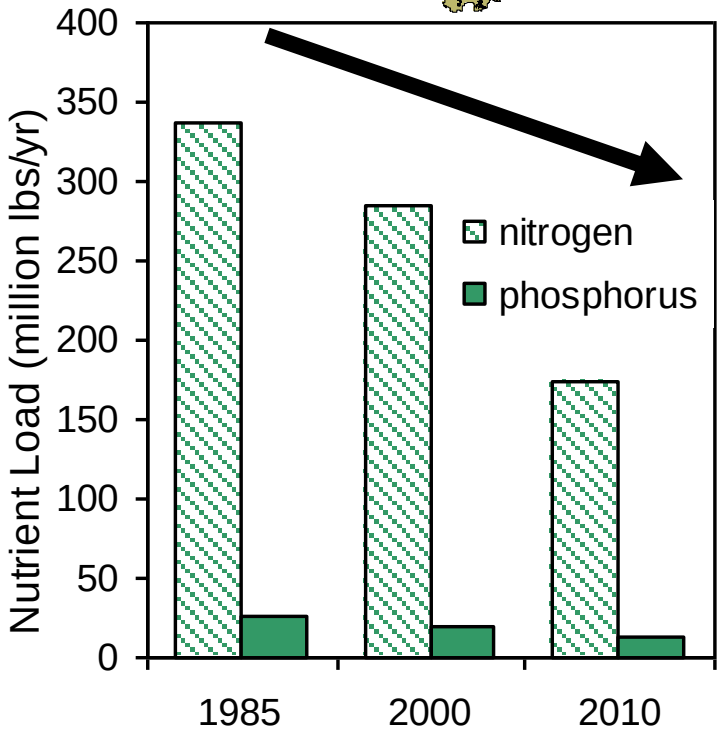
Watershed : Estuary ~ 15:1

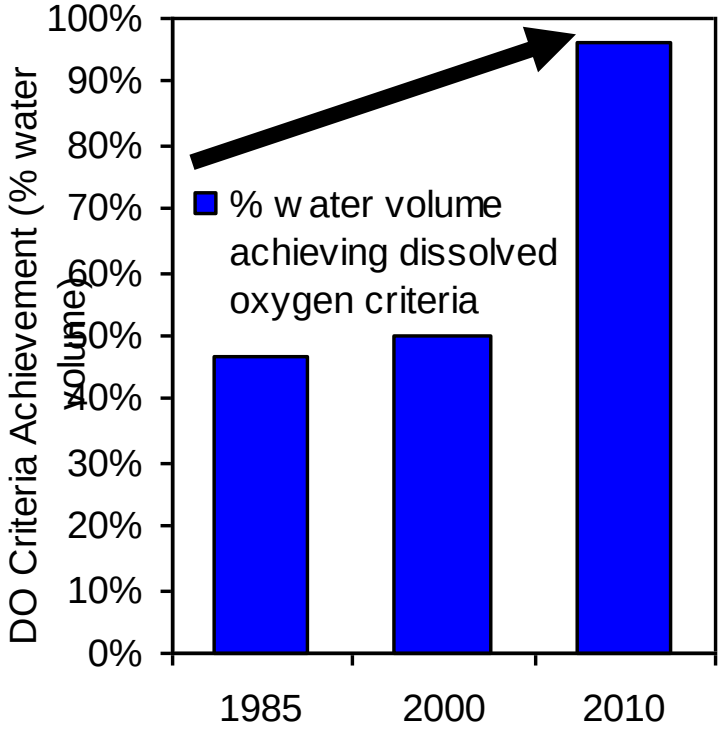
Reduce Nutrient Pollution Loads

As we reduce loads...



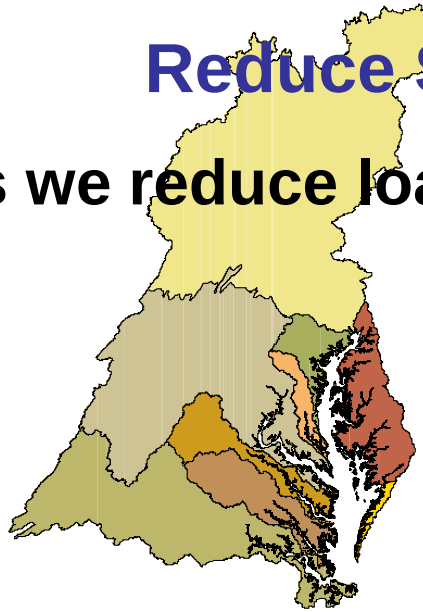
…we increase achievement of water quality conditions.

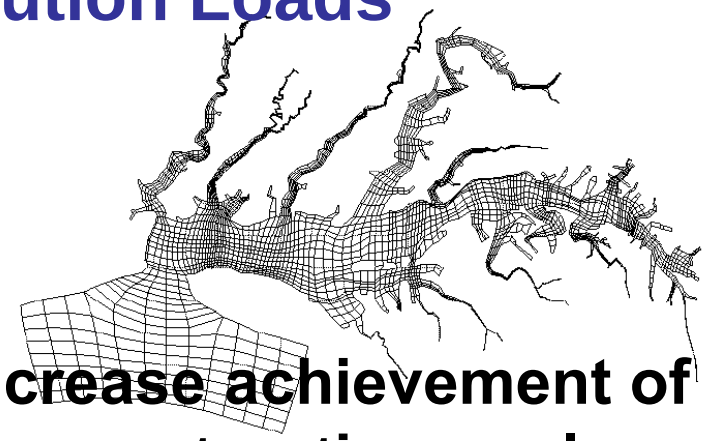




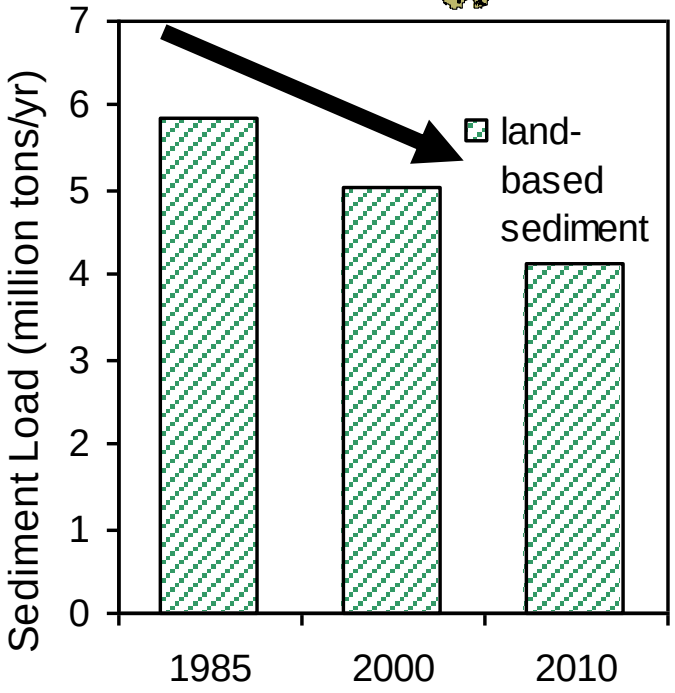
Reduce Sediment Pollution Loads

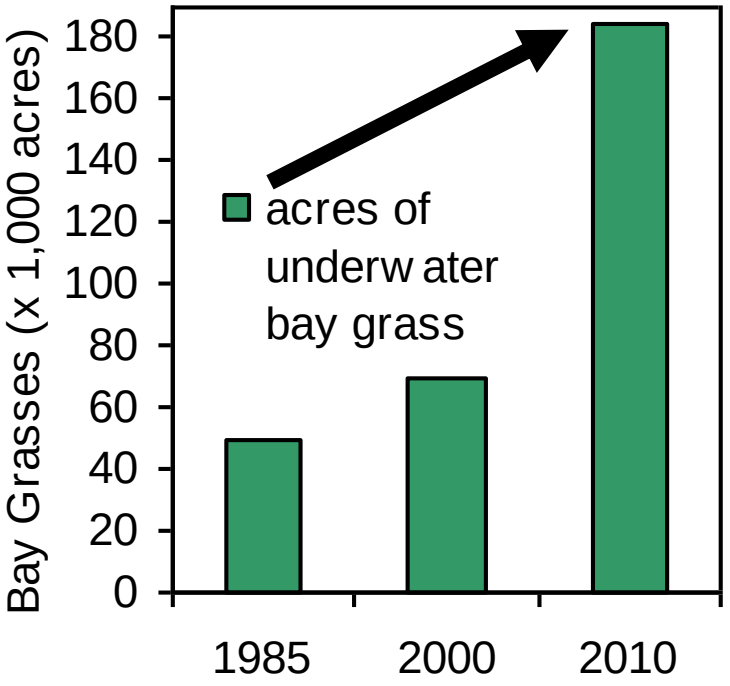
As we reduce loads...





…we increase achievement of bay grass restoration goals.

