Modeling the Urban Stormwater (and the rest of the watershed)

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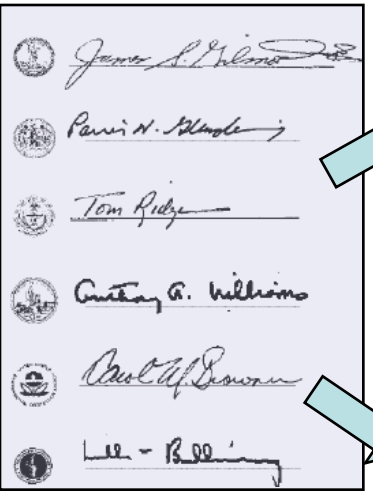
Water Quality Team
U.S. EPA Chesapeake Bay Program Office

May 13, 2010

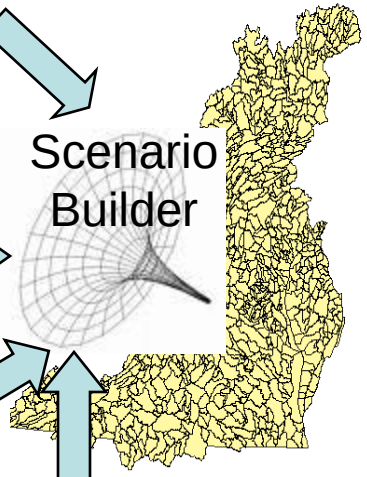
Chesapeake Bay Program Decision Support System

Management Actions

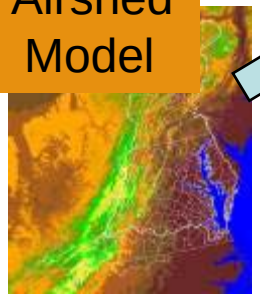


Land Use Change Model

Scenario Builder

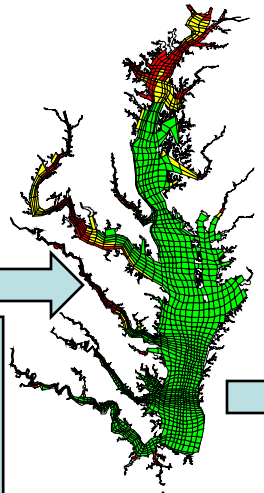


Airshed Model

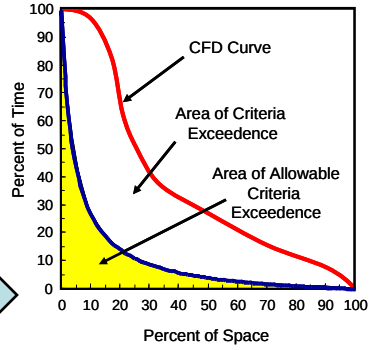


Watershed Model

Bay Model



Criteria Assessment Procedures

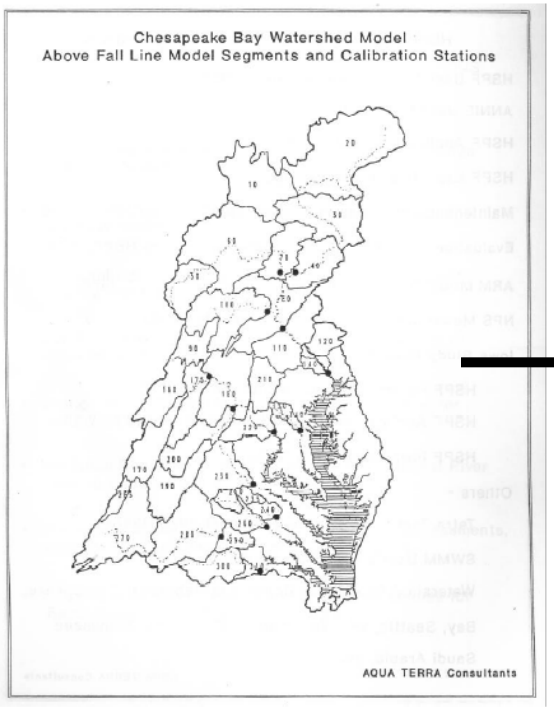


Effects

Target Loads and Allocations

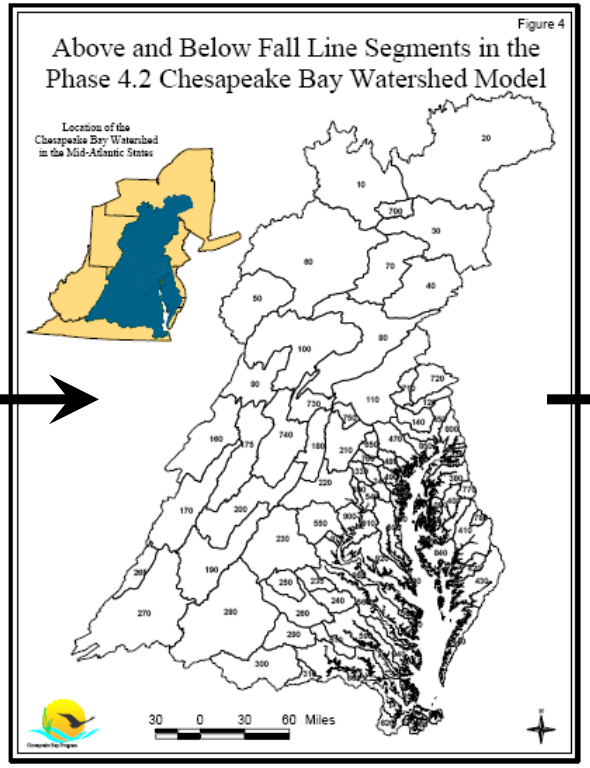
A Quarter Century of Watershed Model Development

Phase 1



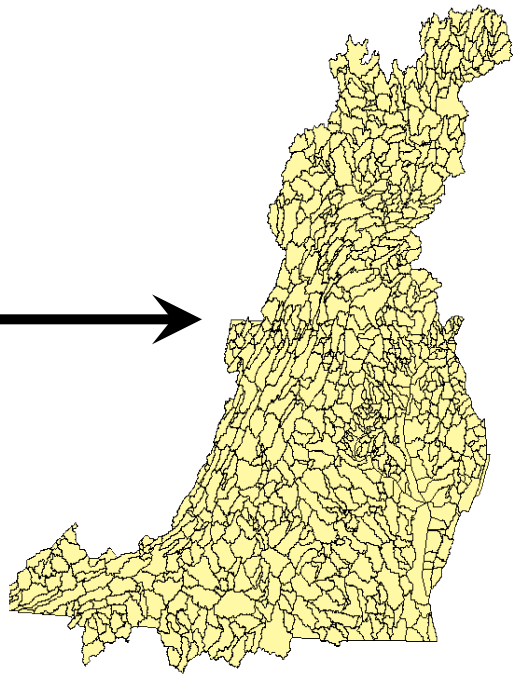
- **Completed in 1982**
- **63 model segments**
- **5 land uses**
- **2 year calibration period (March- October)**

