A History of Nutrient and Sediment Inputs to Chesapeake Bay, 1985-2016:

Three decades of monitoring and coordinated restoration in the Chesapeake Watershed

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Purpose

1. Provide feedback on net observed changes in inputs to Chesapeake Bay
2. Clarify technical trend jargon for fluvial systems
3. Help bridge the understanding of watershed changes with estuarine response

Scope

1. River Monitoring\(^1\) (RIM 1985-2016)
2. Watershed models (WSM6.0\(^3\)) (SPARROW\(^2\))
3. Wastewater inputs (CBPO\(^3\))
4. Atmospheric Deposition (NADP\(^3\))

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\(^3\) Chesapeake Bay Program Office, 2018.
Average Inputs to Chesapeake Bay

**Freshwater**
- Direct Deposition: 15.9%
- Direct Wastewater: 2.2%
- Unmonitored: 16.1%
- Monitored (RIM): 66%

**Nitrogen**
- Shoreline Erosion: 1%
- Direct Deposition: 6%
- Direct Wastewater: 14%
- Unmonitored Non Point: 21%
- Monitored Fluvial: 58%

**Phosphorus**
- Shoreline Erosion: 7.8%
- Direct Deposition: 7.7%
- Direct Wastewater: 11%
- Unmonitored Non Point: 17%
- Monitored Fluvial: 57%

**Sediment**
- Shoreline Erosion: 43%
- Direct Wastewater: 0.2%
- Unmonitored Non Point: 12%
- Monitored Fluvial: 45%
Expected Total Nutrient and Sediment Reduction Due to Agricultural and Developed BMPs

Improvements based on local load to streams based on WSM 5.3.2

- **Nitrogen**
  - 1985: 1.5%
  - 2014: 11.0%

- **Phosphorus**
  - 1985: 0.5%
  - 2014: 19.0%

- **Sediment**
  - 1985: 8.70%
  - 2014: 23%

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Preliminary information-Subject to revision. Not for citation or distribution.
Flow Normalized Loads

PATUXENT RIVER AT BOWIE MD
TOTAL NITROGEN

LOAD KG/m³

WATER YEAR

USGS
science for a changing world
# Characterizing Observed Changes in Annual Load

<table>
<thead>
<tr>
<th>Test / Slope Estimate</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann Kendall / Sen Slope</td>
<td>• Robust nonparametric trend test on annual data.</td>
<td>• Limited power relative to sampled observations</td>
</tr>
<tr>
<td></td>
<td>• Slope scaled to annual time series</td>
<td></td>
</tr>
<tr>
<td>Seasonal Kendall / Seasonal Sen Slope</td>
<td>• Robust nonparametric trend test on seasonal (monthly) data.</td>
<td>• Slope is scaled to monthly observation</td>
</tr>
<tr>
<td></td>
<td>• Increased power in trend detection (12 seasons per year)</td>
<td>• Slope is insensitive to seasons with large change</td>
</tr>
</tbody>
</table>
Trends in Observed Loads

**PATUXENT RIVER AT BOWIE MD**

**TOTAL NITROGEN**

LOAD KG/Å6


WATER YEAR

Sen Slope **-0.012** Mkg/yr, MK p=0.003

Seasonal Sen Slope **-0.0013** Mkg/yr, SK p<0.00001
Trends in Observed Loads

JAMES RIVER AT CARTERSVILLE, VA
TOTAL NITROGEN

LOAD KG^6

WATER YEAR


Sen Slope -0.059 Mkg/yr, MK p=0.243
Seasonal Sen Slope -0.024 Mkg/yr, SK p<0.02
Trends in Observed Loads

SUSQUEHANNA RIVER AT CONOWINGO, MD
SUSPENDED SEDIMENT

LOAD KG^6

0 5000 10000 15000


WATER YEAR

Sen Slope 1.58 Mkg/yr, MK p=0.92
Seasonal Sen Slope -0.294 Mkg/yr, SK p=0.8
# Summary of Observed and Flow-Normalized Change

<table>
<thead>
<tr>
<th></th>
<th>Total Nitrogen</th>
<th>Total Phosphorus</th>
<th>Suspended Sediment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slope</td>
<td>Slope</td>
<td>Slope</td>
</tr>
<tr>
<td>Choptank</td>
<td>0.00406</td>
<td>0.00701</td>
<td>0.000453</td>
</tr>
<tr>
<td>Susquehanna</td>
<td>-0.378</td>
<td>-10.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Patuxent</td>
<td>-0.013</td>
<td>-0.816</td>
<td>-0.000497</td>
</tr>
<tr>
<td>Potomac</td>
<td>-0.0475</td>
<td>-2.33</td>
<td>-0.00285</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>0.00305</td>
<td>-0.541</td>
<td>0.00393</td>
</tr>
<tr>
<td>Mattaponi</td>
<td>-0.00333</td>
<td>0.00792</td>
<td>0.000409</td>
</tr>
<tr>
<td>Pamunkey</td>
<td>0.000243</td>
<td>-0.0213</td>
<td>-0.0000166</td>
</tr>
<tr>
<td>James</td>
<td>-0.0587</td>
<td>-1.12</td>
<td>-0.0269</td>
</tr>
<tr>
<td>Appomattox</td>
<td>-0.00499</td>
<td>-0.0153</td>
<td>-0.000193</td>
</tr>
</tbody>
</table>

Slope reported in million kg/yr

- **Green** Decreasing
- **Yellow** Increasing
Load vs. Flow Weighted Concentration Trend
Susquehanna River at Conowingo, Md.