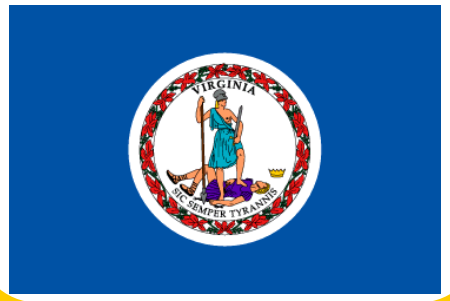




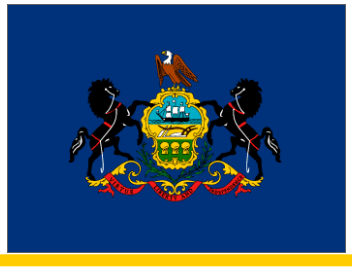
The Chesapeake Bay Program Partnership

Governor of MD

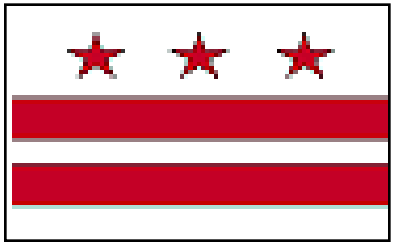
Governor of VA



Governor of PA



Mayor of DC



EPA Administrator

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Executive Council

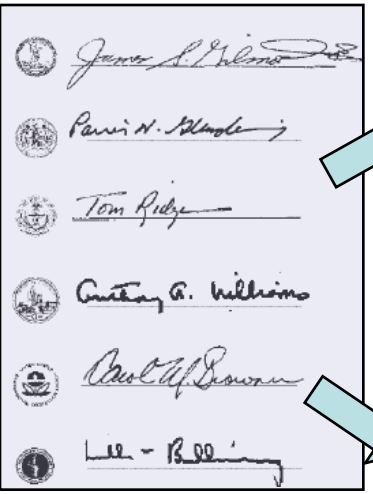
Chesapeake Bay Program

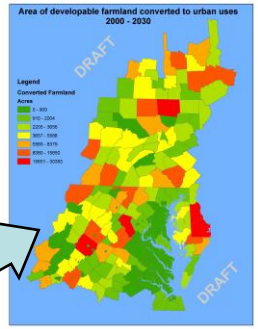
Chair of Chesapeake Bay Commission

Chesapeake Bay Program Decision Support System

Land Use Change Model

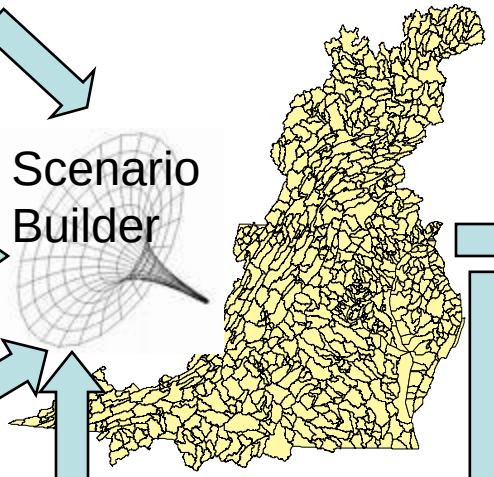
Management Actions



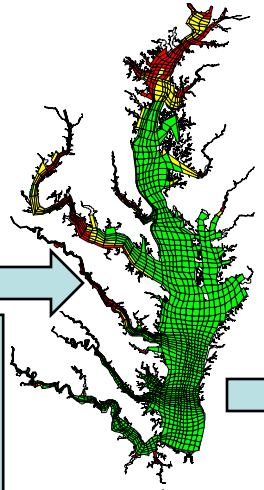


Scenario Builder

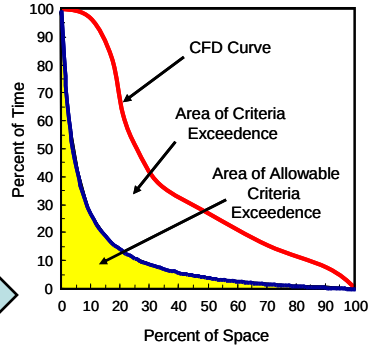
Watershed Model



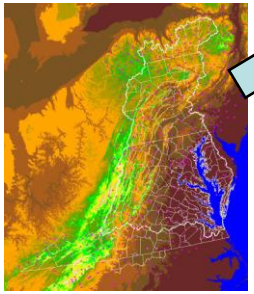
Bay Model



Criteria Assessment Procedures



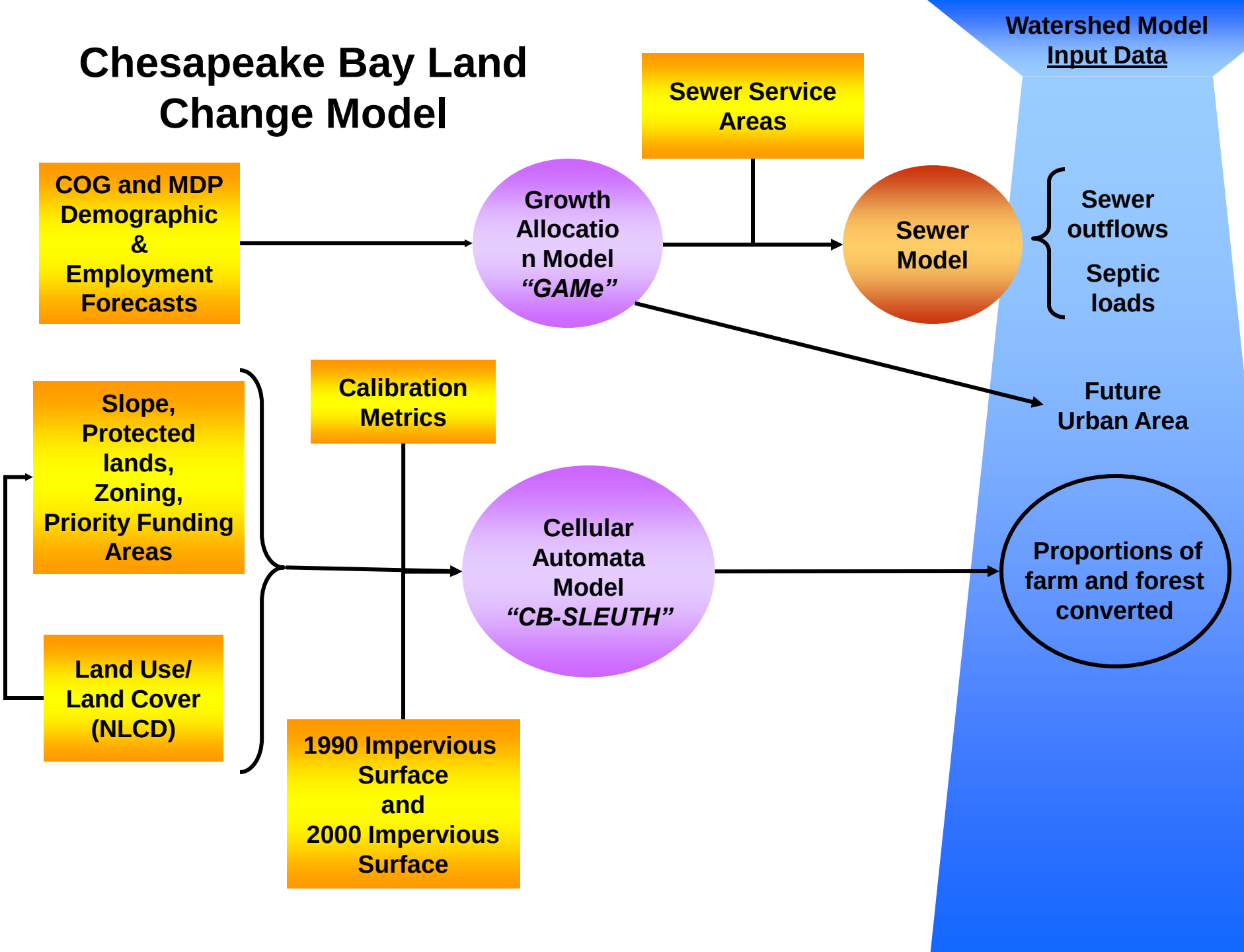
Airshed Model



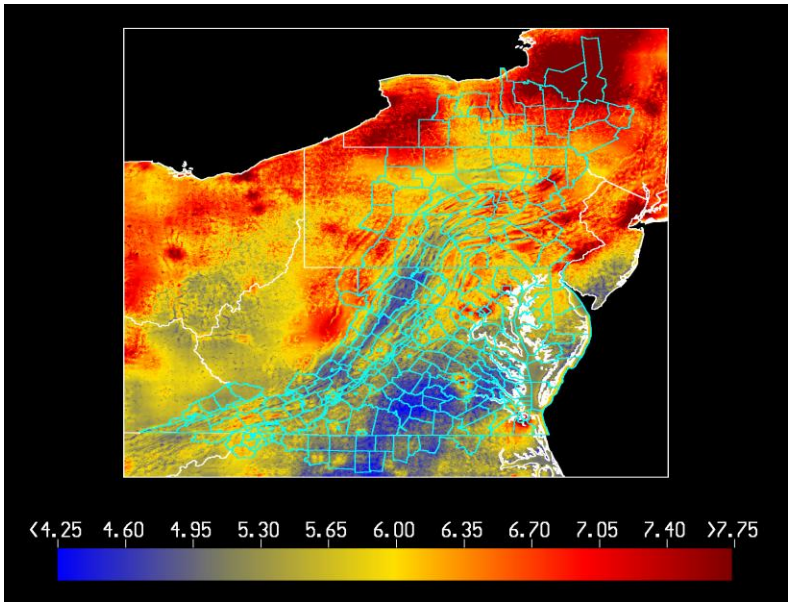
Effects

Allocations

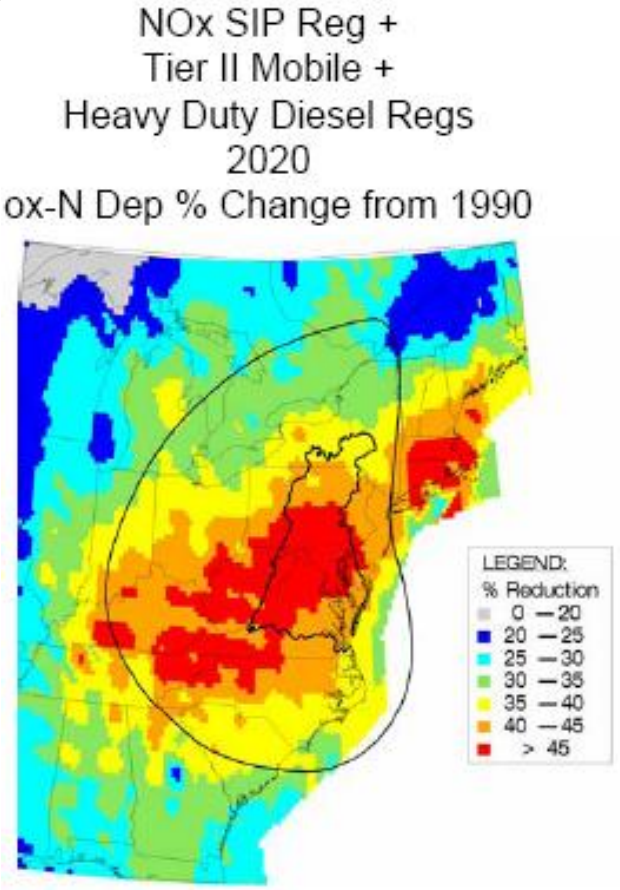
Chesapeake Bay Land Change Model



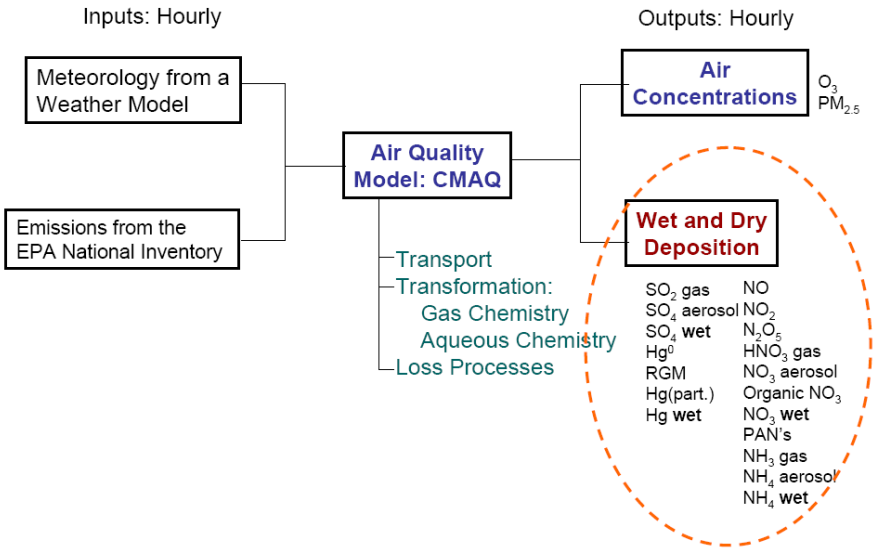
Atmospheric Deposition Estimates



Combining a regression model of wetfall deposition...



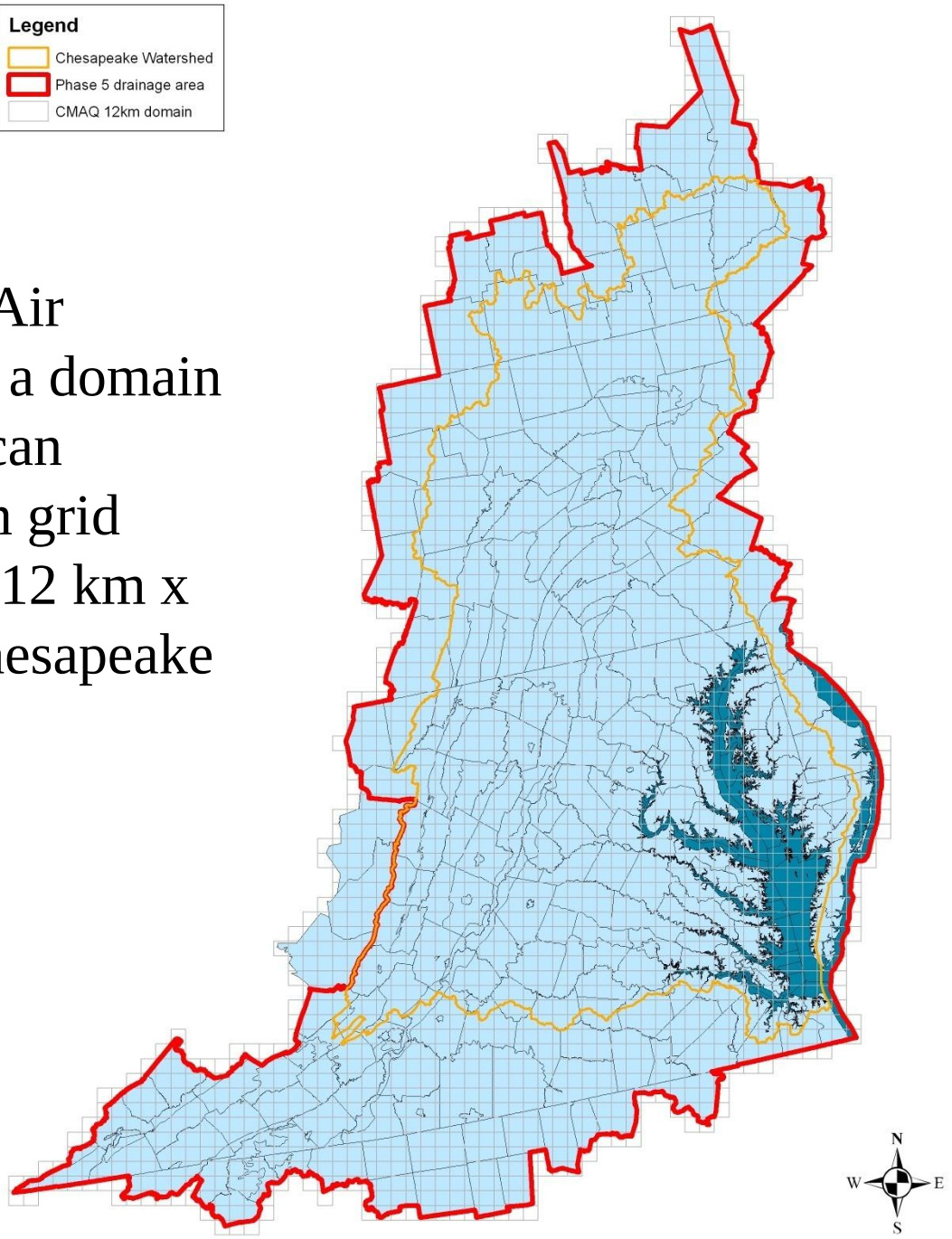
…with CMAQ estimates of dry deposition for the base…



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

CMAQ Model

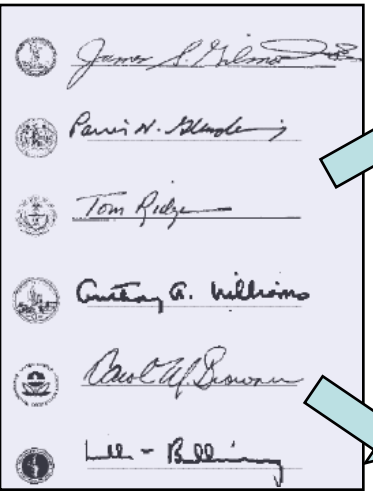
The Community Multiscale Air Quality Model (CMAQ) has a domain that covers the North American continent at a 36 km x 36 km grid scale and is nested at a finer 12 km x 12 km grid scale over the Chesapeake watershed and Bay.

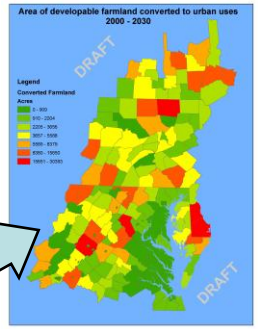


Chesapeake Bay Program Decision Support System

Land Use Change Model

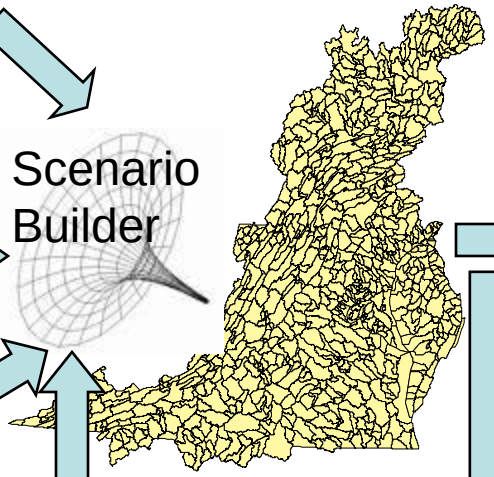
Management Actions



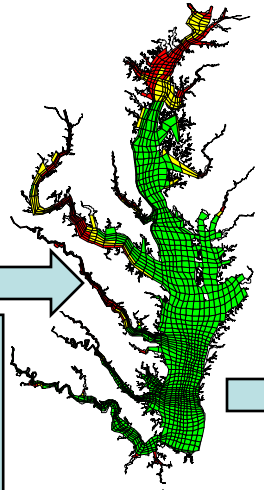


Scenario Builder

Watershed Model



Bay Model



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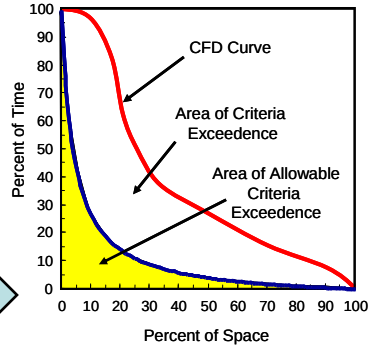
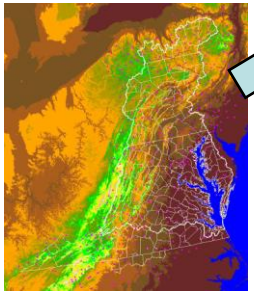


Airshed Model



Effects

Allocations

Quick Overview of Watershed Model **Scenarios**

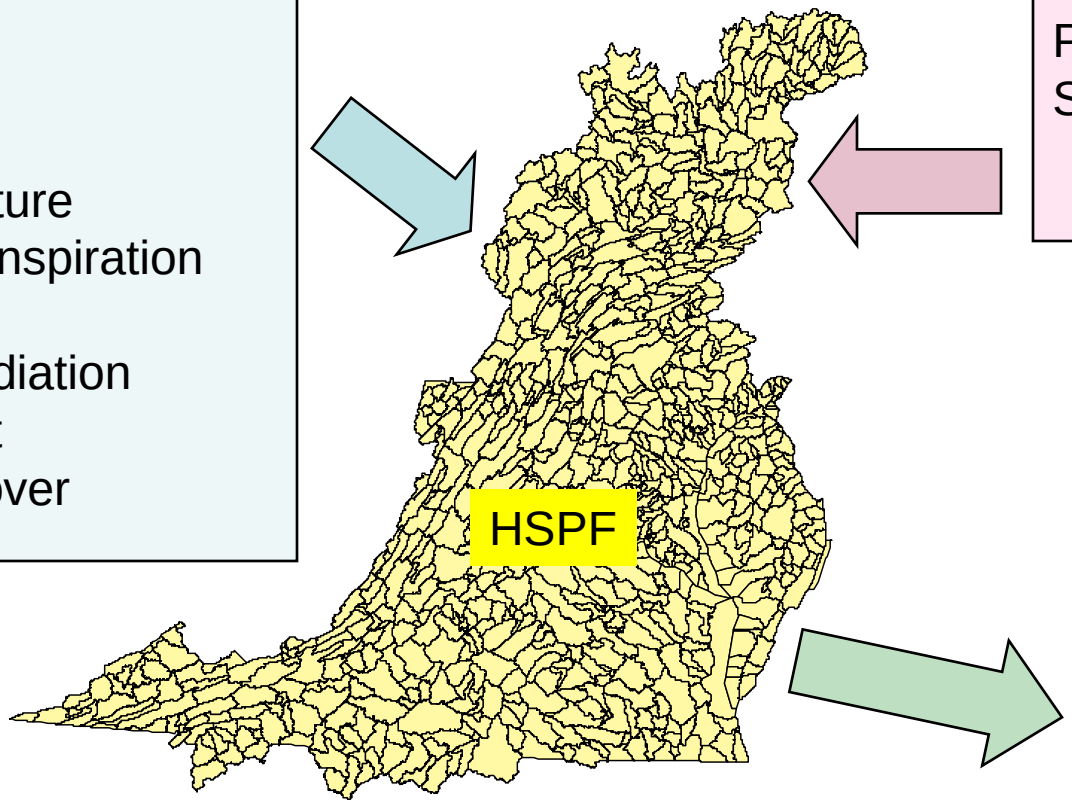
Hourly output is summed over 10 years of hydrology to compare against other management scenarios

Hourly Values:

Rainfall
Snowfall
Temperature
Evapotranspiration
Wind
Solar Radiation
Dewpoint
Cloud Cover

Snapshot:

Land Use Acreage
BMPs
Fertilizer
Manure
Atmospheric Deposition
Point Sources
Septic Loads

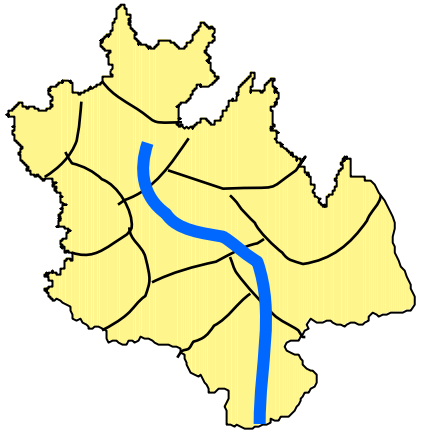


1991-2000

"Average Annual Flow-Adjusted Loads"

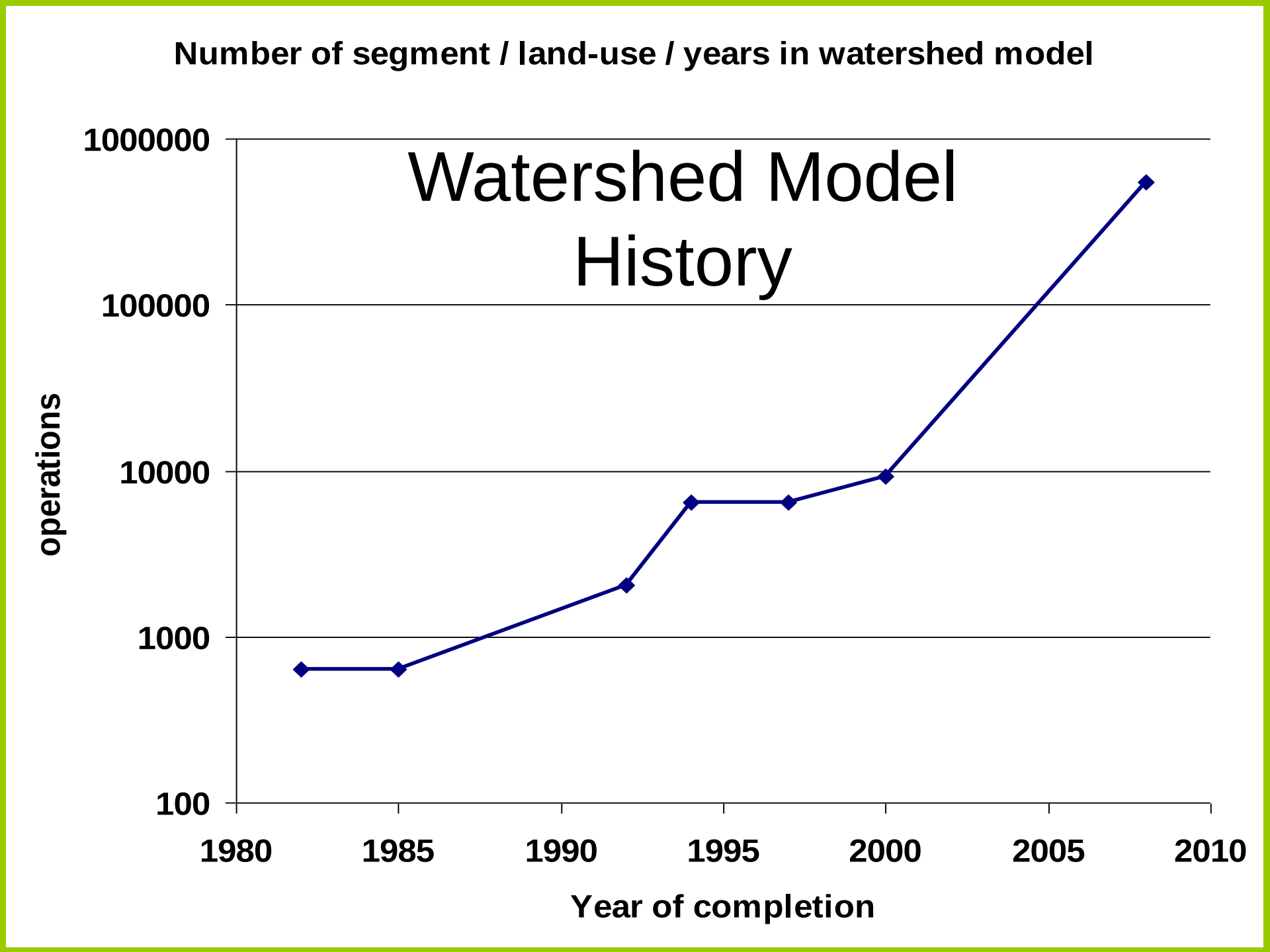
Each segment consists of separately-modeled land uses

- High Density Pervious Urban
- High Density Impervious Urban
- Low Density Pervious Urban
- Low Density Impervious Urban
- Construction
- Extractive
- Wooded
- Disturbed Forest



Plus Point Source and Septic

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


Number of segment / land-use / years in watershed model
Watershed Model History
1000000
100000
10000
1000
100
operations
1980
1985
1990
1995
2000
2005
2010
Year of completion

Watershed Model History

Year	Segs	Years	Land Uses	Purpose
1982	64	2	5	**Split point source and nonpoint source**
1985	64	2	5	**Establish 40% goal**
1992	64	4	8	**Define 40% by basins**
1994	89	8	9	**Simulate nutrient cycle in more detail**
1997	89	8	9	**Re-evaluate and redefine 40% by major basin**
2000	94	11	9	**Set new goals and distribute by major subbasin**
2008	1000	22	25	**TMDL**

Management questions and model have been both increasing exponentially in complexity.