Phase 4



- **Completed in 1998**
- **94 model segments**
- **9 land uses**
- **14 year calibration period (1984-97)**

Phase 5



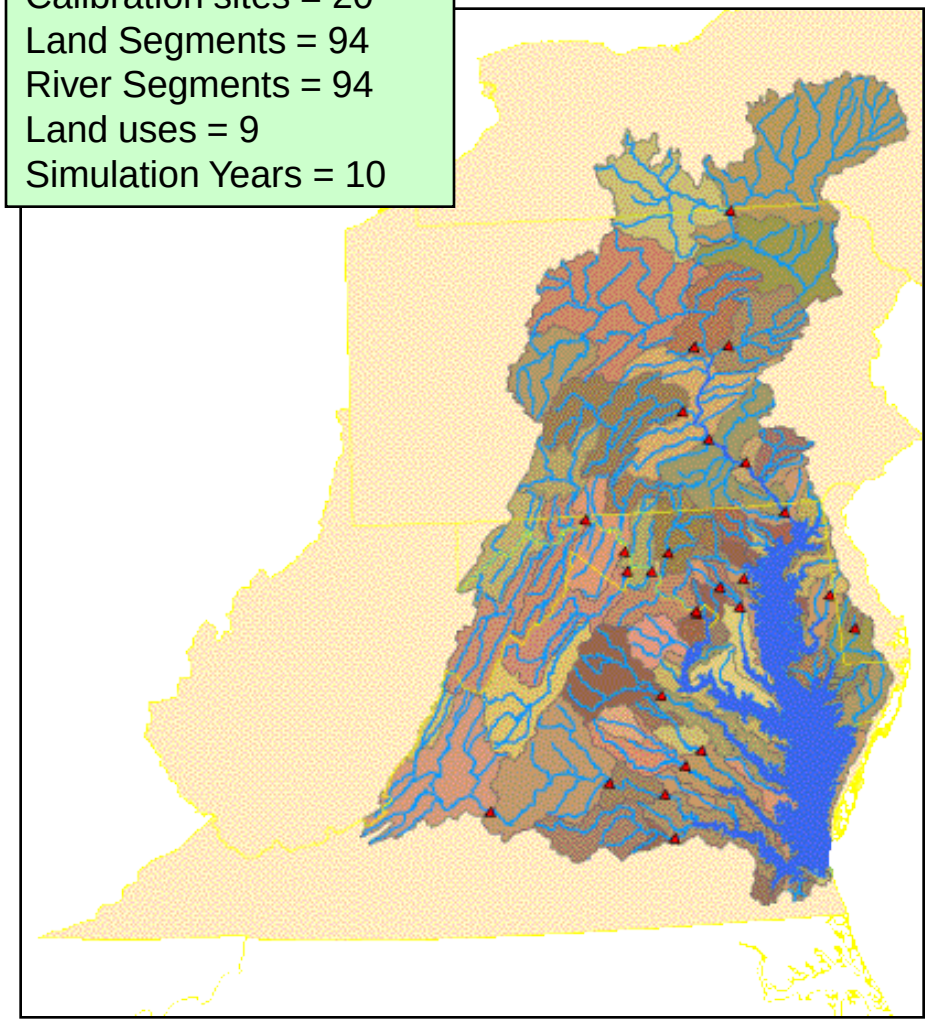
- **May 2009 roll-out (Phase 5.1)**
- **~ 1,000 model segments**
- **25 land uses using time-varying land use & BMPs**
- **21 year calibration period (1985-2005)**

Peer Review Status: CBP STAC independent peer reviews of Phase 5 Watershed Model conducted in 2007 and 2009

Finer Segmentation and Longer Simulation Periods Increases the Calibration Sites By An Order of Magnitude

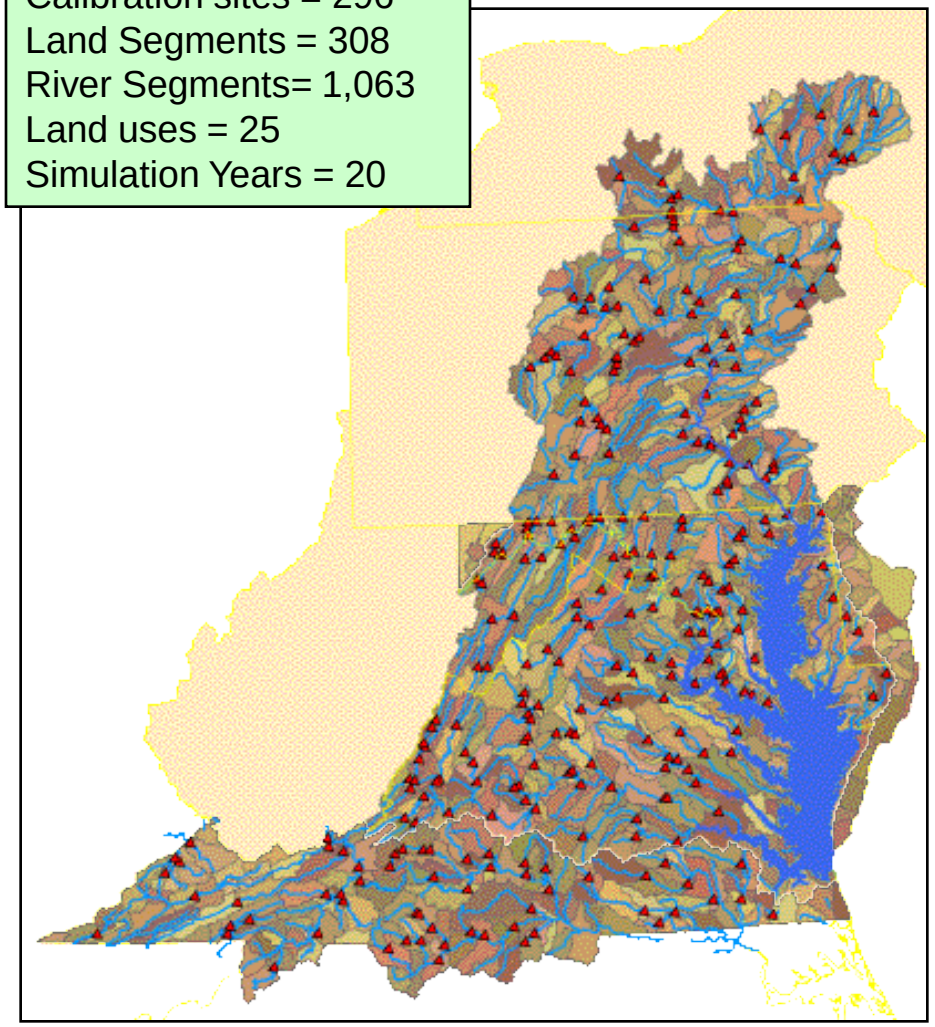
Phase 4 Segmentation and Calibration Sites