Flow-Weighted Concentration = \frac{\text{True Condition Load}}{\text{Annual Flow}}
## Summary of Flow Weighted Concentration Trends

<table>
<thead>
<tr>
<th></th>
<th>Mean annual FWC, mg L-1</th>
<th>Change in FWC, mg L-1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P00600</td>
<td>P00665</td>
</tr>
<tr>
<td>Choptank</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Susquehanna</td>
<td>1.7</td>
<td>0.07</td>
</tr>
<tr>
<td>Patuxent</td>
<td>2.2</td>
<td>0.17</td>
</tr>
<tr>
<td>Potomac</td>
<td>2</td>
<td>0.15</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>1.2</td>
<td>0.19</td>
</tr>
<tr>
<td>Pamunkey</td>
<td>0.74</td>
<td>0.09</td>
</tr>
<tr>
<td>Mattoponi</td>
<td>0.6</td>
<td>0.06</td>
</tr>
<tr>
<td>James</td>
<td>0.78</td>
<td>0.17</td>
</tr>
<tr>
<td>Appomattox</td>
<td>0.61</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*Decreasing* | *Increasing*
A History of Nutrient and Sediment Inputs to Chesapeake Bay: 1985-2016

ESTIMATED LOADS DOWNSTREAM FROM MONITORING

USGS science for a changing world
Unmonitored Nonpoint source Nitrogen
From CBP WSM 6.0 Calibration runs

Western Shore

Nitrogen Load, million kg/yr


p=.09

Eastern Shore

Nitrogen Load, million kg/yr


p=.59

Sen Slope Line
Loess Smooth
Unmonitored Nonpoint source Phosphorus

From CBP WSM 6.0 Calibration runs

Western Shore

Eastern Shore

Phosphorus Load, million kg/yr


p=.03

Phosphorus Load, million kg/yr


p=0.9

Sen Slope Line
Loess Smooth

USGS
Unmonitored Nonpoint source Suspended Sediment
From CBP WSM 6.0 Calibration runs

Western Shore

Eastern Shore

Sediment Load, million kg/yr

Sen Slope Line
Loess Smooth
Direct Nitrogen Deposition to Tidal Waters
Wastewater Load Reduction

Nitrogen
- Tidal: 61% reduction
- Streams: 31% reduction

Phosphorus
- Tidal: 78% reduction
- Streams: 75% reduction
Nitrogen Sources

Nitrogen non-point source delivered yield (kg/ha)
- 60% of area delivers 24% of TN load (<5.11 kg/ha)
- 30% of area delivers 36% of TN load (<13.3 kg/ha)
- 10% of area delivers 40% of TN load (max 92.0 kg/ha)

Nitrogen kg/Ha

<table>
<thead>
<tr>
<th>River</th>
<th>Nitrogen kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choptank</td>
<td>17.4</td>
</tr>
<tr>
<td>Susquehanna</td>
<td>19.5</td>
</tr>
<tr>
<td>Patuxent</td>
<td>17.3</td>
</tr>
<tr>
<td>James</td>
<td>16.3</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>10.4</td>
</tr>
<tr>
<td>Mattaponi</td>
<td>5.0</td>
</tr>
<tr>
<td>Pamunkey</td>
<td>3.9</td>
</tr>
<tr>
<td>James</td>
<td>6.9</td>
</tr>
<tr>
<td>Appomattox</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Phosphorus Yields

Phosphorus non-point source delivered yield (kg/ha)
- 80% of area delivers 39% of TP load (<0.42 kg/ha)
- 15% of area delivers 33% of TP load (<1.15 kg/ha)
- 5% of area delivers 28% of TP load (max 9.12 kg/ha)

Phosphorus kg/Ha

Choptank 1.1
Susquehanna 0.9
Patuxent 1.4
James 1.3
Patuxent 1.6

Load
0e+00 2e+08 4e+08
MKp = 0.104
SS = 2760000

Summary of Findings

• Observed long-term trends in loads at times differ from flow-normalized trend estimate.

• Realized changes are often considerably smaller than flow-normalized results suggest.

• Interannual variations in weather and streamflow can mask real changes in mass flux delivery to the bay.

• Flow-Weighted concentration trends indicate a real difference in the quality of water entering the bay.
Implications from measures of progress

• Eastern Shore NPS show little change, yet Choptank River continues to show increasing trends.

• Watershed model results for the Western shore shows continued slight increases in loads, which are consistent with development in unmonitored regions.

• Sediment and phosphorus trends at the Susquehanna River at Conowingo suggest that impacts of reservoir infill on Chesapeake Bay are largely episodic.