Co-Developers of the Chesapeake Bay Program's Phase 5 Watershed Model

Chesapeake Bay Program

Developers

EPA

UMCES

USGS

NRCS

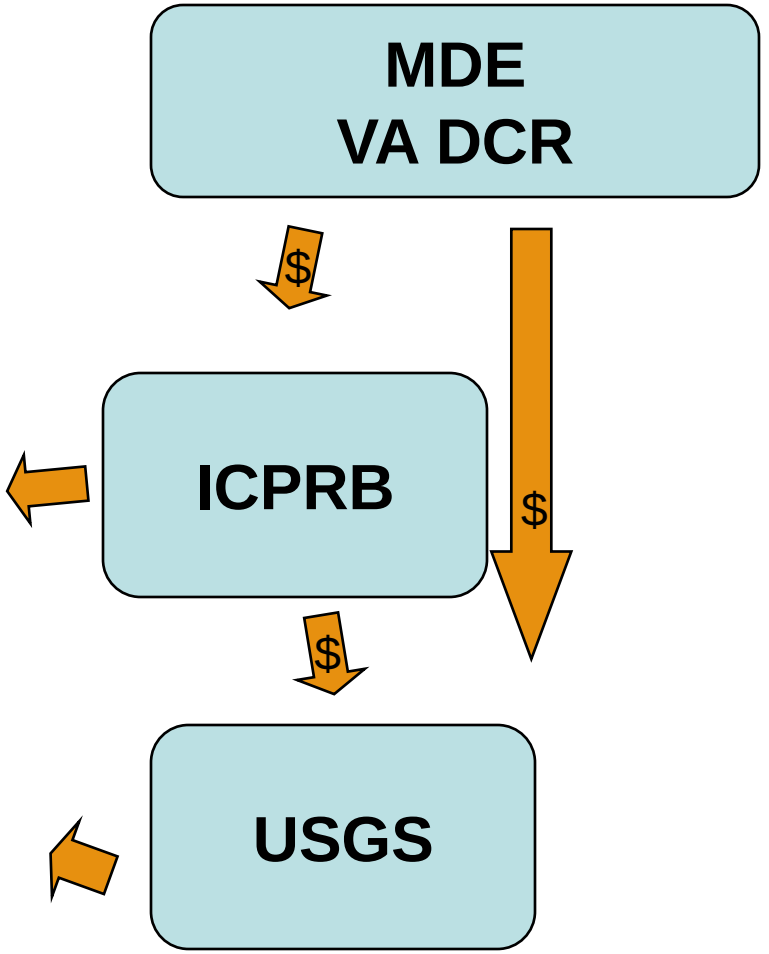
CRC

VPISU

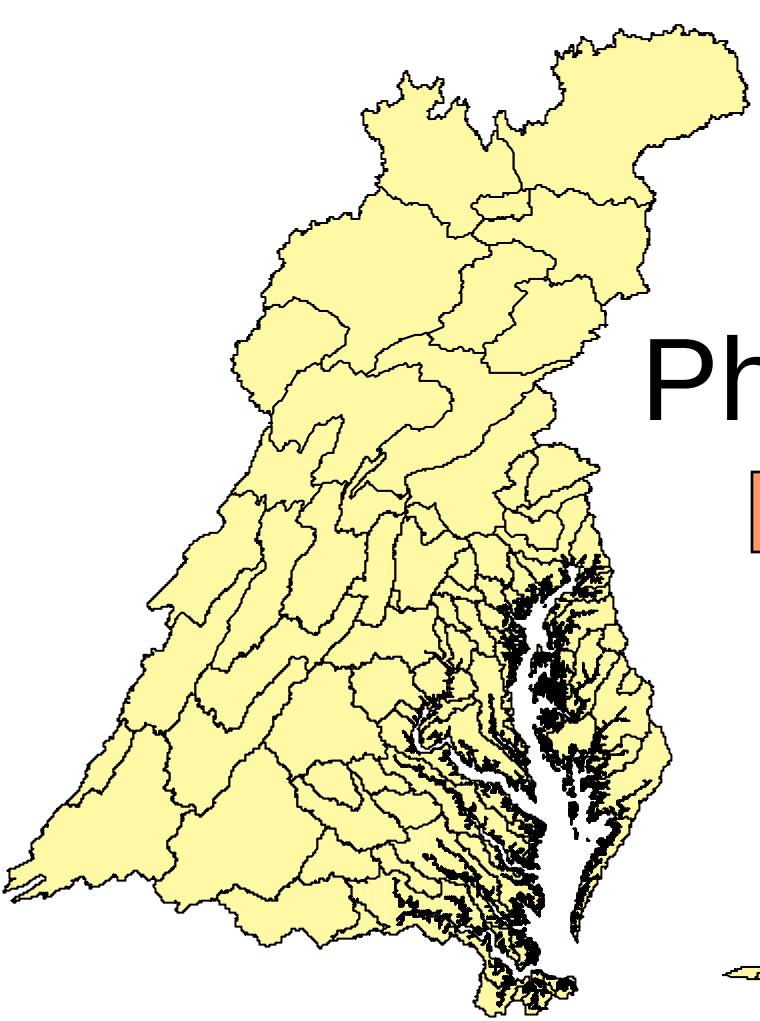
Advisors and data suppliers

NY, PA, MD, DE, VA, WV, DC

STAC

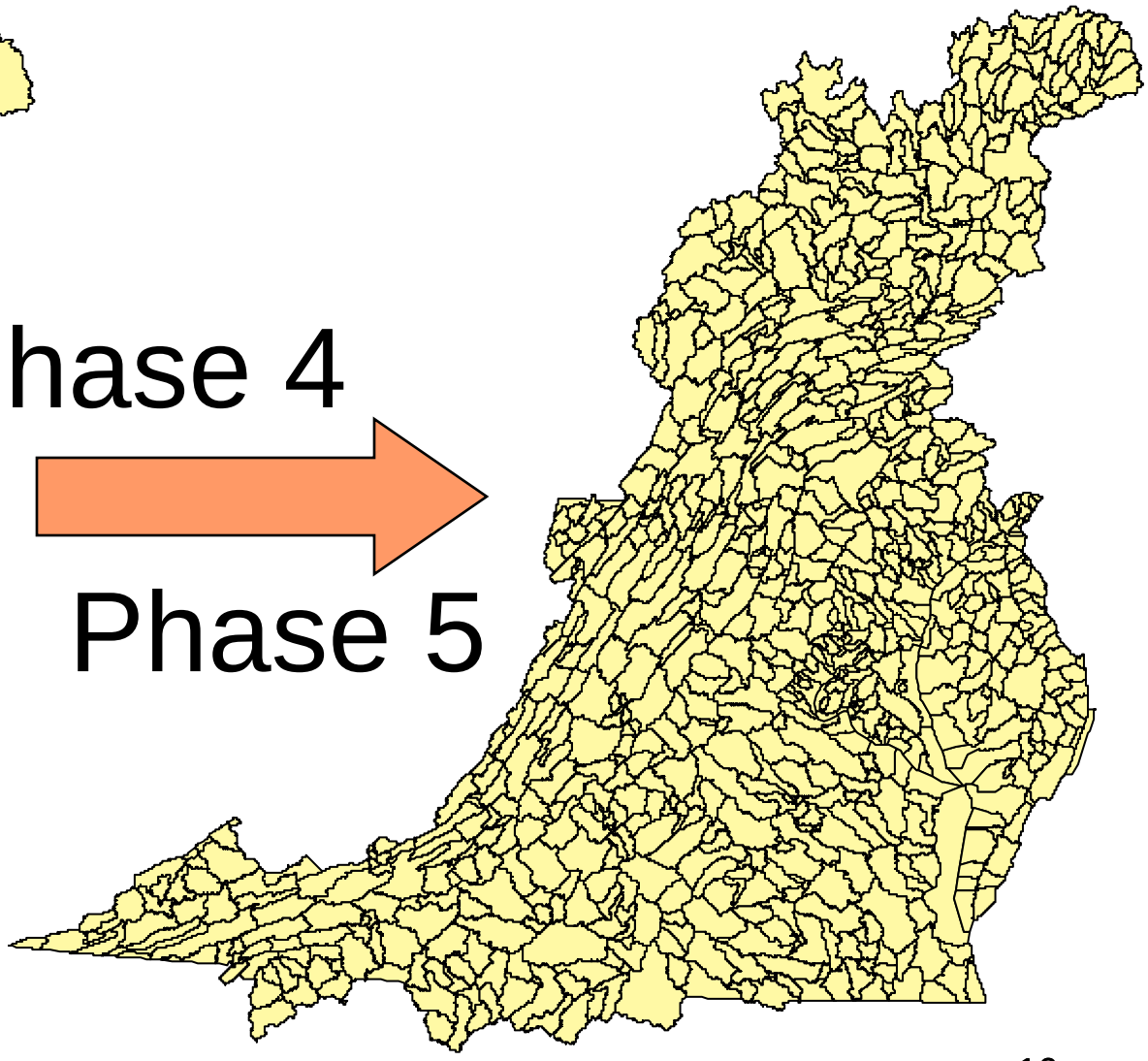


Finer Segmentation



Phase 4

Phase 5

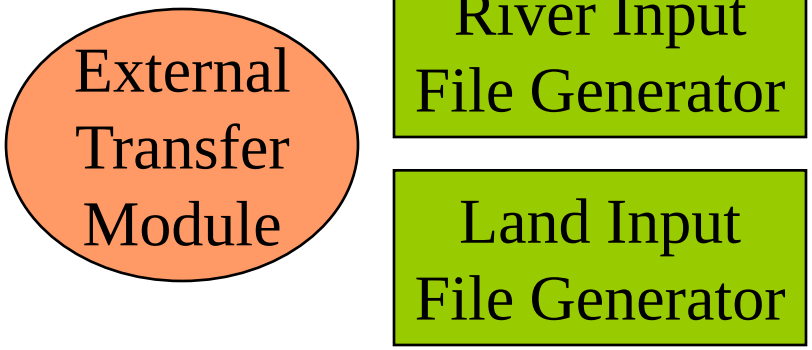


Functionality

- Normal HSPF editing modes
  - hand-edited ASCII files
  - windows-based point-and-click database
  - GIS-based population
- CBP phase 5 software
  - Automated file creation and modification in a linux scripting environment

Overall software system functionality

The software system devised for phase 5 has other advantages over a traditional HSPF application:



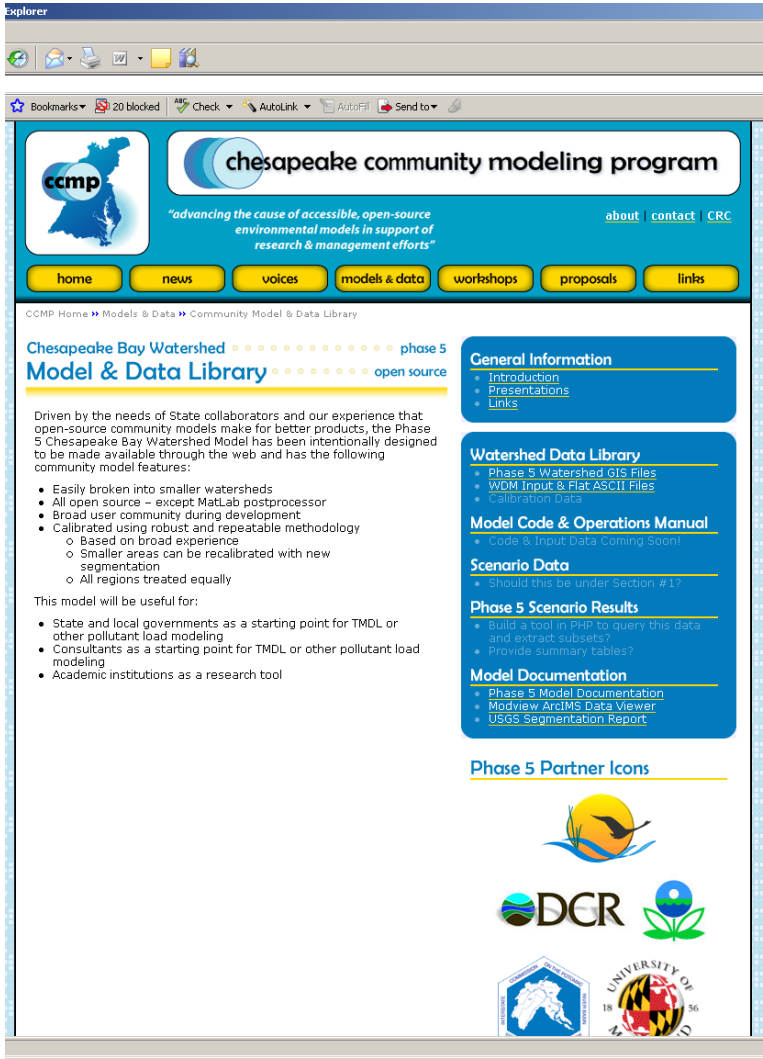
- Easily allows large-scale parameter adjustments during calibration
- Parallel computing operations convenient
- Easy to add new land use types
- Easily integrated into outside databases for scenarios
- Relatively Easy to add new WQ constituents (bacteria)

Functionality

Transferability

Open-Source Model

- Entire model available on web
  - Input data
  - Modified HSPF
  - Phase 5 system
- Already in Use
  - Community model in Climate Change Study
  - Community model at ICPRB
  - Phase 5 output in Potomac PCB TMDL
  - Phase 5 information in MDE TMDLs
  - Phase 5 information in USGS Watershed Study
  - USGS Shenandoah Models
  - Phase 5 output in Academic studies
  - UNC / Baltimore LTER study



Improved Input Data

Better, extended, and finer scale data sets

Precipitation
Temperature
Evapotranspiration
Wind
Solar Radiation
Dewpoint
Cloud Cover

Land Use Acreage
BMPs
Fertilizer
Manure
Atmospheric Deposition
Point Sources
Septic Loads

Simulation period is 1984-2005:
Two decades of meteorology
and watershed management data

Daily output compared
To observations

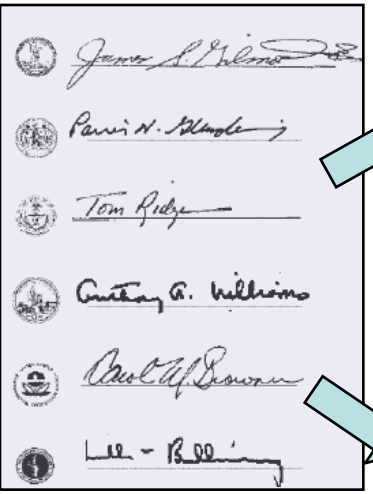
Automated Calibration

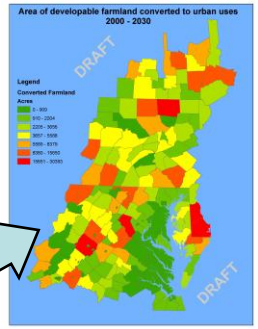
- Ensures even treatment across jurisdictions
- Fully documented calibration strategy
- Repeatable
- Makes Calibration Feasible
- Enables uncertainty analysis