Calibration sites = 20
Land Segments = 94
River Segments = 94
Land uses = 9
Simulation Years = 10



Phase 5 Segmentation and Calibration Sites

Calibration sites = 296
Land Segments = 308
River Segments= 1,063
Land uses = 25
Simulation Years = 20



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

Chesapeake Bay Program

Developers

EPA

U of MD

USGS

NRCS

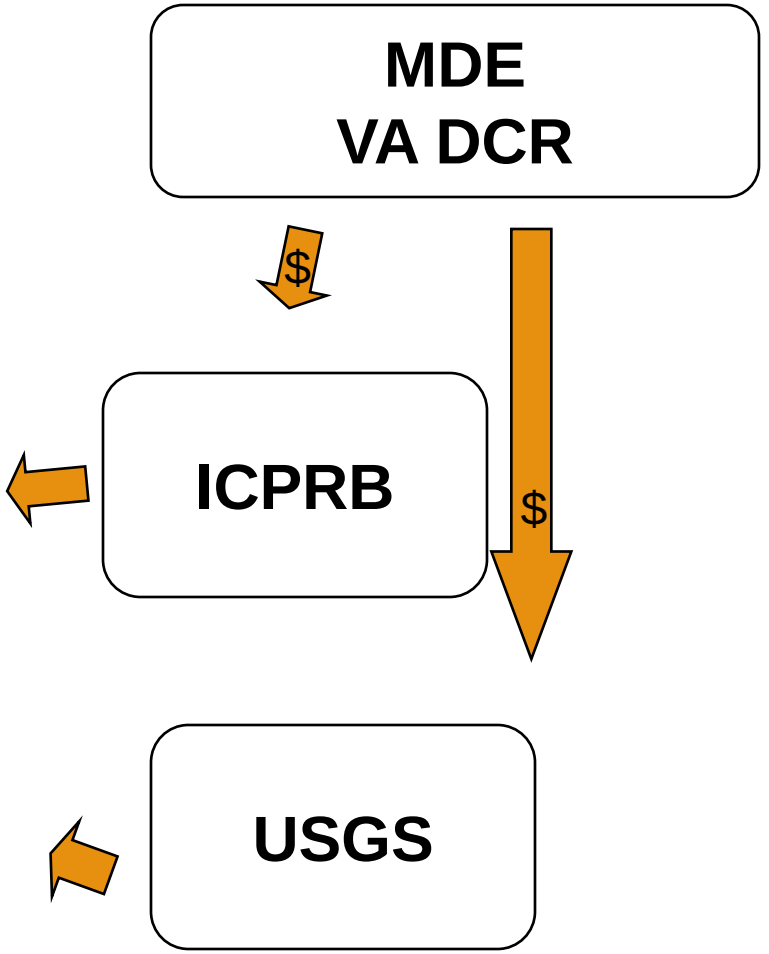
CRC

VaTech

Advisors and data suppliers

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

Penn State



How the Watershed Model Works

Hourly output is summed over 10 years of hydrology (1991-2000) to compare against other management scenarios

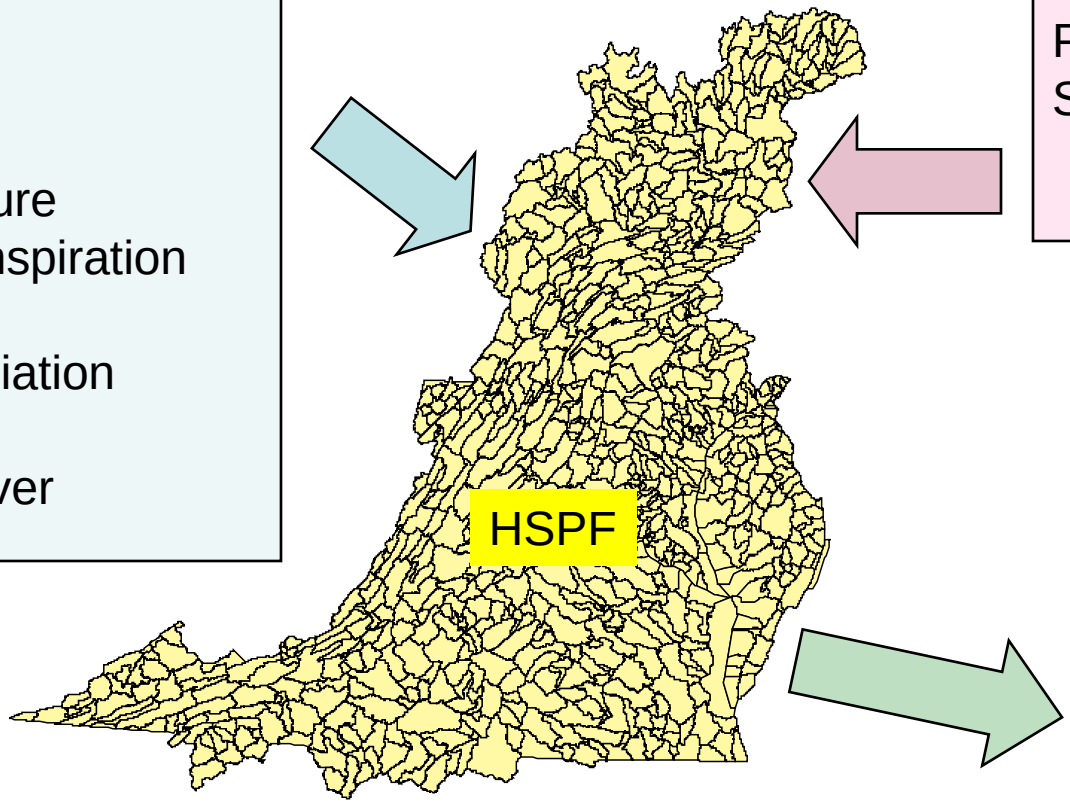
The result: Average annual flow-adjusted loads

Annual or Monthly:

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

Hourly Values:

