Modeling and Multiple Modeling in the Chesapeake Bay Program

- Models in the Chesapeake TMDL
- Future Multiple Model Activities
- CBP view of M3
Chesapeake Bay Partnership Models

Use in the TMDL
Use of modeling suite in the Chesapeake TMDL

Basin-wide load is 190 N and 12.7 P (MPY)
TN, p5.3, goal=190, WWTP = 4.5-8 mg/l, other: max=min+20%

Allocation Method Agreed to by Majority of Principals’ Staff Committee Members
Pollution Diet by River

Pollution Diet by State

Note: There is also an Atmospheric Deposition Allocation of 15.70 million pounds/year.
Accountability Framework

1. Watershed Implementation Plans identify nutrient and sediment targets that meet water quality standards.

2. 2-Year Milestones with programmatic and pollutant reduction commitments

3. Track and Assess Progress implementing WIPs and milestones

4. Federal Actions if insufficient Watershed Implementation Plans or 2-year milestones

Source: Chesapeake Bay TMDL Section 7
Accountability Framework

1. Watershed Implementation Plans identify nutrient and sediment targets that meet water quality standards.

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4. Federal Actions if insufficient Watershed Implementation Plans or 2-year milestones

CAST

Watershed Model

Land Change Model

Scenario Builder

Monitoring Data

BayTAS

NEIEN

Environmental Information Exchange Network
TMDL Margin of Safety

• TMDL = WLA + LA + MOS

• Chesapeake TMDL

• TMDL = WLA + LA
  – Models has sufficient conservative assumptions to consider the margin of safety as implicit.
Chesapeake Bay Partnership Models

Possible Future
Multiple Models

Reduce/Readjust Loads to Meet Standards

INPUTS

BMP Data
LU Data
Point Sources Data
Septic Data
U.S. Census Data
Agricultural Census Data

MODEL-DERIVED

Airshed Model
Land Use Change Model

SCENARIO BUILDER

WATERSHED MODEL

CHESAPEAKE BAY MODEL

MEET WQS?

NO
YES

ALLOCATION METHODOLOGY

Precipitation Data
Meteorological Data
Elevation Data
Soil Data
Big caveat: Can we make the money available?
Multiple Models in the Watershed Model

- Precipitation
- Fertilizer
- Manure
- Atmospheric deposition
- Management filter
- Runoff
- Hydrology submodel
- Sediment submodel
- Phosphorus submodel
- Nitrogen submodel
- River
AGCHEM Loading Model - simulated separately in each soil layer

- Atmospheric Deposition
- Denitrification

Trees

Roots

Leaves

Nitrate

Solution Ammonia

Solution Labile Organic N

Particulate Labile Organic N

Particulate Refractory Organic N

Adsorbed Ammonia

Solution Labile Organic N

Solution Refractory Organic N

Exports:
- Ammonia
- Nitrate
- Particulate Organic N
- Solution Organic N
- Refractory Organic N

Exports:
- Trees
- Roots
- Leaves

Exports:
- Atmospheric Deposition
- Denitrification
PQUAL loading model

- SURFACE
  - flow * conc

- INTERFLOW
  - flow * conc
  - sed * factor

- Groundwater
  - flow * conc
AGCHEM vs PQUAL

• Calibration is complex and time consuming
• Calibration is imprecise
• Longer run time
• Simulated sensitivity to inputs

• Calibration is relatively simple and fast
• Calibration is precise
• Shorter run time
• Sensitivity to inputs must be specified

Multiple Models
Reduction in forest loads 1985 to CAIR

AGCHEM

Reduction in forest loads 1985 to CAIR

Export Reduction vs. Atmospheric Deposition Reduction

- AGCHEM

- DE
- DC
- MD
- NY
- PA
- VA
- WV

- 0% 10% 20% 30% 40% 50% 60% 70%
- 0% 5% 10% 15% 20% 25% 30% 35% 40%

Atmospheric Deposition Reduction

Export Reduction
Results:

Regression of monthly nitrate yield

Estimating nitrate export from Chesapeake Bay watersheds using MODIS and climate data