Chesapeake Bay Program Decision Support System

Land Use Change Model

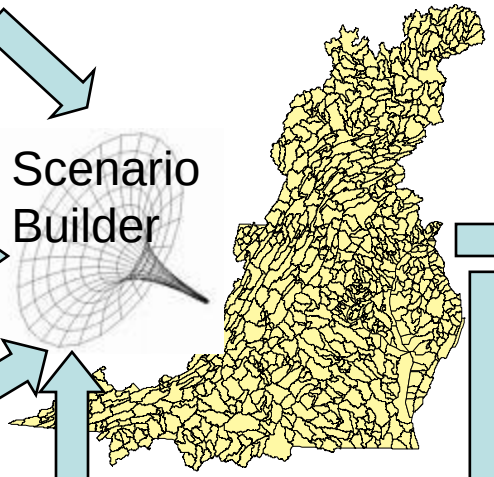
Management Actions



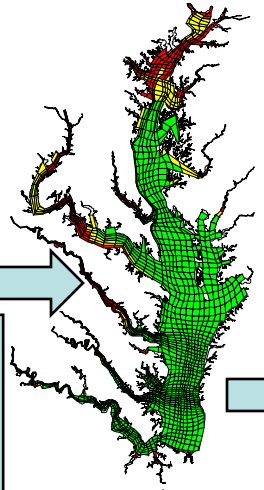


Scenario Builder

Watershed Model



Bay Model



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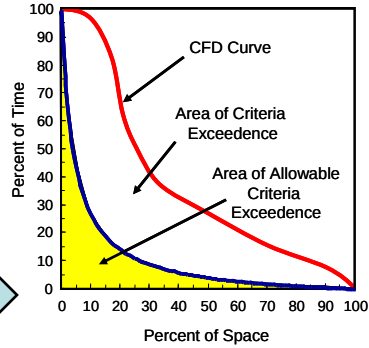

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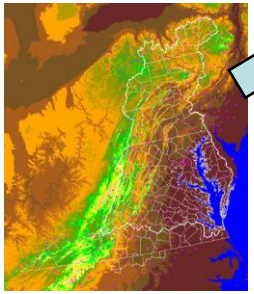
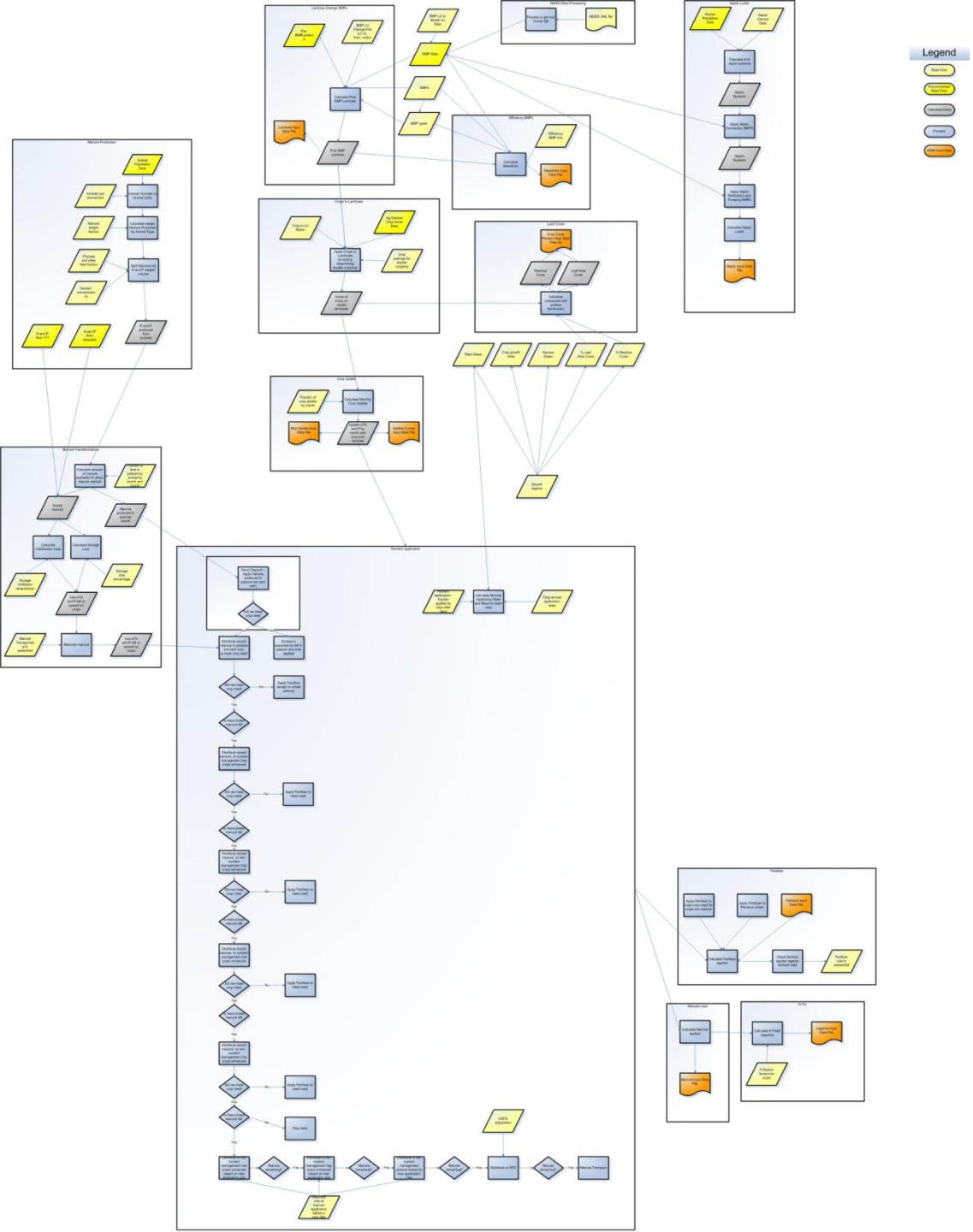


Effects

Allocations



Scenario Builder

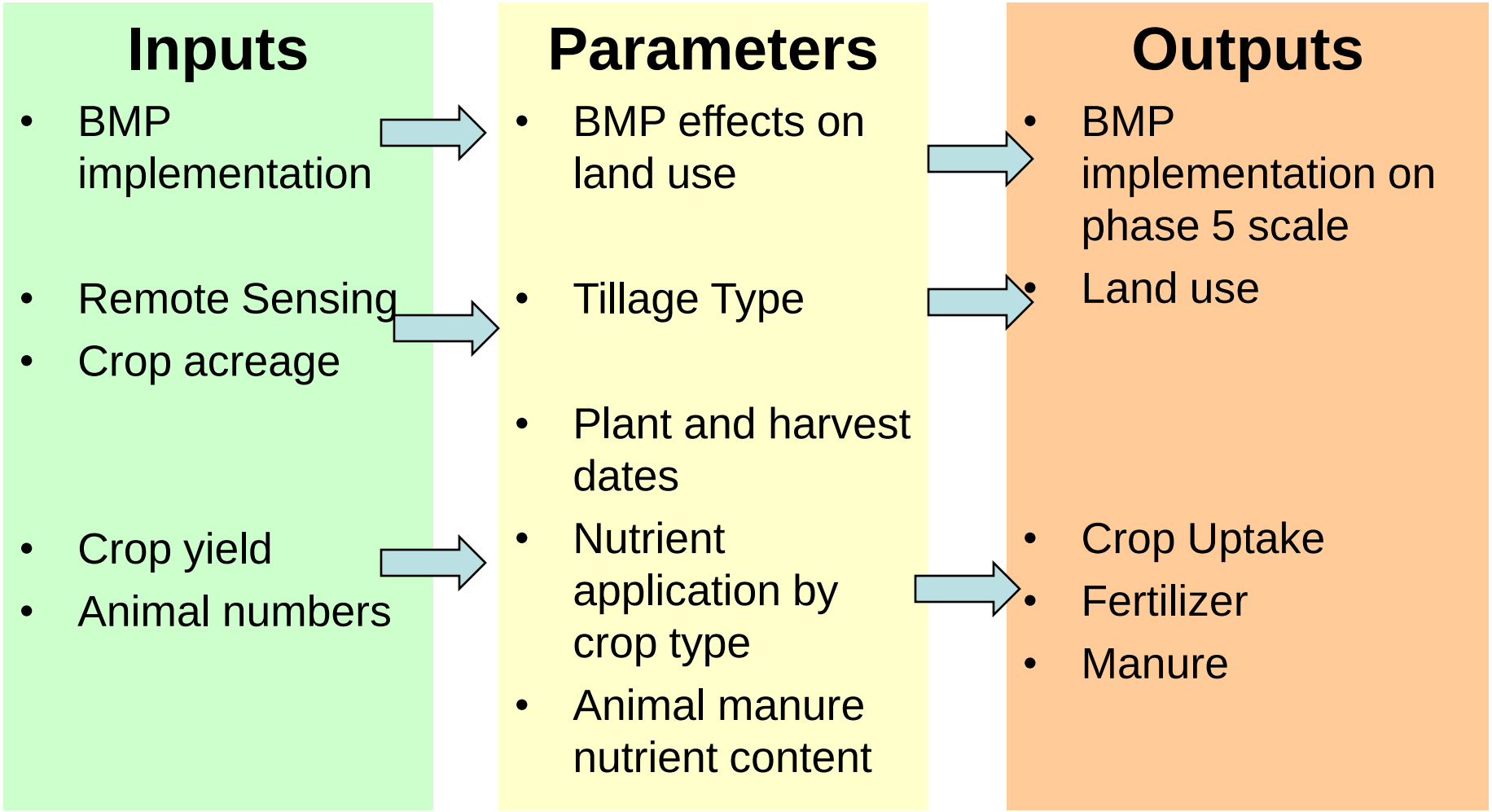
Snapshot:

Land Use Acreage
BMPs
Fertilizer
Manure
Atmospheric Deposition
Point Sources
Septic Loads

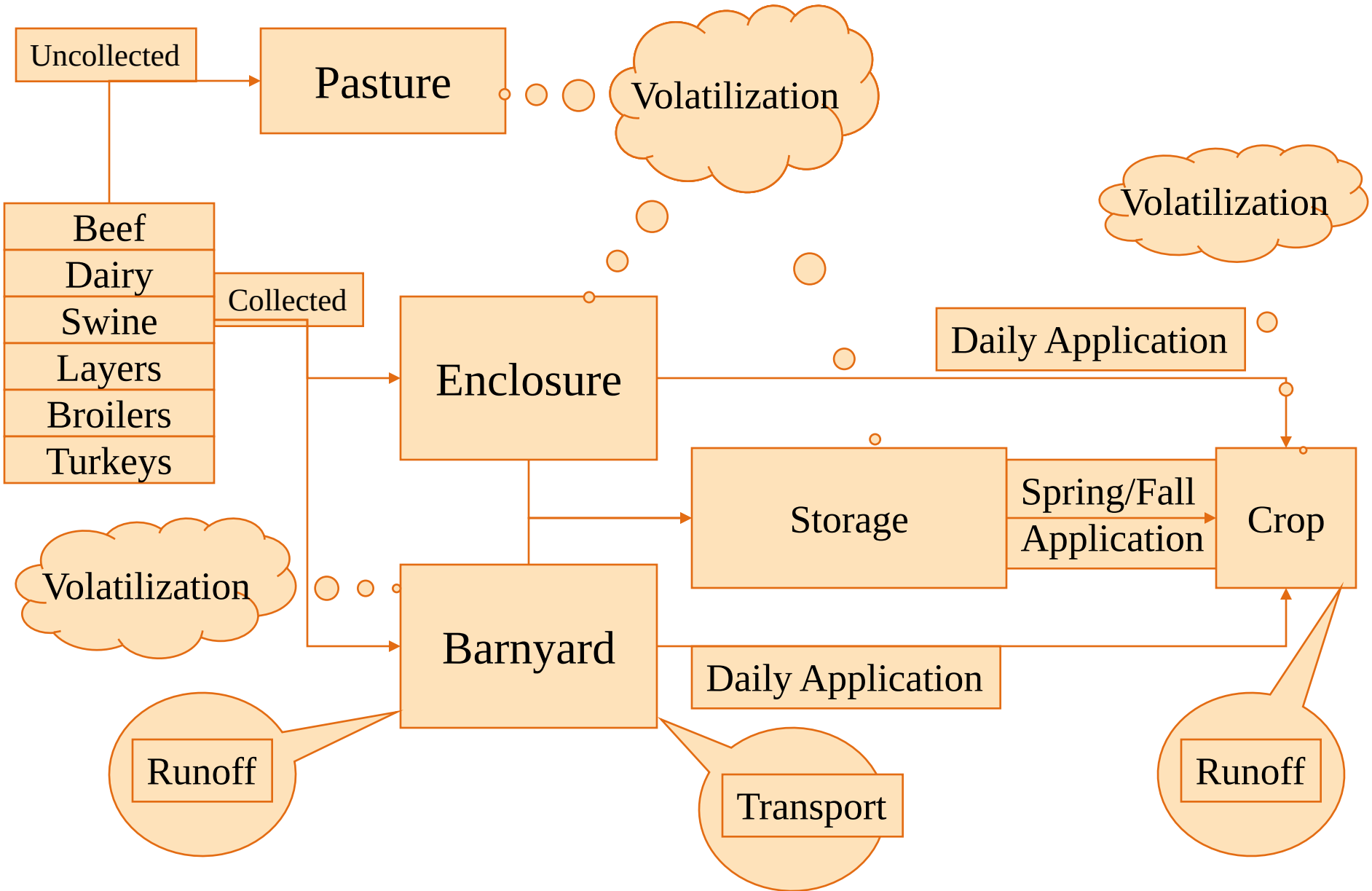
Number of Scenarios

- Phase 1 – 0
- Phase 2 – fewer than 10
- Phase 3 – never used
- Phase 4.1 – 37
- Phase 4.3 – 400-500
- Phase 5 – about 30 pre-finalization
  - Lauren Hay plans to run 600
  - 1000s? For management

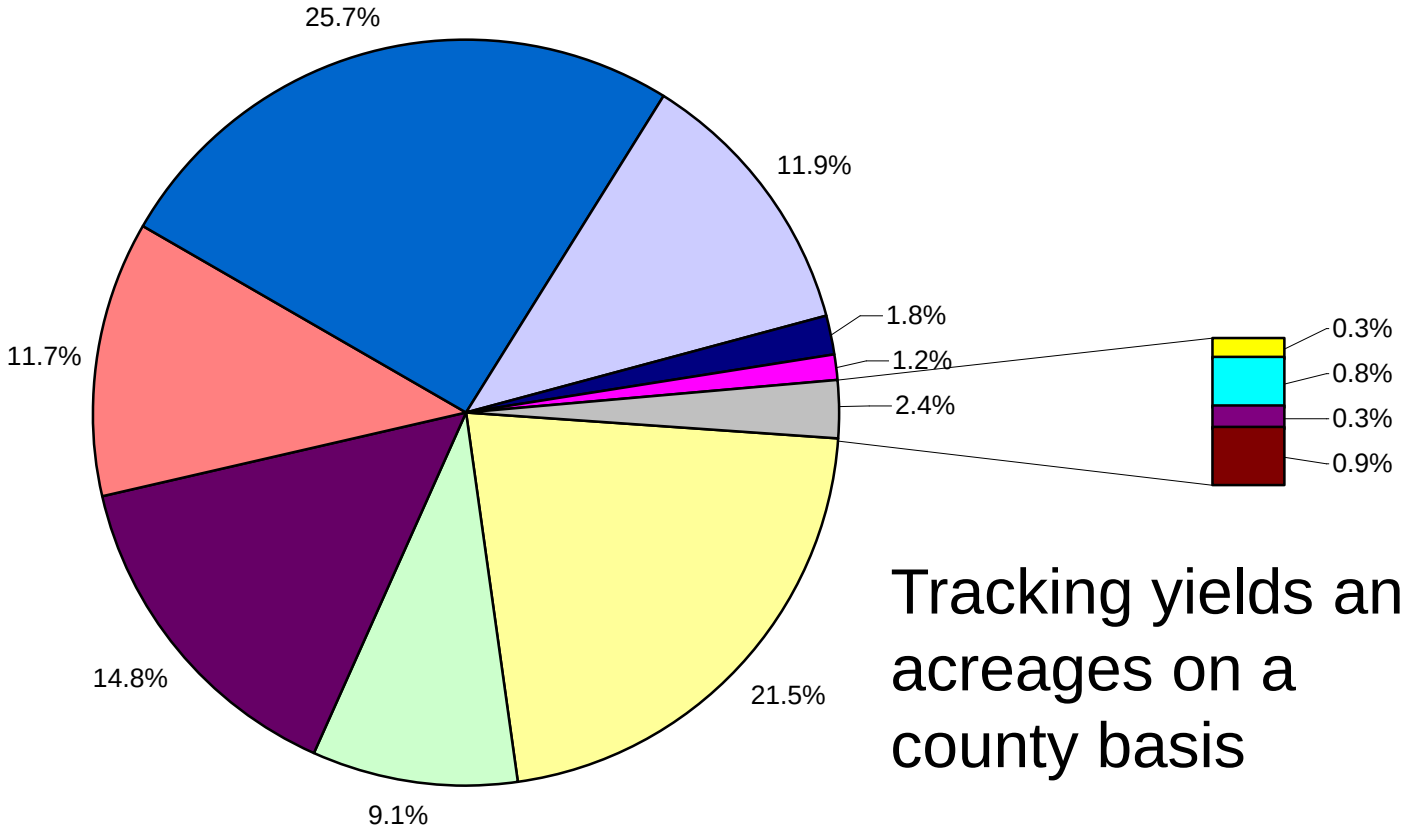
Sample Input and Output



Simplified Manure Data Model



Watershed Wide Crops by Acreage



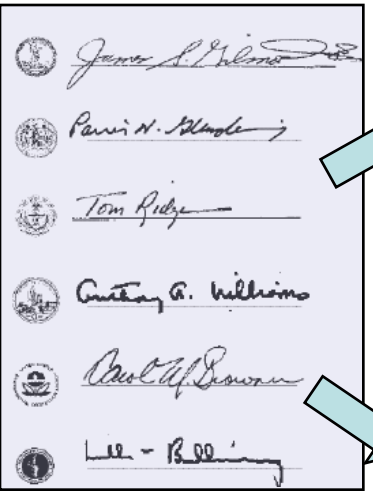
Tracking yields and acreages on a county basis