Rainfall
Snowfall
Temperature
Evapotranspiration
Wind
Solar Radiation
Dewpoint
Cloud Cover

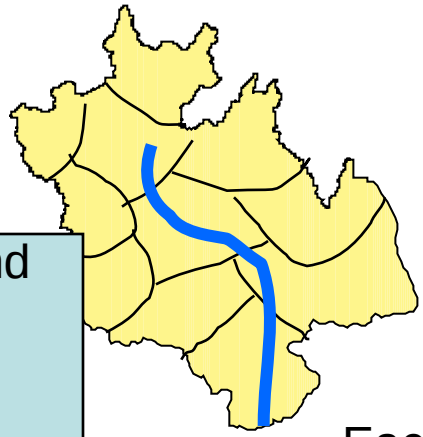


Daily output compared To observations

How the Watershed Model Works

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
- Combined Sewer System
- Wooded / Open
- Disturbed Forest



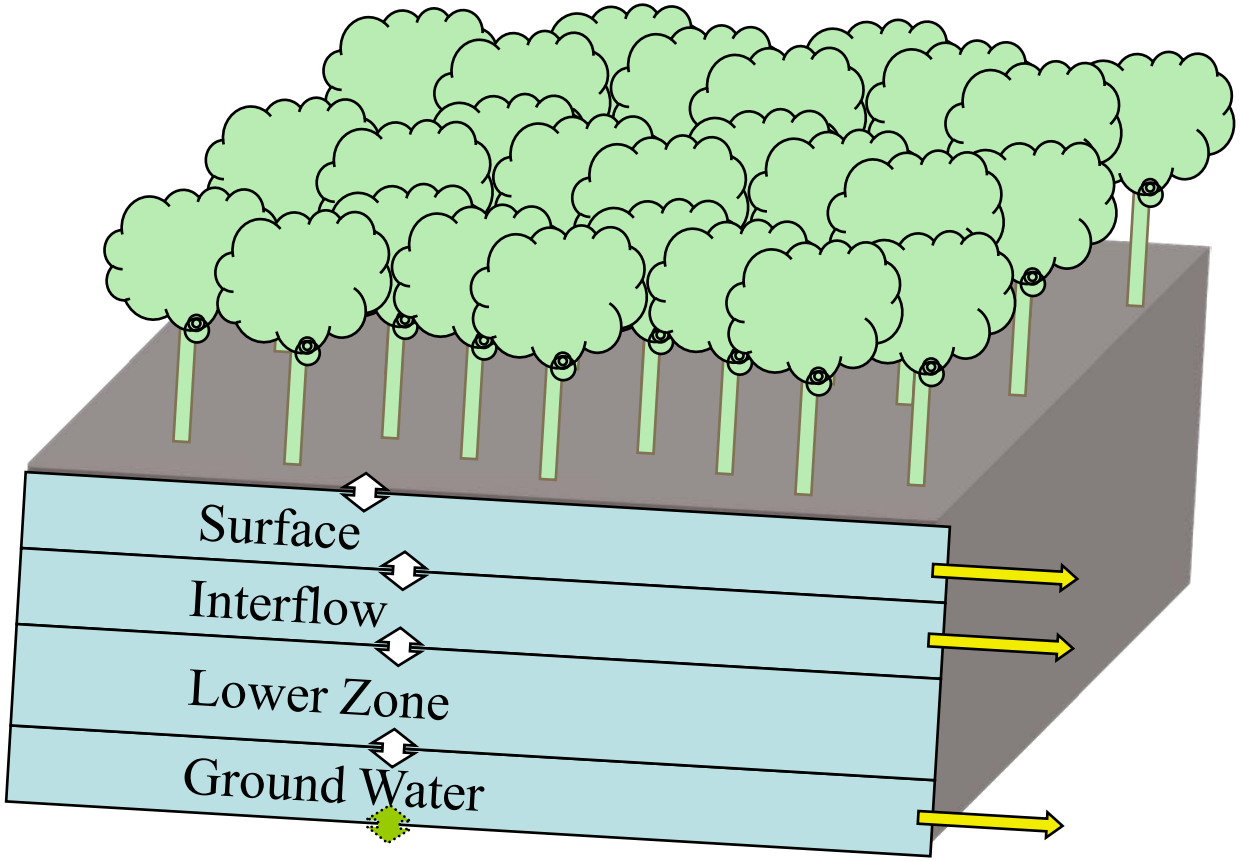
- Corn/Soy/Wheat rotation (high till)
- Corn/Soy/Wheat rotation (low till)
- Other Row Crops
- Alfalfa
- Nursery
- Pasture
- Degraded Riparian Pasture
- Manure Areas
- Fertilized Hay
- Unfertilized Hay
  - Nutrient management versions of the above

