Chesapeake Bay: the Science, the TMDL, the Models
Your Tour Guides for the Next 14 Hours:

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First, a Chesapeake Bay TMDL Primer
Clean Water Act Requires Protection of Designated Uses

A. Cross Section of Chesapeake Bay or Tidal Tributary

- Shallow-Water Bay Grass Use
- Deep-Water Seasonal Fish and Shellfish Use
- Deep-Channel Seasonal Refuge Use
- Open-Water Fish and Shellfish Use

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

- Migratory Fish Spawning and Nursery Use
- Open-Water Habitat
- Deep-Channel Seasonal Refuge Use
- Deep-Water Seasonal Fish and Shellfish Use
- Shallow-Water Bay Grass Use

Source: U.S. EPA 2003
States Adopt Water Quality Standards to Protect Designated Uses

Minimum Amount of Oxygen (mg/L) Needed to Survive by Species

- Migratory Fish Spawning & Nursery Areas
  - Striped Bass: 5-6
  - American Shad: 5
  - White Perch: 5
  - Yellow Perch: 5
  - Hard Clams: 5
  - Alewife: 3.6
  - Bay Anchovy: 3
  - Spot: 2
  - Worms: 1

- Shallow and Open Water Areas
  - Spot: 2

- Deep Water
  - American Shad: 5
  - White Perch: 5
  - Yellow Perch: 5
  - Alewife: 3.6
  - Bay Anchovy: 3
  - Spot: 2

- Deep Channel
  - American Shad: 5
  - White Perch: 5
  - Yellow Perch: 5
  - Alewife: 3.6
  - Bay Anchovy: 3
  - Spot: 2
  - Worms: 1
The Partners Established a Pollution Diet for Each Tidal Water Segment
The Partners Uses a Suite of Models to Determine the Nutrient Loads Achieving the States’ Water Quality Standards
The Partnership uses a science-based approach to allocating responsibility for reducing nutrient and sediment loads necessary to meet states’ Chesapeake Bay water quality standards.
Pollution Diet by River

Pollution Diet by State

Note: There is also an Atmospheric Deposition Allocation of 10.72 million pounds/year.
The Chesapeake Bay Program Partnership Uses a Suite of Models to Support Collaborative Decision Making…
Data and Model Inputs:
- Pollution Control Data
- Land Use Data
- Point Sources Data
- Septic Data
- U.S. Census Data
- Agricultural Data

Phase 6 Watershed Model/CAST

Estuary Model

Model Outputs:
Prediction of Impacts:
- Population Growth
- Climate Change
- Chemical Fertilizers
- Land Use Changes

BMP Implementation Results:
- Nitrogen
- Phosphorus
- Sediment
- Water Quality
- Dissolved Oxygen
...But Most Partners Think in Terms of the Chesapeake Bay Watershed Model as THE MODEL
Phase 6 Model Structure

Average Load $+ \Delta$ Inputs $\times$ Sensitivity

* Land Use Acres
* BMPs
* Land to Water
* Stream Delivery
* River Delivery
Average Load $+ \Delta$ Inputs * Sensitivity

* Land Use Acres
* BMPs
* Land to Water
* Stream Delivery
* River Delivery

Models
- CBP Phase 5.3.2
- USGS SPARROW
- USDA CEAP
- HSPF
- APLE
- RUSLE
- USGS-Modflow
Let’s Briefly Explore How the Partners Have Used Science, Data, and Monitoring to Confidently Simulate the Watershed
Partnership’s Phase 6 Watershed Model is Built on High Resolution & Local Land Cover and Land Use Data

1 meter resolution land cover data for entire Bay watershed and all of Virginia supplemented by local government’s submission of local land cover, land use, planning and zoning data
How the Partners Account for Estimated Reductions Based on Reported Practices

- Atmospheric deposition
- Biosolids
- Fertilizer
- Manure
- Management filter (Efficiency BMPs)
- Sediment delivery factor
- Management filter (Pound BMPs)
- In-stream transport processing