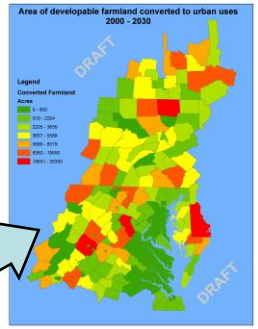
Approximately 100 crop types and 10 growing regions with different parameters for each

Chesapeake Bay Program Decision Support System

Land Use Change Model

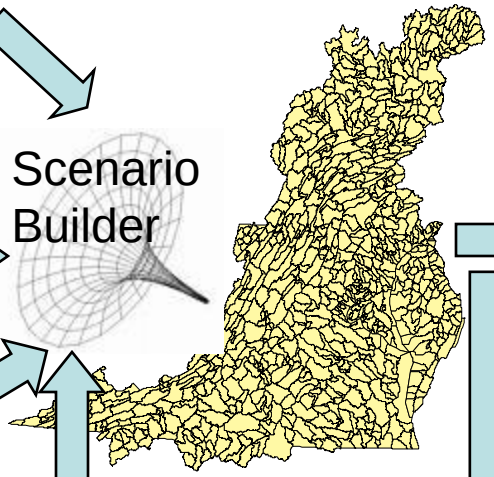
Management Actions



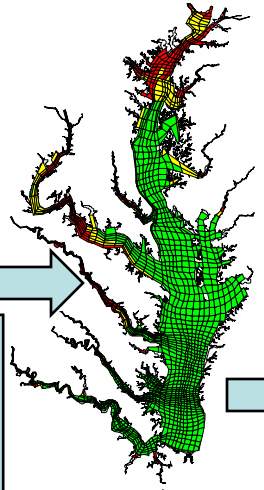


Scenario Builder

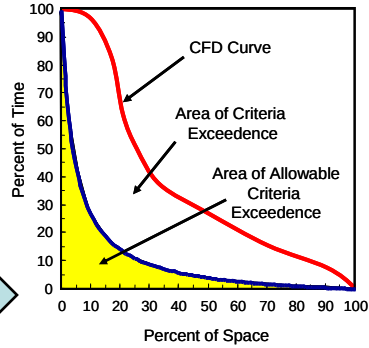
Watershed Model



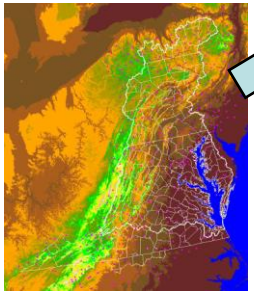
Bay Model



Criteria Assessment Procedures

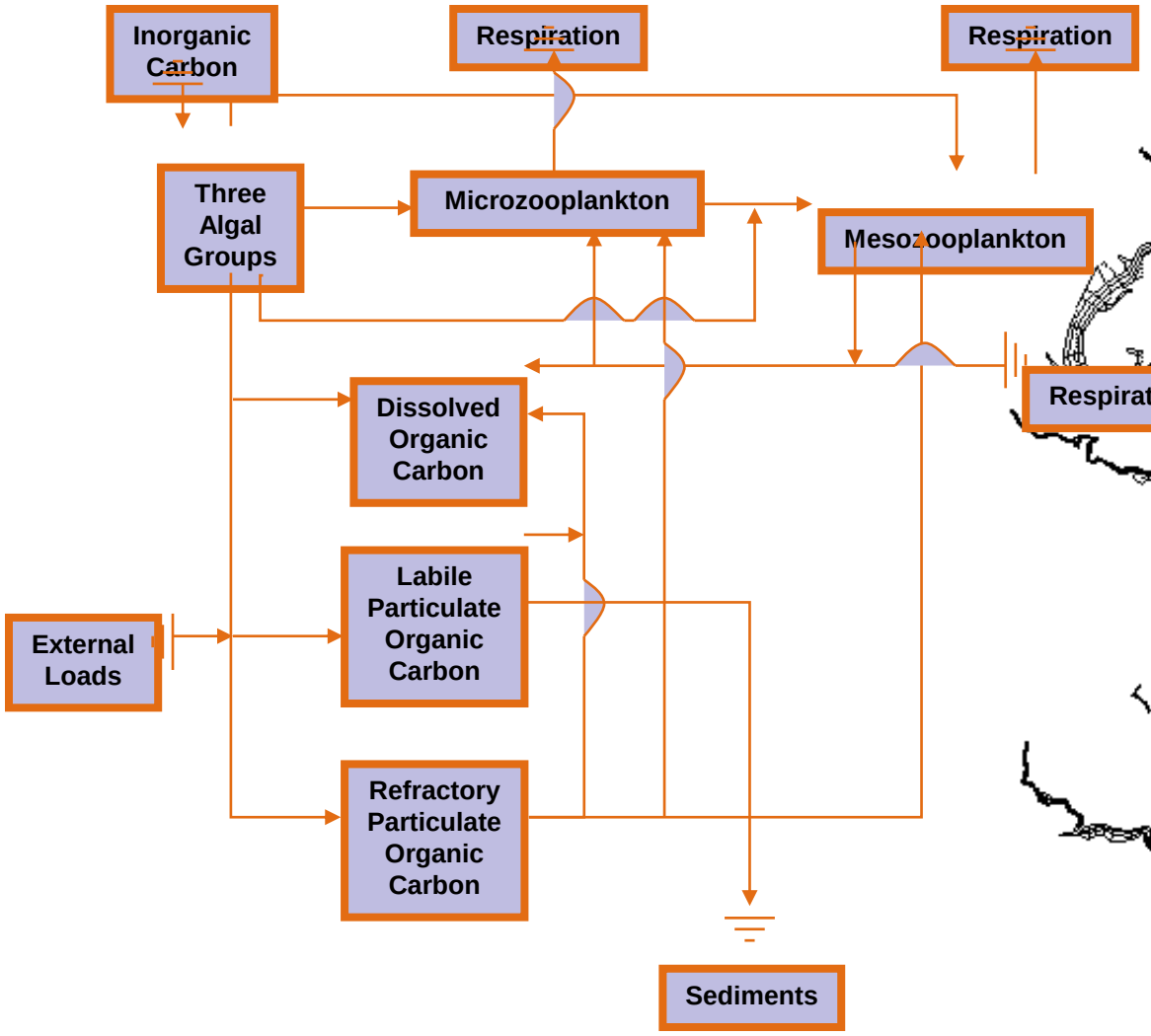


Airshed Model

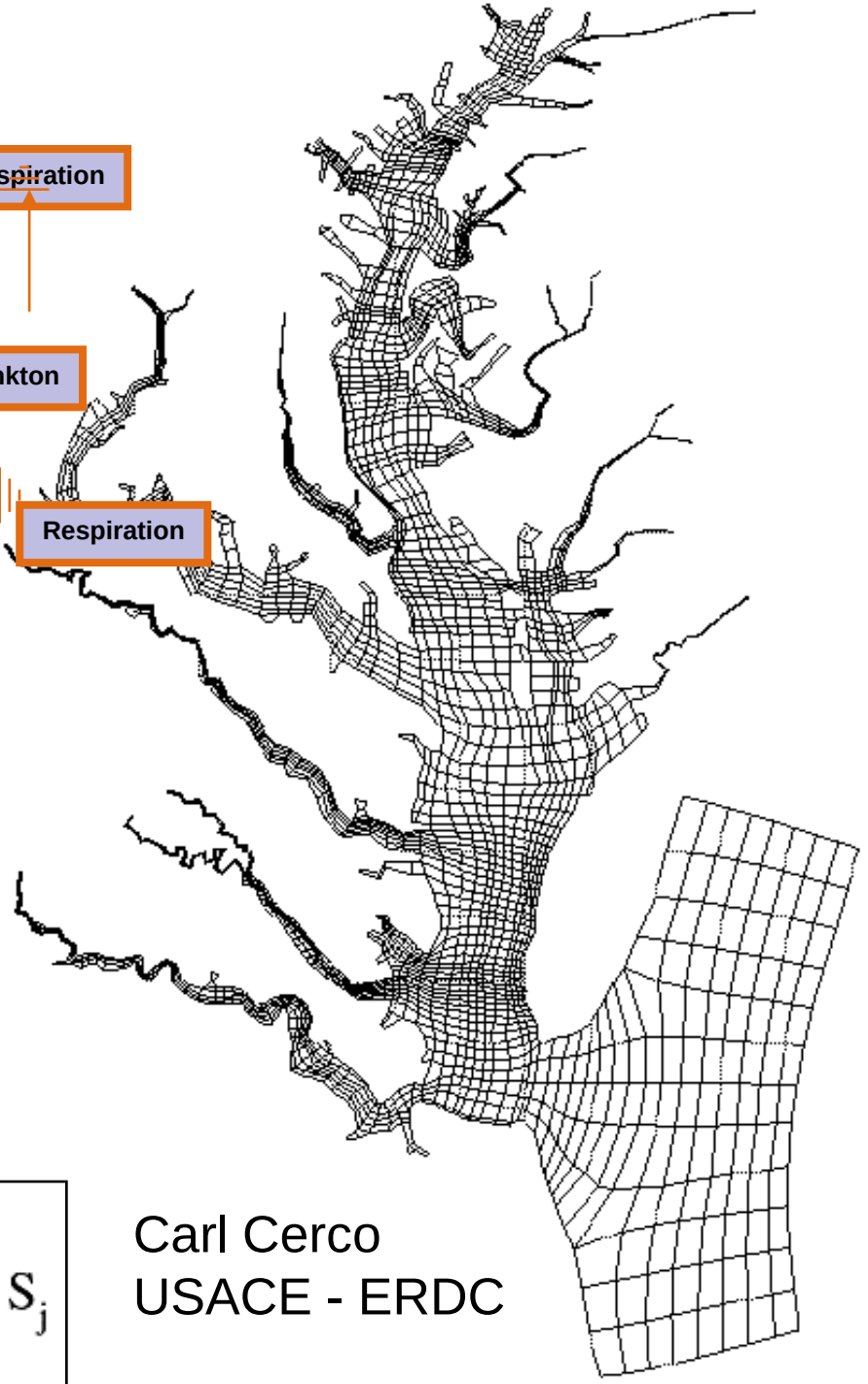


Effects

Allocations



$$\frac{\delta V_j C_j}{\delta t} = \sum_{k=1}^{n} Q_k C_k + \sum_{k=1}^{n} A_k D_k \frac{\delta C}{\delta x_k} + \sum S_j$$

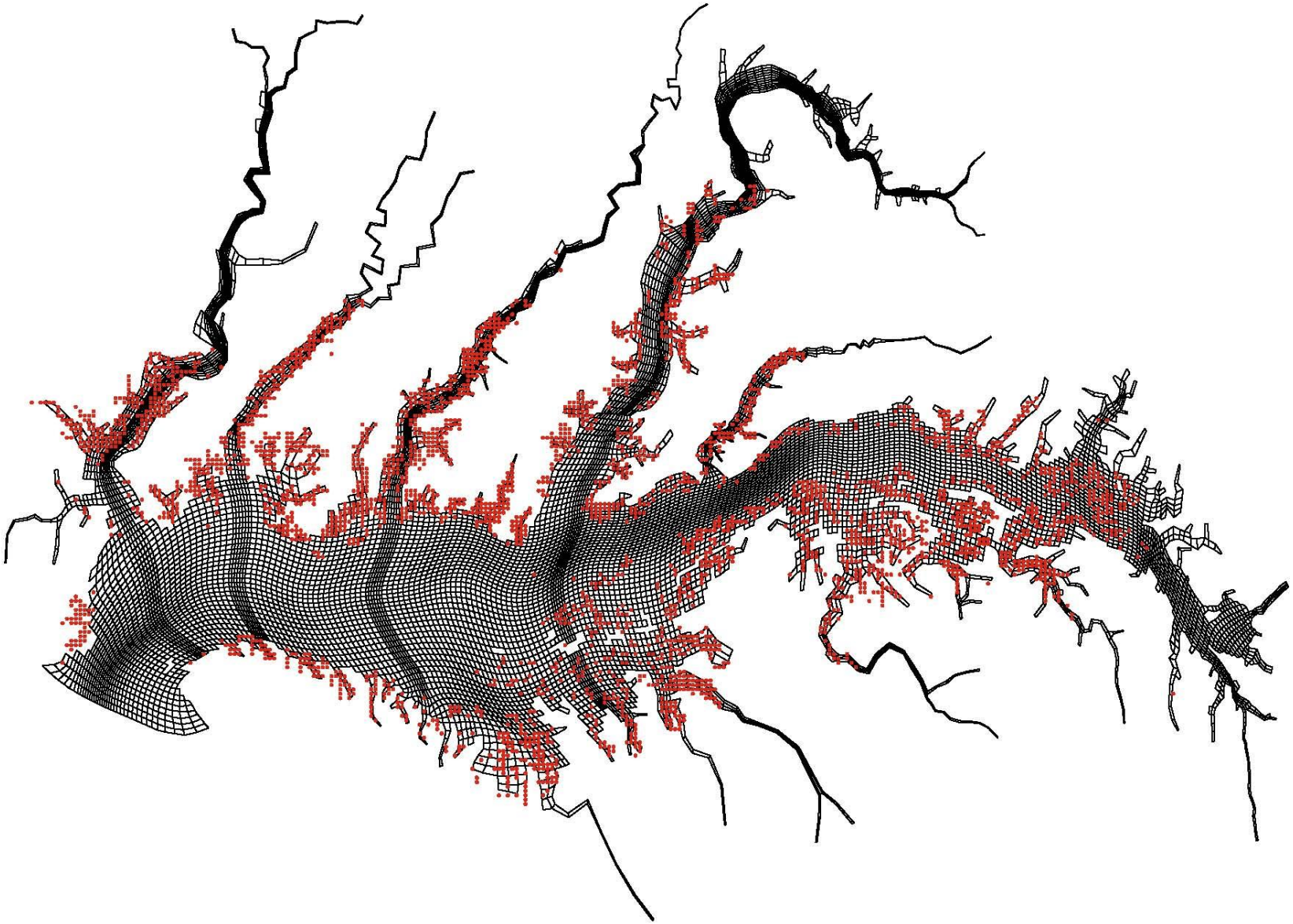


Carl Cerco
USACE - ERDC

Bay WQ/ST Model Includes:

- Circulation/hydrodynamics
- Water Quality: DO, clarity, N, P, sediment
- Algae
- Zooplankton
- SAV
- Oysters
- Benthos
- Menhaden (coming soon!)