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

Each calibrated to nutrient and Sediment targets

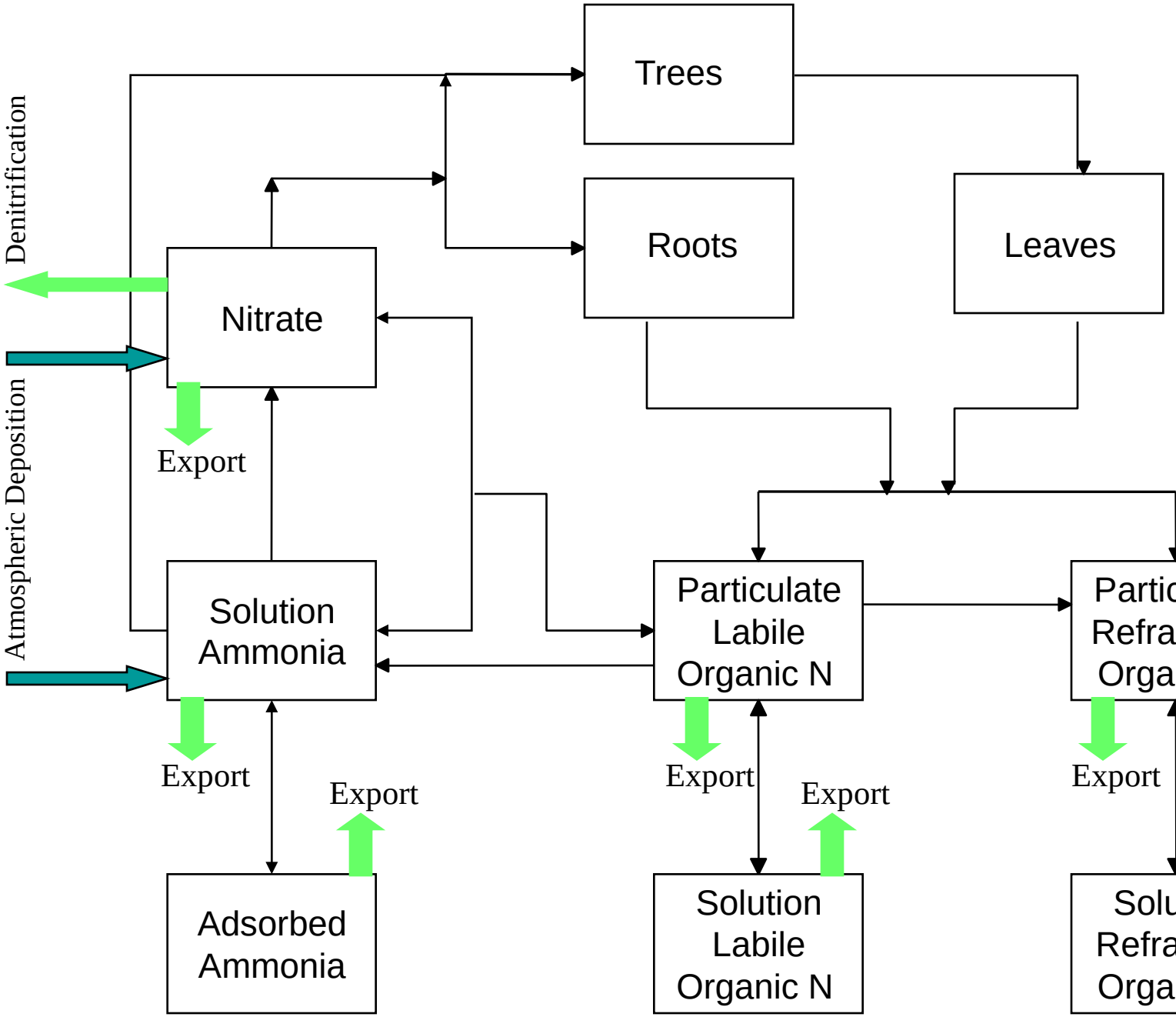
How the Watershed Model Works

Each land use type is divided into four soil layers:



Composed of Water, Sediment, Nitrogen, and Phosphorus submodels

How the Watershed Model Works

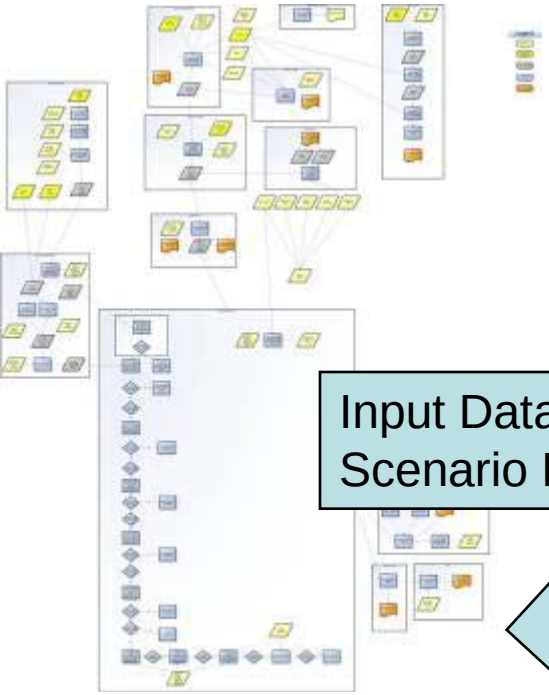


Each submodel has a complex hydrologic or nutrient cycling structure.

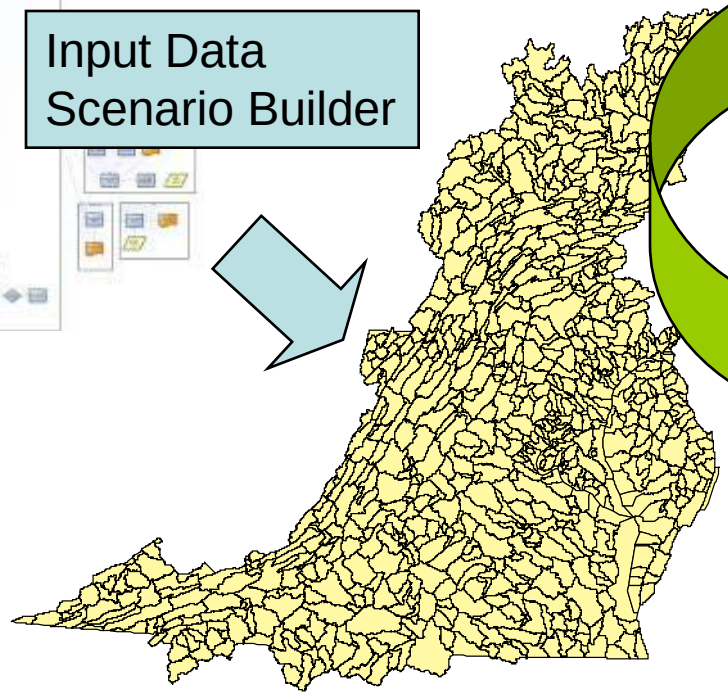
Available Developed Land BMPs in Phase 5.3

Riparian Forest Buffers	**Stream Restoration**
Riparian Grass Buffers	**Erosion & Sediment Control**
Wetland Restoration	**Nutrient Management**
Tree Planting	**Abandoned Mine Reclamation**
Forest Conservation	**Dirt & Gravel Road Erosion & Sediment Control**
Urban Growth Reduction	**Street Sweeping**
Wet Ponds & Wetlands	**Septic Connections**
Dry Detention Ponds & Hydrodynamic Structures	**Septic Pumping**
Dry Extended Detention Ponds	**Septic Denitrification**
Infiltration Practices	**Structural Shoreline Erosion Control**
Filtering Practices	**Non-Structural Shoreline Erosion Control**