**Precipitation**

**Applications**

**Loads**

- Hydrology submodel
- Sediment submodel
- Phosphorus submodel
- Nitrogen submodel

**Land Use**

**To Bay**

**River**

**Edge-of-stream**

**In-Stream**
Nutrient Spread Components: Easy Version

1) Define Crop Application Goal
2) Define Manure Available to Crops
3) Spread Manure to Crops
4) Define Inorganic Fertilizer Available to Crops
5) Spread Inorganic Fertilizer to Crops
1. Define Crop Application Goal

2. Define Manure Available to Crops

3. Spread Manure to Crops

4. Define Inorganic Fertilizer Available to Crops

5. Spread Fertilizer to Crops

Actual Nutrient Spread:
Based on literally thousands of decisions by Partnership agency, conservation district and scientific experts.
How Phosphorus is Modeled

Inputs:
• Fertilizer
• Manure

Influenced by:
• Fertilizer sales
• Ag animal populations
• % Nutrient Management plans

Phosphorus

Inputs

Soil storage

• State P soil test data
• USDA APLE model
• Expert advice from external reviewers

output

BMPs reported annually by states

Load
Scientific Direction on Modeling Phosphorus

- Track drawdown and buildup of soil P reservoirs by segment as a source of P runoff
- Get better manure, fertilizer, application method, and soil P data
- Account for management (method, timing, tillage, etc)
The Partnership’s Model Simulate the Loss of Trapping Capacity Behind Conowingo Dam to Support Policy Decision Making

Early 1990’s, about 50% of P trapped

Early 2000’s, about 40% of P trapped

Early 2010’s, Approaching no net trapping

Loads Into Reservoir System
- Long term improving trend

Loads Out of Reservoir System - Conowingo
- Long term degrading trend

- loads are approximate and in units of million lbs/year using estimates for 1992, 2002, and 2012
The Partnership Depends on Decades of Monitoring Data at Hundreds of Stations Across the Bay and Watershed to Calibrate its Models
Phase 6 Watershed Model Calibrated Using A LOT of Monitoring Data from Hundreds of Stations

**Nitrate Per Acre Load, NSE = 0.9538**

\[ y = 0.9688x \]
\[ R^2 = 0.95449 \]

**Nitrogen Per Acre Load, NSE = 0.9713**

\[ y = 0.9578x \]
\[ R^2 = 0.97369 \]

**Phosphorus Per Acre Load, NSE = 0.9479**

\[ y = 1.0278x \]
\[ R^2 = 0.95194 \]

**Sediment Per Acre Load, NSE = 0.9608**

\[ y = 0.9818x \]
\[ R^2 = 0.95963 \]
Phase 6 Model Much Improved over Phase 5 Model

[Bar chart showing Spatial Predictive Power for Nitrogen and Phosphorus]

- **Nitrogen**
  - Phase 5: Perfect
  - Phase 6: 90%
- **Phosphorus**
  - Phase 5: 90%
  - Phase 6: Perfect

Perfect

No predictive power
NSE of monthly nitrogen load = 0.716
NSE of annual nitrogen load = 0.737
Partnership-Based Model Development, Review and Management Application

Water Quality Goal Implementation Team
30 State, Federal, Academic, and NGO members
7 WQGIT Workgroups
Over 300 State, Federal, Academic, and NGO members (as of 1/2016)

Modeling Workgroup
17 State, Federal, and Academic members (as of 1/2016)

CBPO Modeling Team
7 federal employees
7 academic employees
5 Contractors
(as of 1/2016)

Scientific and Technical Advisory Committee
41 Academic and Federal Members

Directs
Reviews
Advises
Direct
Advises
Directs
Chesapeake Bay Program Partnership’s Phase 6 Watershed Model = CAST

- All users access the same Phase 6 Ches. Bay Watershed Model
- Users can generate their own scenarios
- Users can query output of their own or official Partnership scenarios
- Anyone can get an account
- Training available

Cast.chesapeakebay.net
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