8400 Oyster Bars

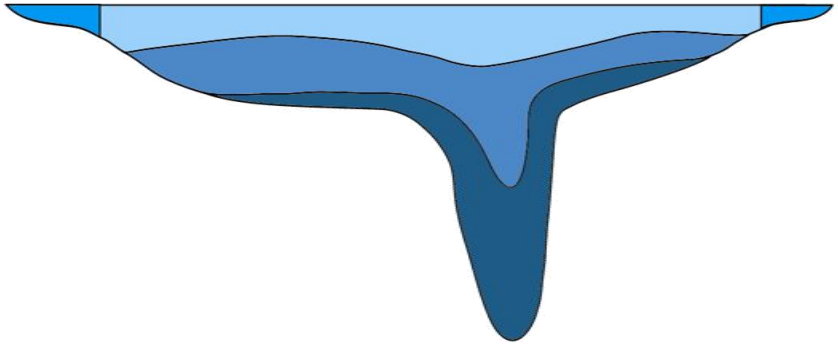


Refined Designated Uses for Chesapeake Bay and Tidal Tributary Waters

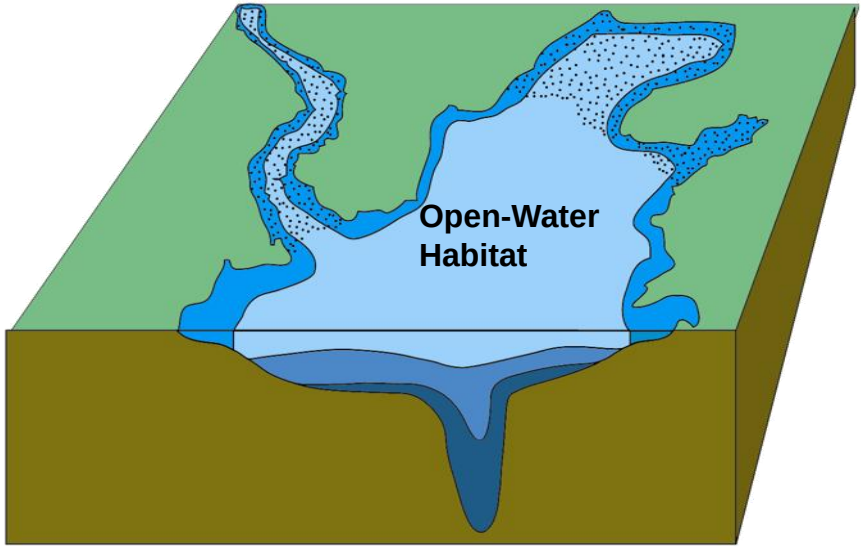
Divide the Bay into Habitats

Determine Appropriate Water Quality Based on Living Resources within that Habitat

A. Cross Section of Chesapeake Bay or Tidal Tributary



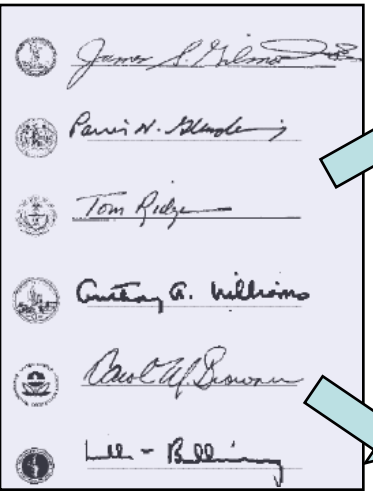
B. Oblique View of the “Chesapeake Bay” and its Tidal Tributaries

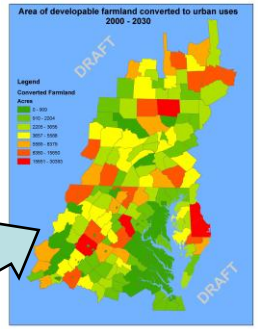


CBP DSS
Use in Management

Land Use
Change Model

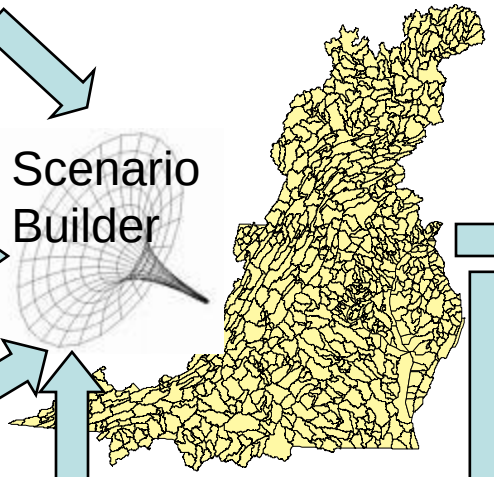
Management
Actions



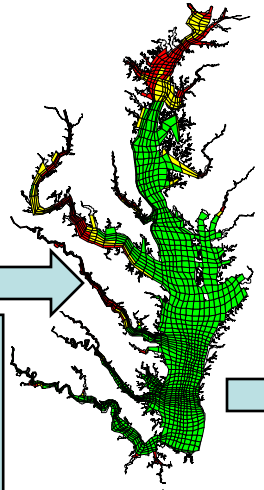


Scenario
Builder

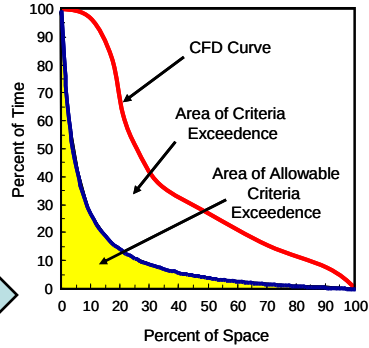
Watershed
Model

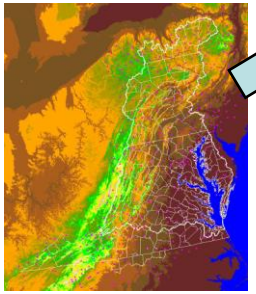


Bay
Model



Criteria
Assessment
Procedures





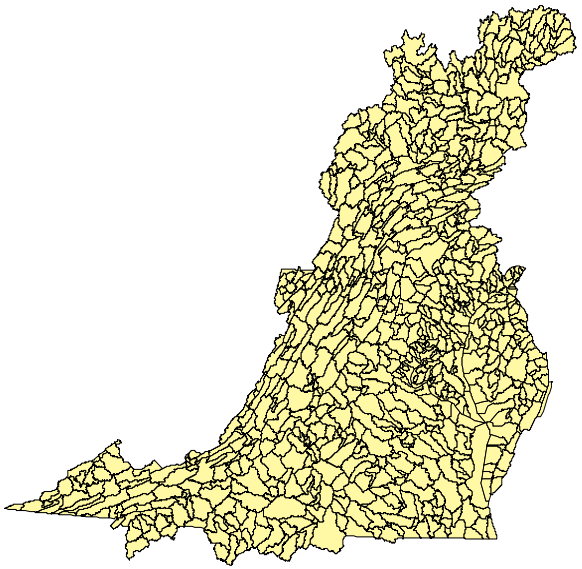
Airshed
Model

Effects

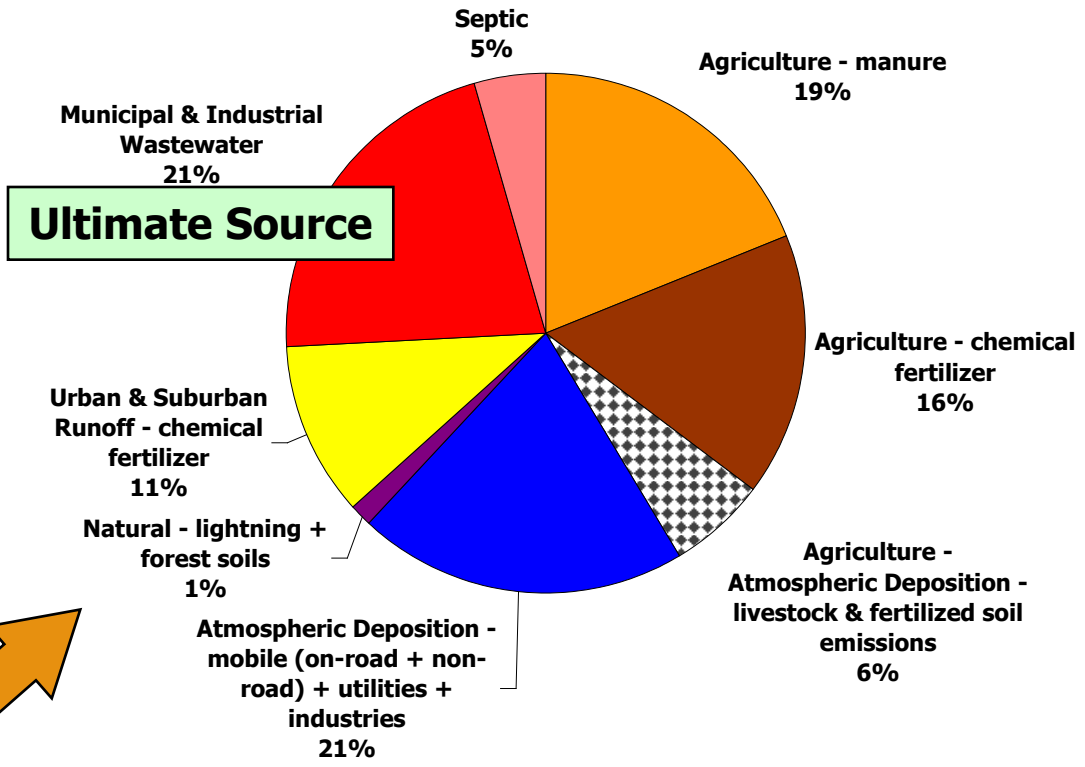
Allocations

WSM Uses:

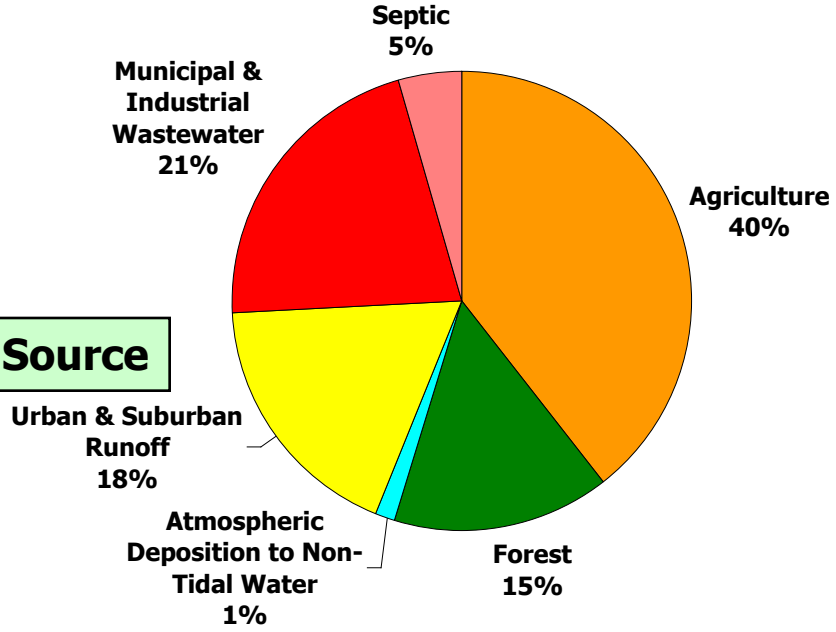
Divide Load into contributing areas and sources