Automated Calibration

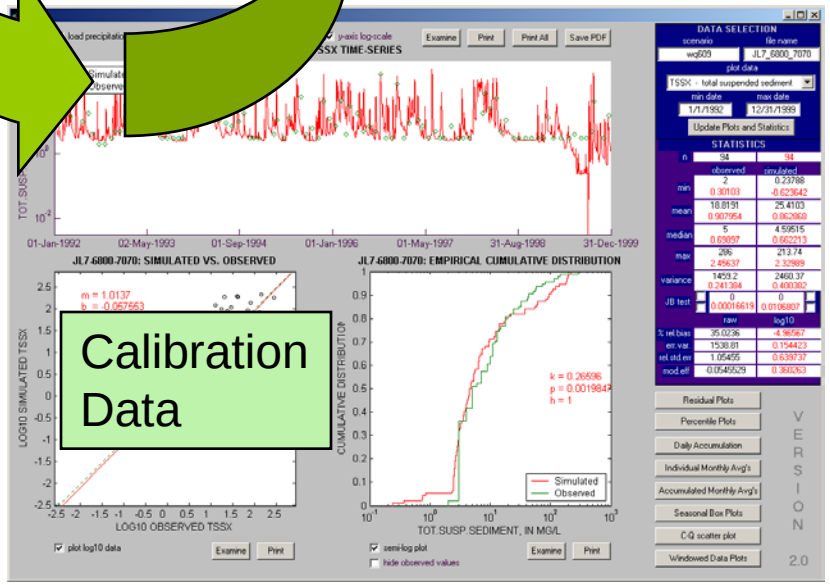


Input Data
Scenario Builder

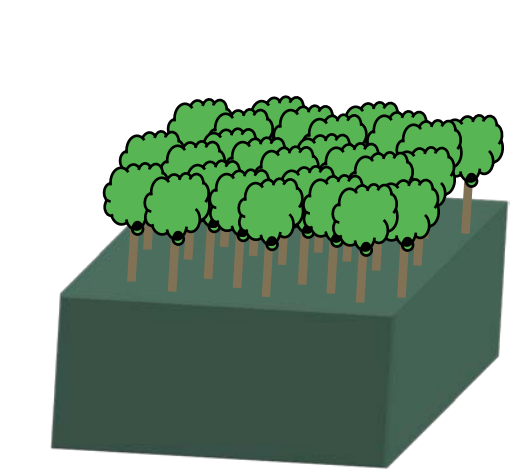


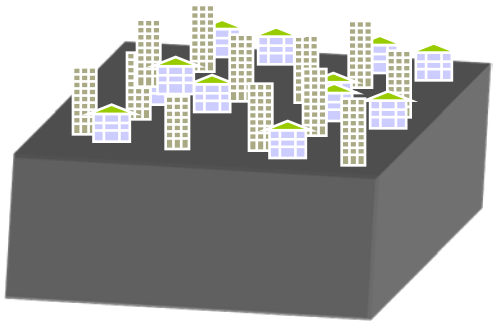
Calibration
Procedures

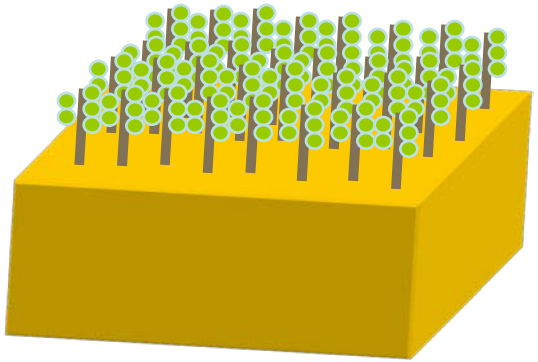
Calibration
Data



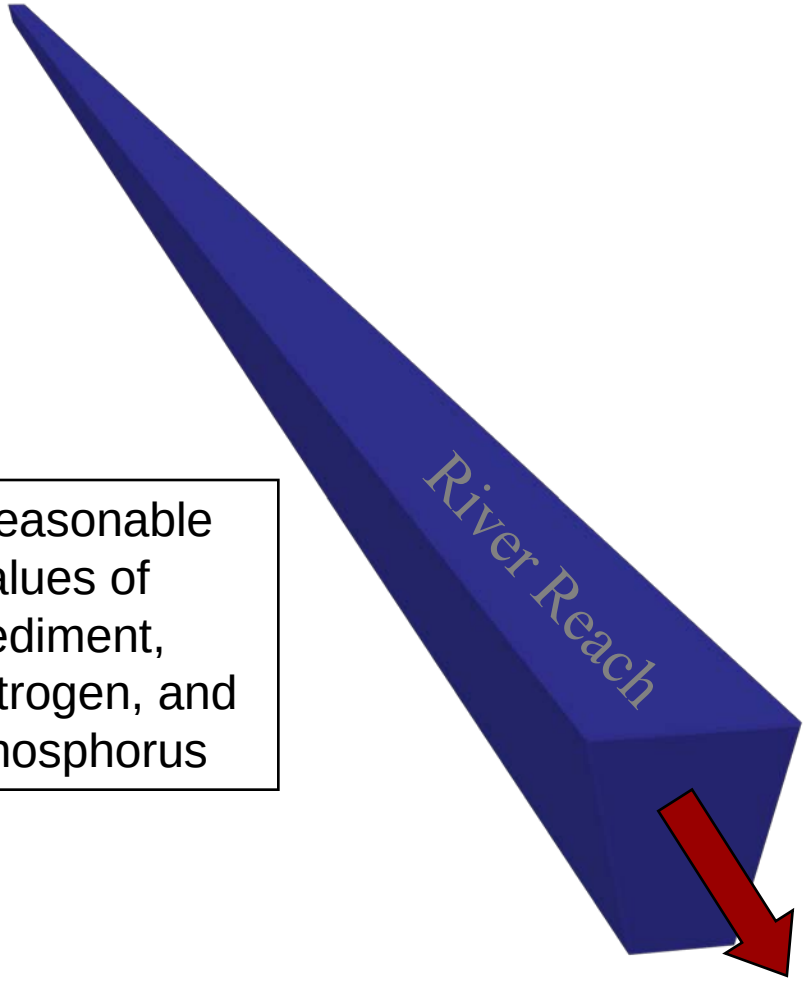
Where do we calibrate?