Aditya Singh and Phil Townsend
Angélica Gutiérrez-Magness
Keith Eshleman
Brenden McNeil
### Total Nitrogen, 2002

\(n = 181, \text{ MSE} = 0.0836, \text{ RMSE} = 0.289, \text{ flux } R^2 = 0.978, \text{ yield } R^2 = 0.85\)

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Estimate</th>
<th>Units</th>
<th>90-percent confidence interval</th>
<th>Standard error</th>
<th>(p^1)</th>
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</thead>
<tbody>
<tr>
<td><strong>Sources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Point sources (kg yr(^{-1}))</td>
<td>0.774</td>
<td></td>
<td>0.375 – 1.17</td>
<td>0.242</td>
<td>0.0008</td>
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<tr>
<td>Crop fertilizer and fixation (kg yr(^{-1}))</td>
<td>0.237</td>
<td></td>
<td>0.177 – 0.297</td>
<td>0.0363</td>
<td>&lt; 0.0001</td>
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<tr>
<td>Manure (kg yr(^{-1}))</td>
<td>0.0582</td>
<td></td>
<td>0.0138 – 0.103</td>
<td>0.0269</td>
<td>0.0157</td>
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<tr>
<td>Atmospheric deposition (kg yr(^{-1}))</td>
<td>0.267</td>
<td></td>
<td>0.179 – 0.355</td>
<td>0.0533</td>
<td>&lt; 0.0001</td>
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<tr>
<td>Urban(^2) (km(^2))</td>
<td>1.090</td>
<td>kg km(^{-2}) yr(^{-1})</td>
<td>707 – 1.480</td>
<td>234</td>
<td>&lt; 0.0001</td>
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<tr>
<td><strong>Land-to-water delivery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ln[Mean EVI for WY02 (dimensionless)]</td>
<td>-1.70</td>
<td></td>
<td>-2.65 – -0.737</td>
<td>0.580</td>
<td>0.0039</td>
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<tr>
<td>ln[Mean soil AWC (fraction)]</td>
<td>-0.829</td>
<td></td>
<td>-1.26 – -0.401</td>
<td>0.260</td>
<td>0.0016</td>
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<tr>
<td>ln[Groundwater recharge (mm)]</td>
<td>0.707</td>
<td>mm(^{-1})</td>
<td>0.499 – 0.916</td>
<td>0.126</td>
<td>&lt; 0.0001</td>
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<tr>
<td>ln[Piedmont carbonate (percent of area)]</td>
<td>0.158</td>
<td></td>
<td>0.0755 – 0.241</td>
<td>0.0500</td>
<td>0.0018</td>
</tr>
</tbody>
</table>

\(A.\) Local yields attributable to atmospheric deposition

![Map showing yield values in square kilometers per year](image-url)
Benefits

• The CBP Partnership wants transparency:
  – Simplicity
  – Scalability
  – Ease of Use
  – Understandability

• Ease of calibration and operations

• Clear role for multiple models
Multiple Models in the Watershed Model

Precipitation

Fertilizer
Manure
Atmospheric deposition

Management filter

Runoff

Hydrology submodel
Sediment submodel
Phosphorus submodel
Nitrogen submodel

River

hourly
Expert Review Panels; Planned and Active

**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
Scientific advantages of MM

• Compares hypotheses about system function
• Identifies agreements (high confidence)
• Identifies disagreements (low confidence)
• Guides research and data collection
• Helps quantify uncertainties
  – Prediction uncertainty
  – Model selection uncertainty
**Possible** management benefits

- Demonstrate skill of decision model (as good or better than others)
- Bolster confidence (scientists, managers, & public) in model and decisions based upon it
Possible objections to MM

• More work, costs more
• Highlights uncertainties
• May confuse public and decision makers
• May provoke legal challenges
• May be incompatible with CWA and TMDL rules
Possible objections to MM

costs

• More work, costs
• Highlights uncertainties
• May confuse public and decision makers
• May provoke legal challenges
• May be incompatible with CWA and TMDL rules
Difference between Hurricane and TMDL: Managers decide where the TMDL lands