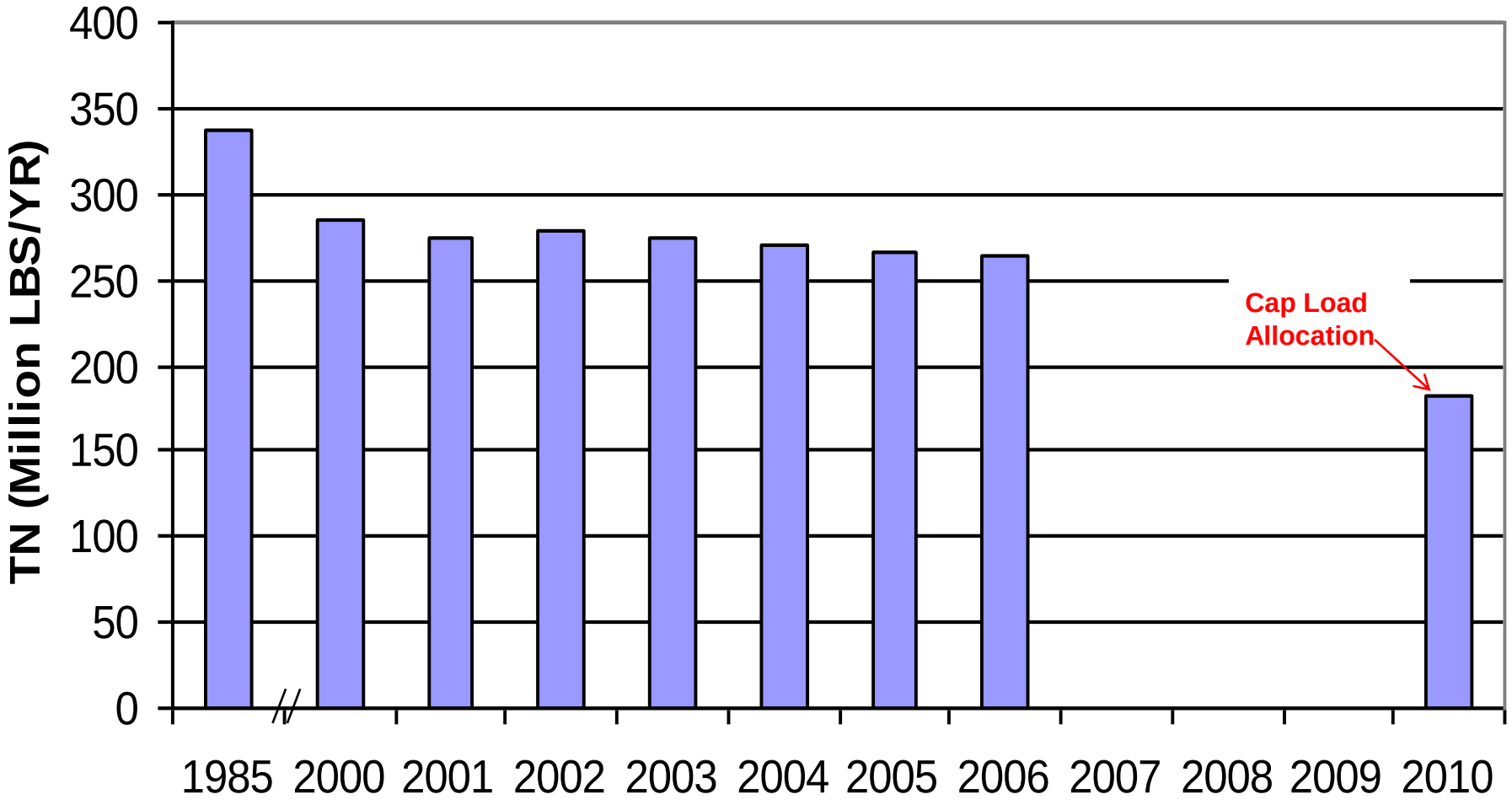
Ultimate Source



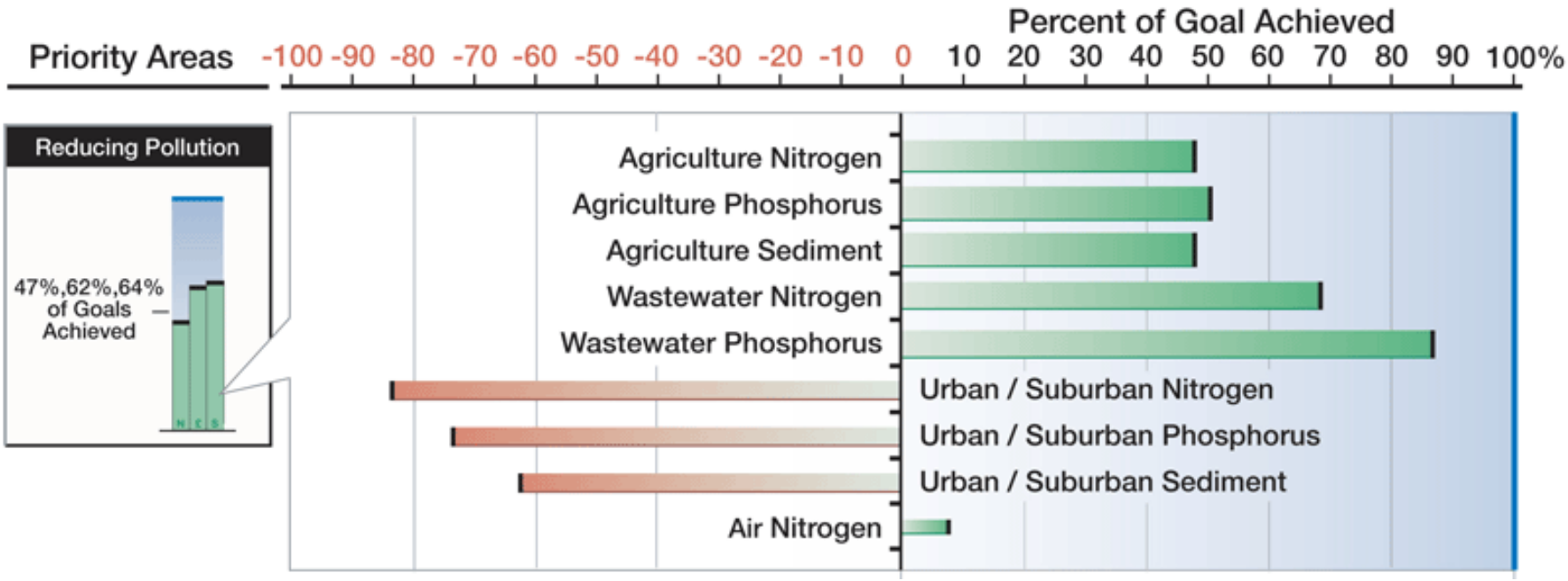
Land Use Source



WSM Uses:
Track Implementation Progress

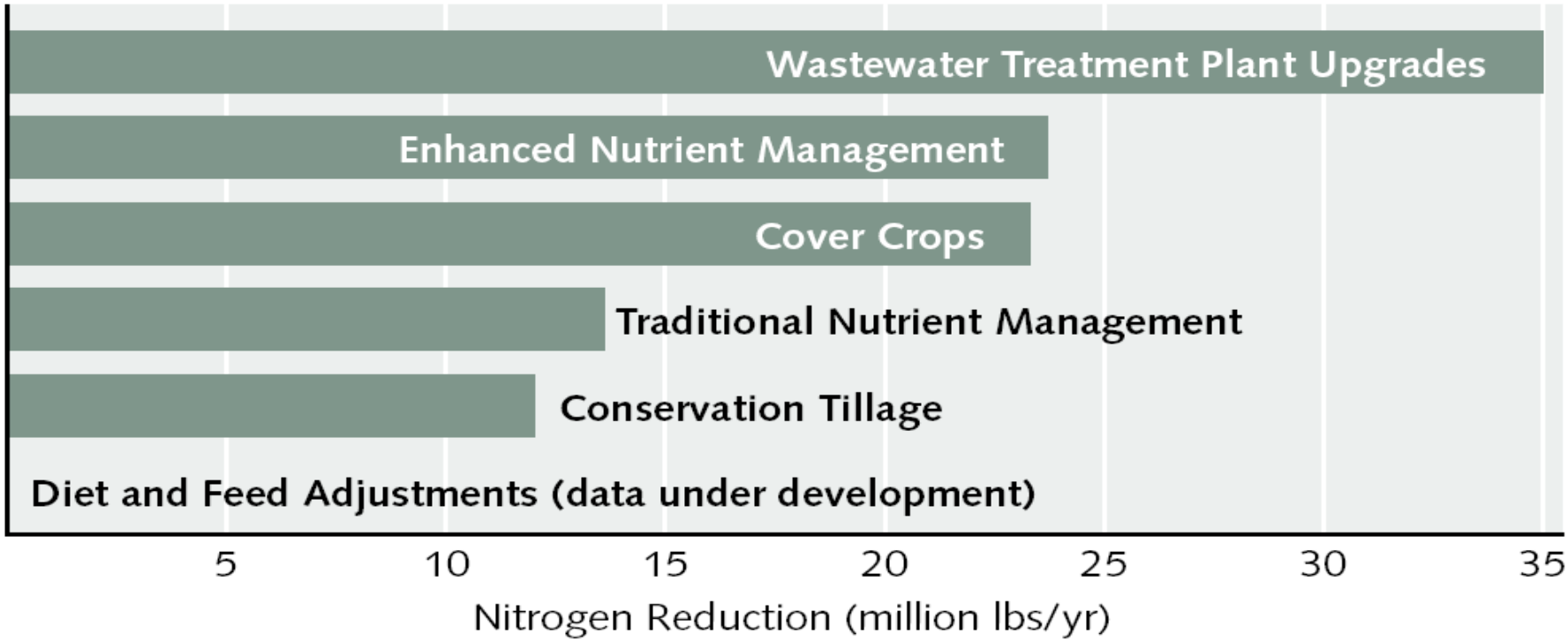


WSM Uses:
Track Implementation Progress



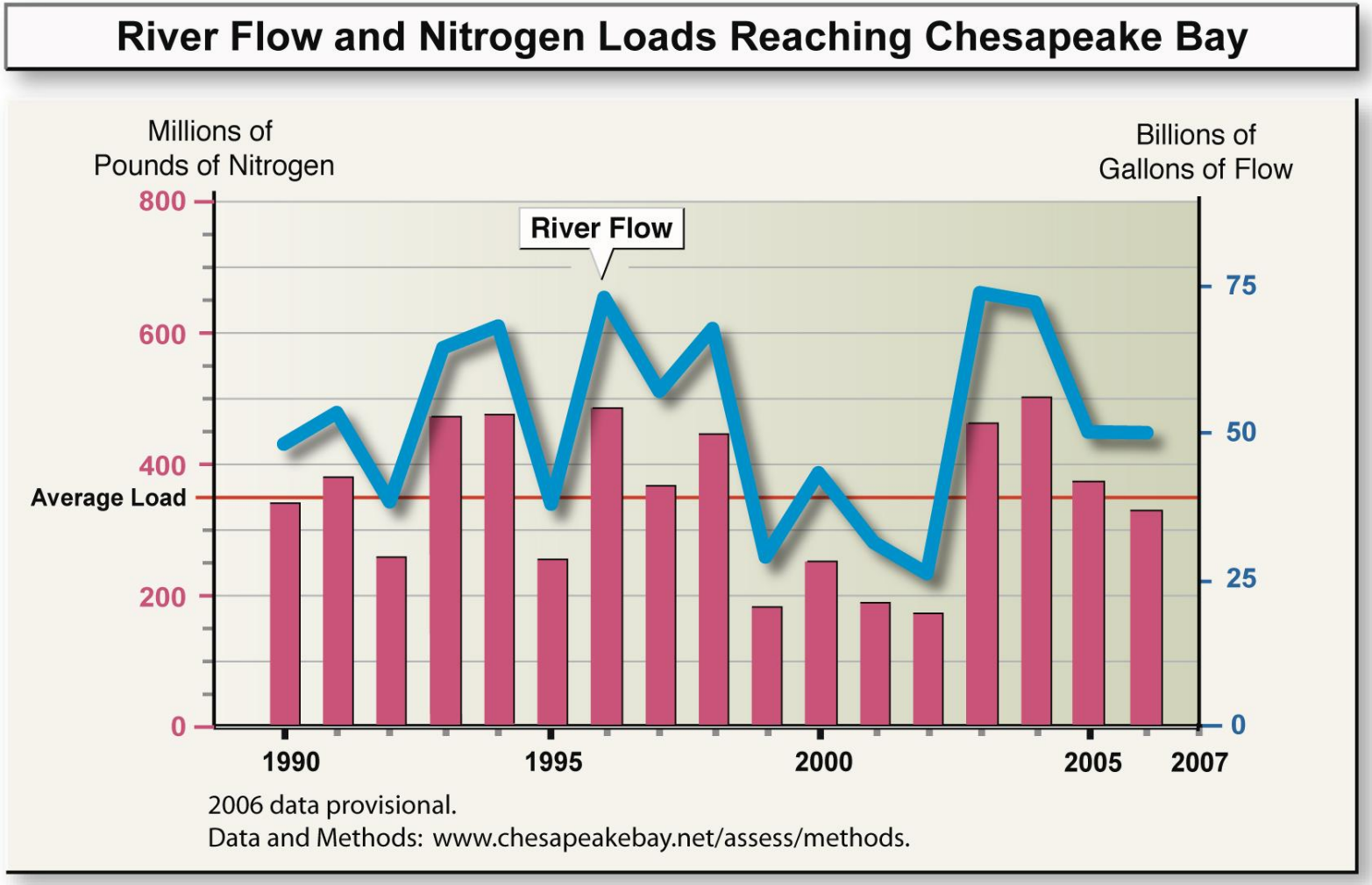
WSM Uses:
Determine Effective Practices

FIGURE 3
MAXIMUM POTENTIAL NITROGEN REDUCTION BAYWIDE*
FOR INDIVIDUAL BEST MANAGEMENT PRACTICES (2002 BASELINE)



From the Chesapeake Bay Commission Report: Cost-Effective Strategies for the Bay
December, 2004

WSM Uses:
Estimate annual loads below monitoring stations

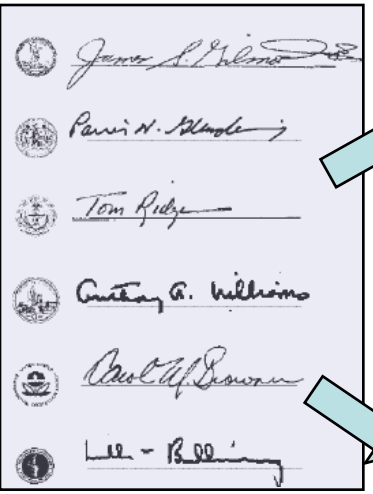


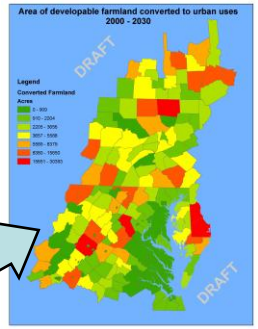
Roughly 25% of the total load is unmonitored