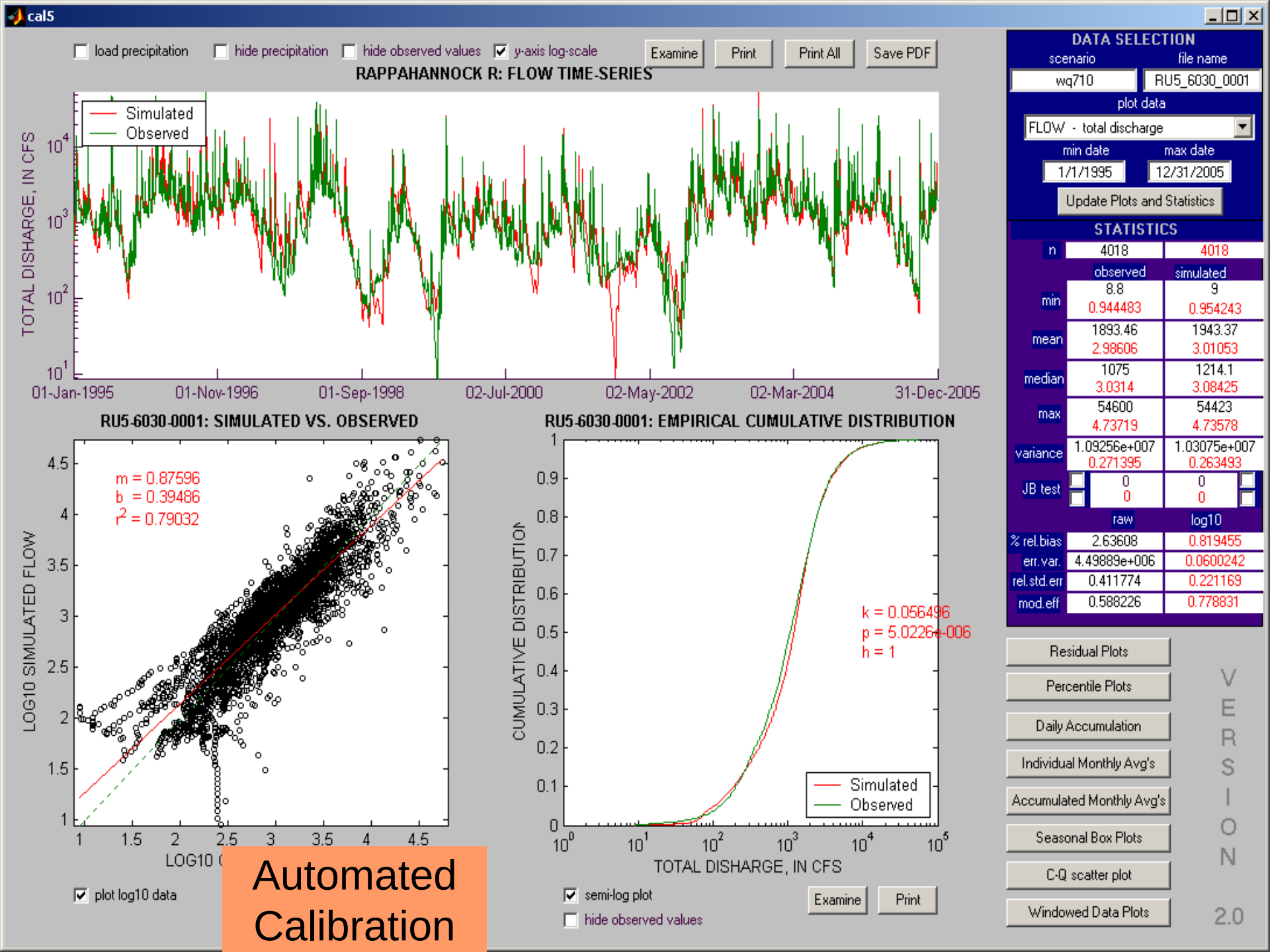
Reasonable values of sediment, nitrogen, and phosphorus



Observations of flow, sediment, nitrogen, and phosphorus

Calibration Strategy

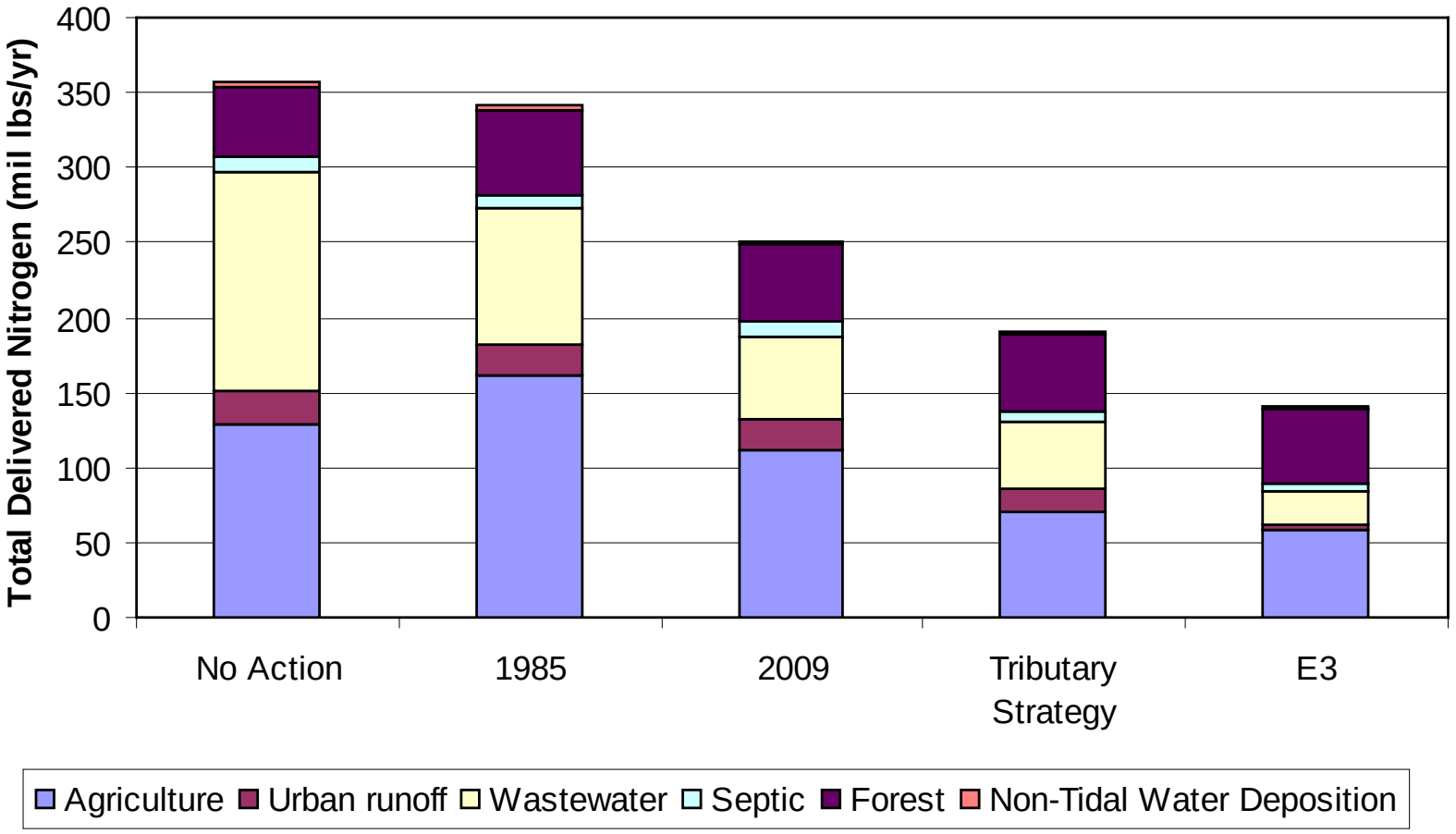
- Match observations in rivers
- Match properties and trends
  - Groundwater recession curve
  - Crop uptake of Nitrogen
- Match literature and other models
  - Reasonable rates of nutrient export
  - USGS estimator and sparrow empirical models


cal5
load precipitation
hide precipitation
hide observed values
y-axis log-scale
Examine
Print
Print All
Save PDF
RAPPAHANNOCK R: FLOW TIME-SERIES
Simulated
Observed
TOTAL DISHARGE, IN CFS
01-Jan-1995
01-Nov-1996
01-Sep-1998
02-Jul-2000
02-May-2002
02-Mar-2004
31-Dec-2005
RU5-6030-0001: SIMULATED VS. OBSERVED
m = 0.87596
b = 0.39486
r2 = 0.79032
LOG10 SIMULATED FLOW
plot log10 data
RU5-6030-0001: EMPIRICAL CUMULATIVE DISTRIBUTION
k = 0.056496
p = 5.0226e-006
h = 1
CUMULATIVE DISTRIBUTION
TOTAL DISHARGE, IN CFS
semi-log plot
hide observed values
Examine
Print
DATA SELECTION
scenario
file name
wq710
RU5_6030_0001
plot data
FLOW - total discharge
min date
max date
1/1/1995
12/31/2005
Update Plots and Statistics
STATISTICS
n 4018 4018
observed simulated
min 8.8 9
0.944483 0.954243
mean 1893.46 1943.37
2.98606 3.01053
median 1075 1214.1
3.0314 3.08425
max 54600 54423
4.73719 4.73578
variance 1.09256e+007 1.03075e+007
0.271395 0.263493
JB test 0 0
0 0
raw log10
% rel.bias 2.63608 0.819455
err.var. 4.49889e+006 0.0600242
rel.std.err 0.411774 0.221169
mod.eff 0.588226 0.778831
Residual Plots
Percentile Plots
Daily Accumulation
Individual Monthly Avg's
Accumulated Monthly Avg's
Seasonal Box Plots
C-Q scatter plot
Windowed Data Plots
VERSION 2.0
Automated Calibration

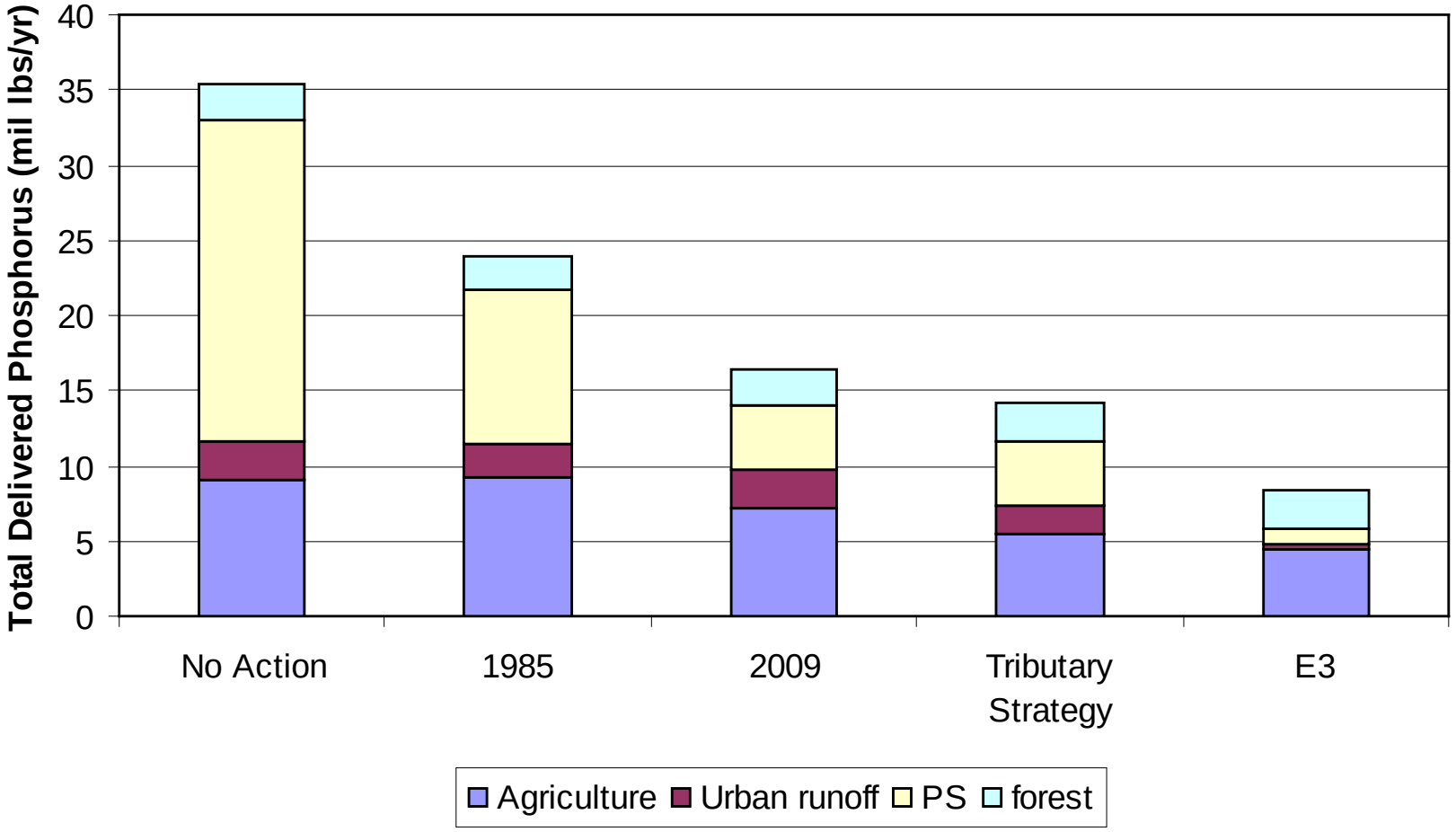
Urban Calibration Strategy

- Use NPDES phase 1 stormwater data
- Vary nitrogen concentration target according to atmospheric deposition of nitrogen
- Load targets are combination of the local concentration target and the local flow

All This to Develop...
Phase 5.3 Watershed Model Scenarios!



All This to Develop...
Phase 5.3 Watershed Model Scenarios!



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http://ches.communitymodeling.org/models/CBPhase5/index.php

ftp://ftp.chesapeakebay.net/Modeling/phase5/Phase53_Loads-Acres-BMPs