CBP DSS Use in Management

Land Use Change Model

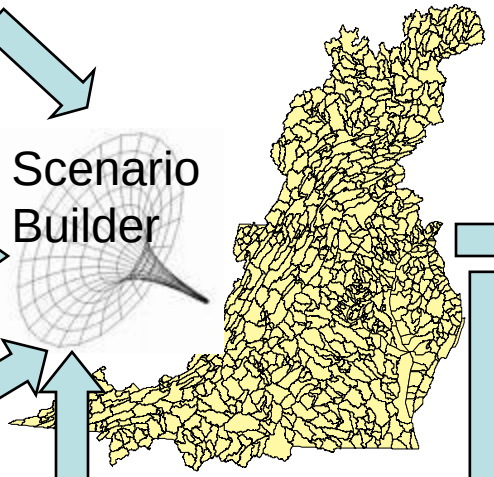
Management Actions



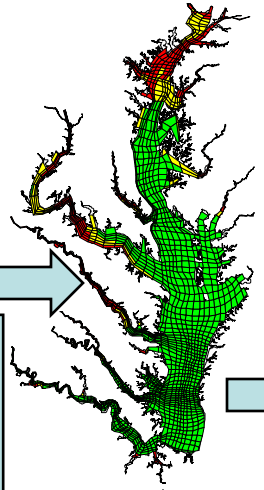


Scenario Builder

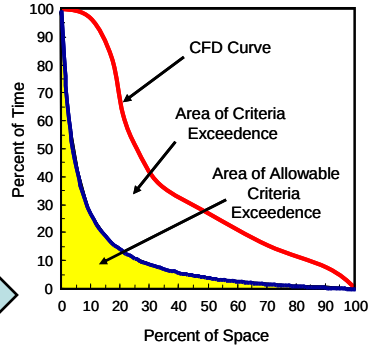
Watershed Model

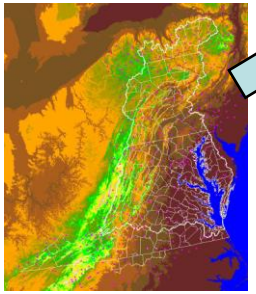


Bay Model



Criteria Assessment Procedures



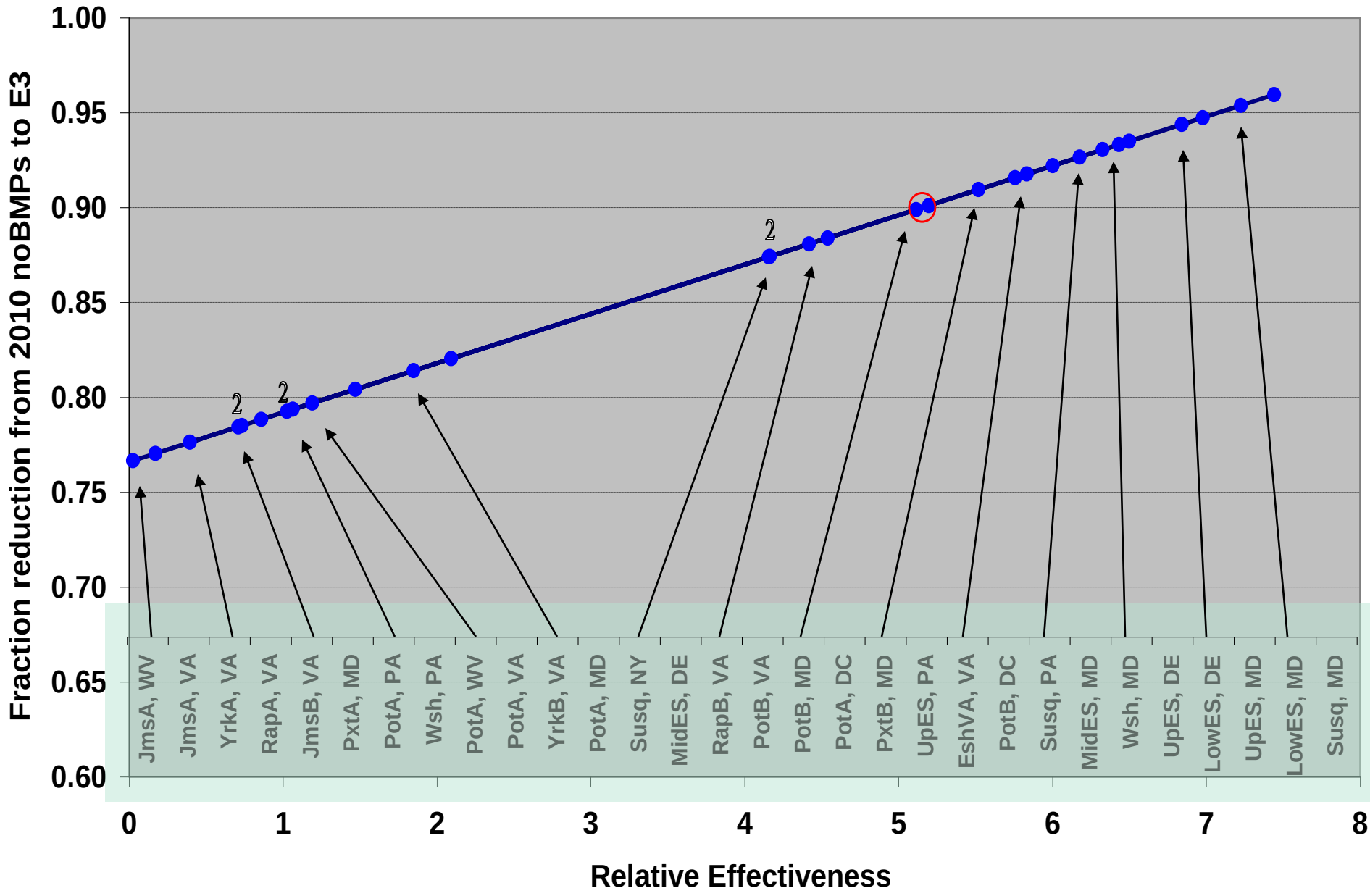


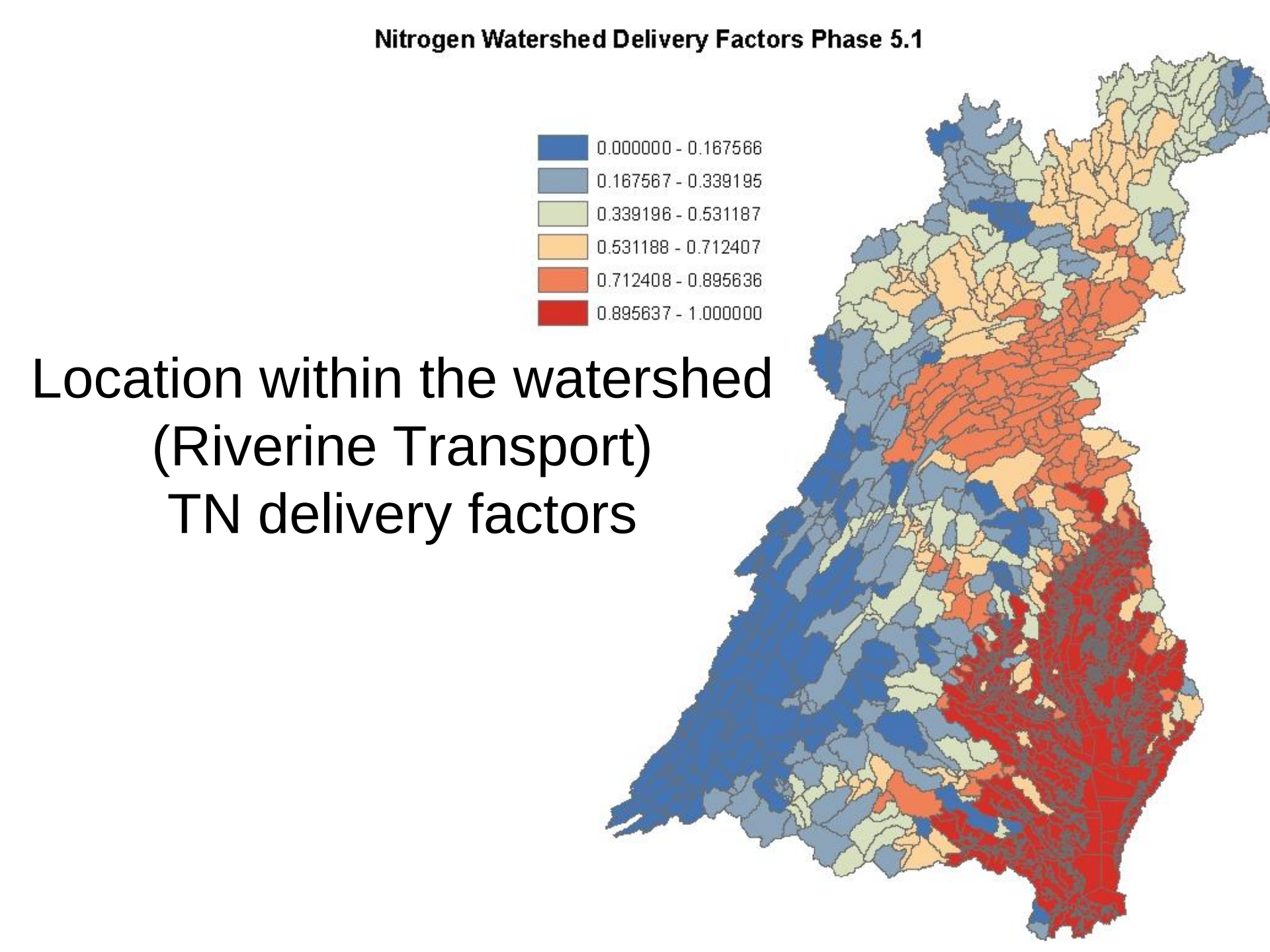
Airshed Model

Effects

Allocations

Target Load Methodology: Linking Effort to Effectiveness

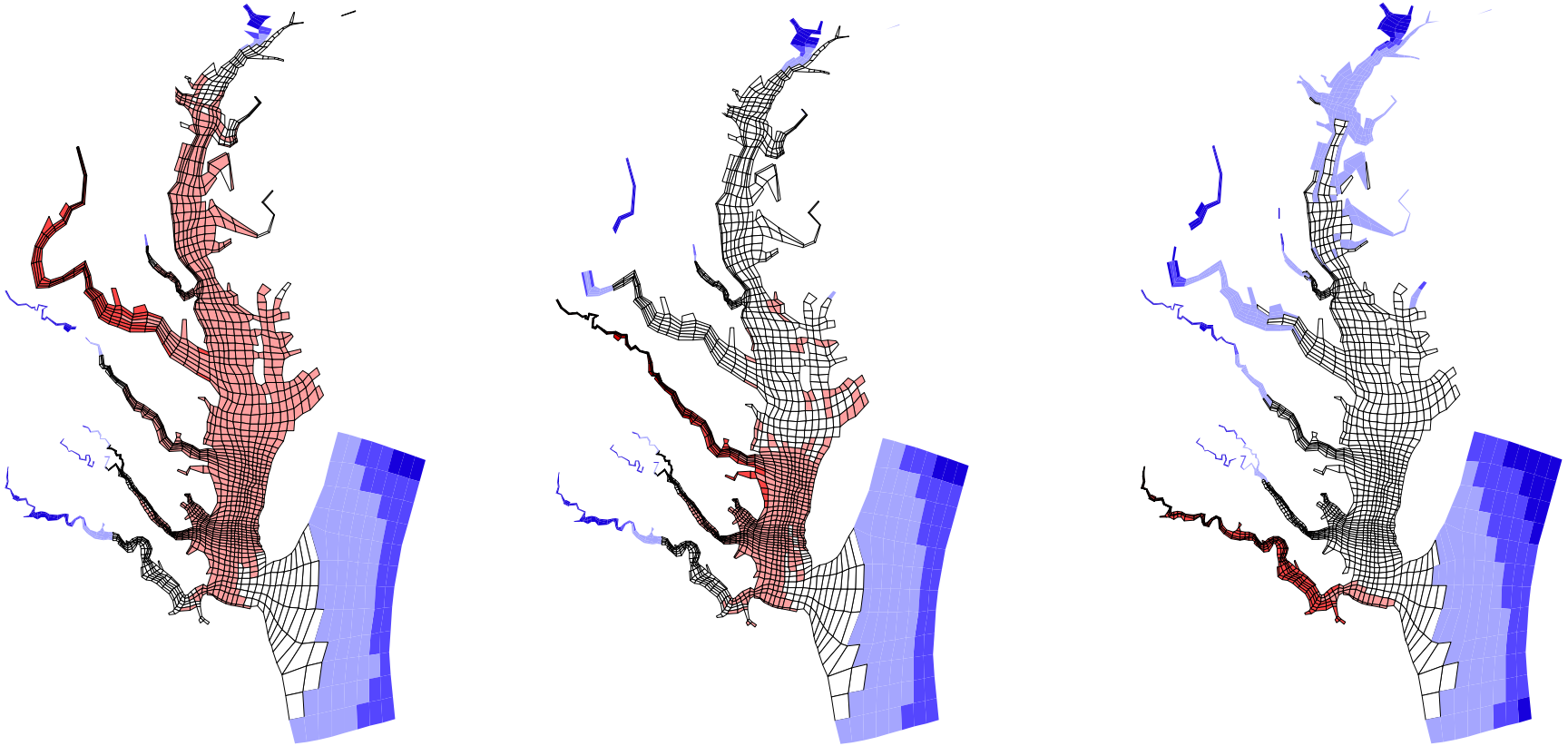


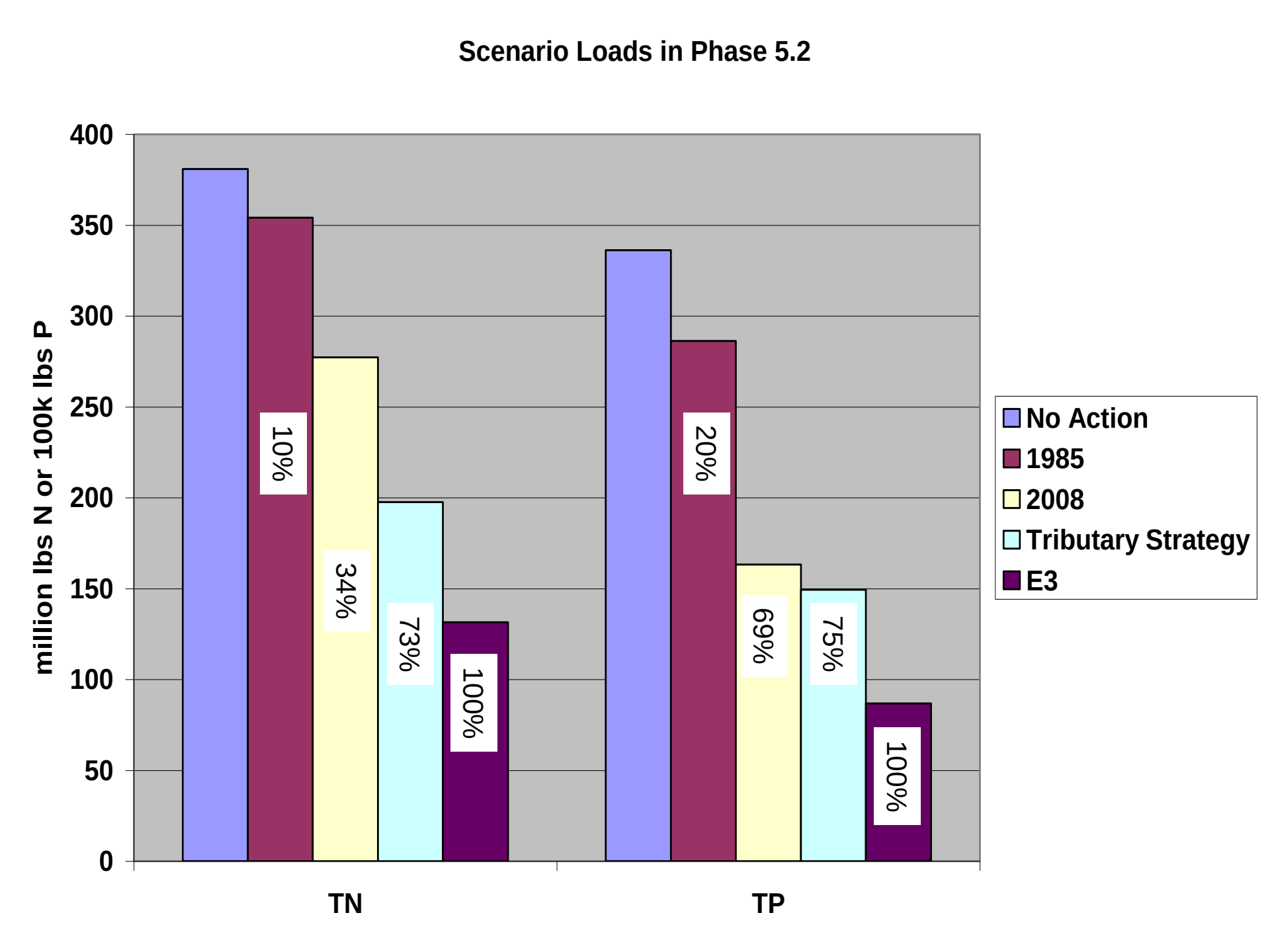


Location within the watershed
(Riverine Transport)
TN delivery factors

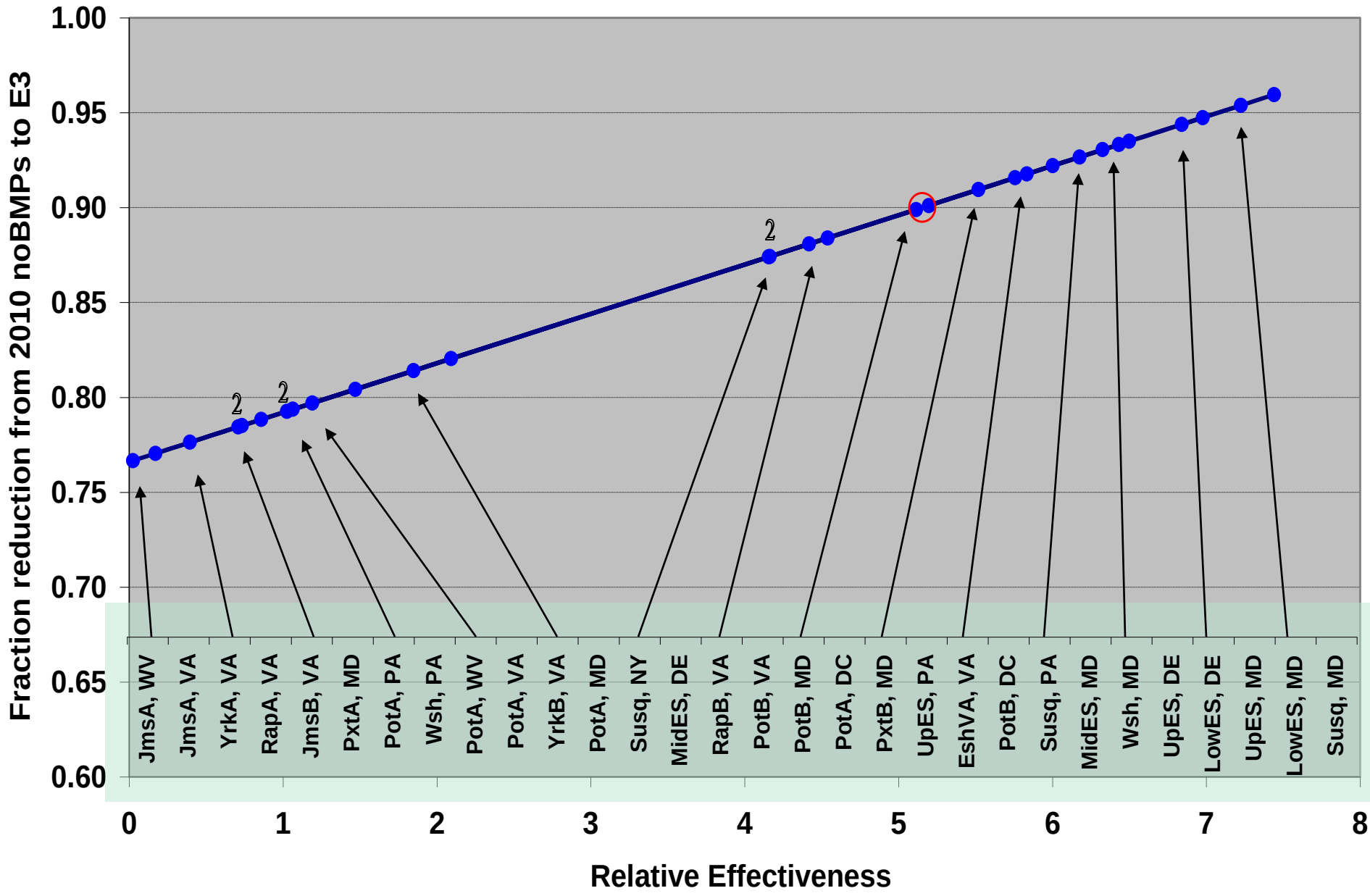
Location on the Bay (Estuarine Transport)

- Understand which basins affect which areas of the bay and by how much




Scenario Loads in Phase 5.2
million lbs N or 100k lbs P
400
350
300
250
200
150
100
50
0
10%
34%
73%
100%
20%
69%
75%
100%
TN
TP
No Action
1985
2008
Tributary Strategy
E3

Target Load Methodology: Linking Effort to Effectiveness



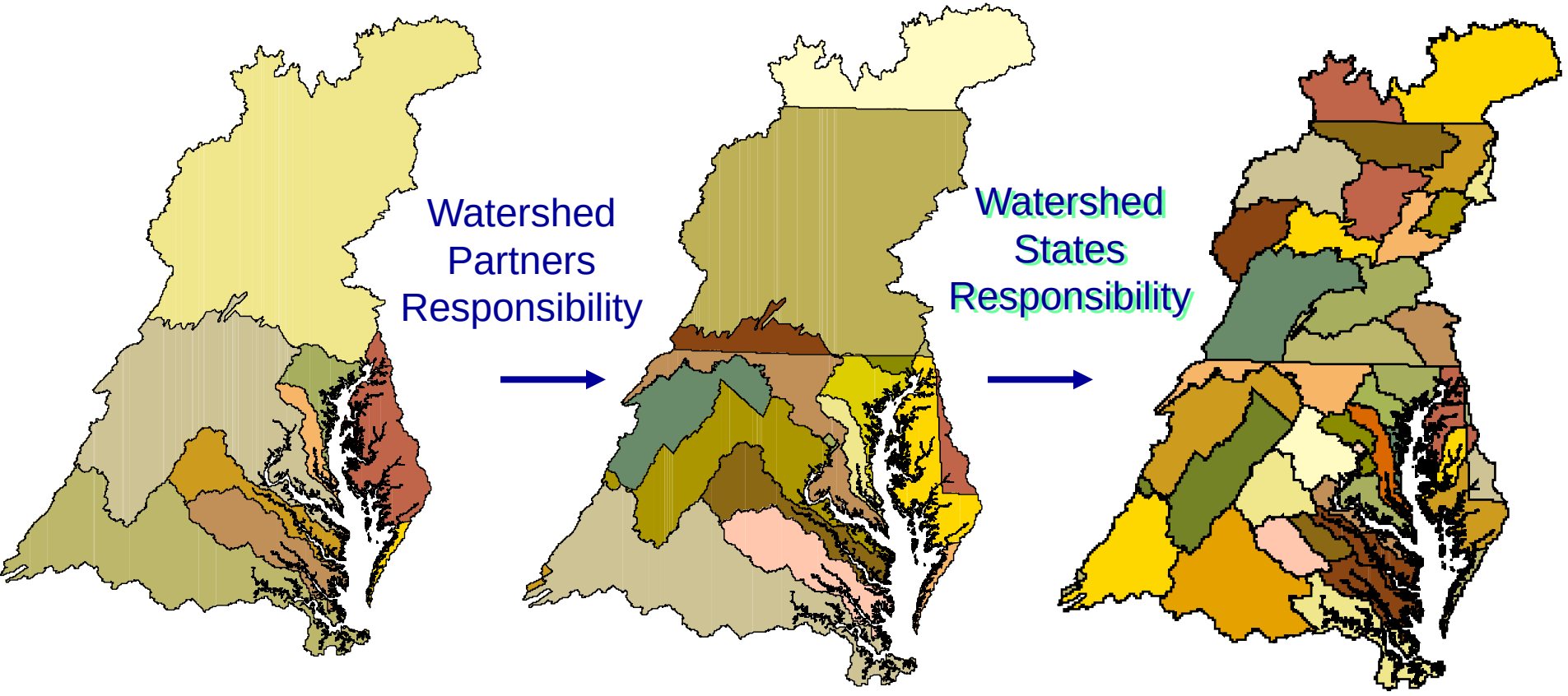
Nitrogen-Phosphorus-Sediment

Load Allocation Process

By **9** major river basins

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

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



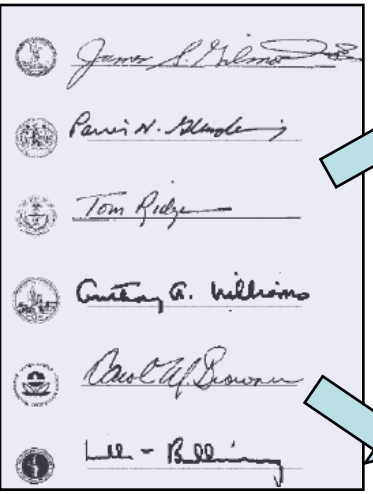
Watershed Partners Responsibility

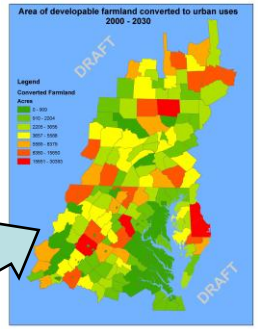
Watershed States Responsibility

Chesapeake Bay Program Decision Support System

Land Use Change Model

Management Actions





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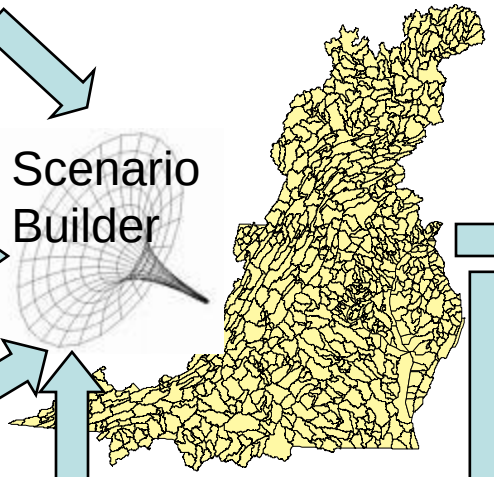
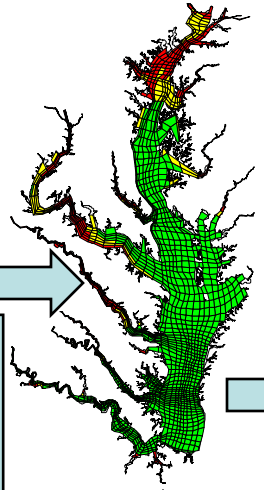


Bay Model



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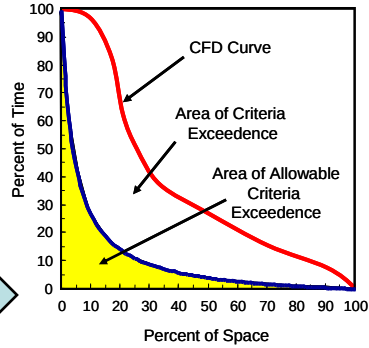
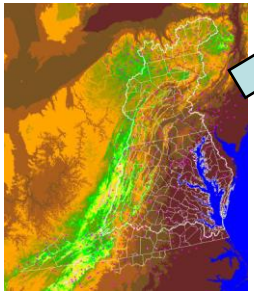


Airshed Model



Effects

Allocations