Linking Science and Policy: Use of Critical Deposition Loads to Inform Environmental Protection Strategies

Collaborating Scientists:
T.J. Sullivan\textsuperscript{1}, B.J. Cosby\textsuperscript{2}, C.T. Driscoll\textsuperscript{3}, T.C. McDonnell\textsuperscript{1}, Q. Zhou\textsuperscript{3}, D.A. Burns\textsuperscript{4}

NYSERDA Conference, October, 2009

\textsuperscript{1} E&S Environmental Chemistry, Inc., P.O. Box 609, Corvallis, OR 97339
\textsuperscript{2} Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22932
\textsuperscript{3} Department of Civil and Environmental Engineering, Syracuse University, Syracuse, NY 13244
\textsuperscript{4} U.S. Geological Survey, Troy, NY 12180
Roadmap for Today’s Talk

Critical load:
- What is it?
- How is it calculated?
- How is it used?

Some examples:
- Virginia and West Virginia – Steady State Model Approach
- Shenandoah National Park – Dynamic Model Approach

What are we doing in New York?
What is a critical load?
What are the sensitive receptors that we want to protect?
How is a critical load calculated?
How can the critical load concept be used?
Major Decision Points

- Aquatic vs terrestrial
- Acidification vs nutrient enrichment
- Steady state vs dynamic
- Critical load vs target load
- Chemistry vs biology
- Site-specific vs regional

What other factors must be considered in calculating a critical or target load?
<table>
<thead>
<tr>
<th>Biological Indicators</th>
<th>Receptors</th>
<th>Chemical Criteria</th>
<th>Critical Limit</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish; other aquatic biota</td>
<td>Surface water chemistry</td>
<td>ANC [\text{NO}_3^-] concentration</td>
<td>0, 20, 50 5, 20</td>
<td>(\mu\text{eq/L})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(\mu\text{eq/L})</td>
</tr>
<tr>
<td>Forest health</td>
<td>Soil B horizon chemistry</td>
<td>Base saturation</td>
<td>10, 15</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>Soil solution (B-horizon) chemistry</td>
<td>Ca:Al molar ratio</td>
<td>1, 10</td>
<td>Unitless</td>
</tr>
<tr>
<td>N uptake</td>
<td>Tree foliar chemistry (species TBD)</td>
<td>Foliar N concentration Chemical ratio (TBD)</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
</tbody>
</table>
Example Models for Calculating Critical Loads:

1) Steady State Water Chemistry Model

\[ CL(A) = BC_{\text{dep}} + BC_{\text{w}} - Bc_{\text{up}} - \text{ANC}_{\text{limit}} \]

2) Dynamic Model

MAGIC

PnET-BGC
It’s mostly about weathering!
A Steady State Example:
Regional Application of SSWC to Streams in VA and WV
What to do about weathering?
1) Simulate weathering at 92 sites using MAGIC
2) Extrapolate MAGIC estimates of weathering to the region
3) Model regional CLs using SSWC
4) Assign CLs to individual stream reaches
5) Calculate CL exceedances
BC_w Predictor Variables

• Landscape Characteristics
  – Watershed Area
  – Elevation
  – Slope
  – Geologic classes
  – Soil variables (% clay, pH, depth)
• Water Chemistry (500+ sites)
  – Sum of base cations
  – Sum of base cations – chloride
  – ANC
  – Sulfate
  – Nitrate
Predicting $\text{BC}_w$ from Available Spatial Data

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>n</th>
<th>Predictor Variables</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With Water Chemistry:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Appalachian</td>
<td>24</td>
<td>SBC, NO$_3$, WS Area</td>
<td>0.93</td>
</tr>
<tr>
<td>Ridge &amp; Valley</td>
<td>42</td>
<td>SBC, Elevation (-), Slope (-)</td>
<td>0.85</td>
</tr>
<tr>
<td>Blue Ridge</td>
<td>26</td>
<td>ANC, NO$_3$</td>
<td>0.90</td>
</tr>
<tr>
<td>Ecoregion</td>
<td>n</td>
<td>Predictor Variables</td>
<td>$r^2$</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-----</td>
<td>----------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Without Water Chemistry:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Appalachian</td>
<td>24</td>
<td>Soil pH (-)</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WS Area</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation (-)</td>
<td></td>
</tr>
<tr>
<td>Ridge &amp; Valley</td>
<td>42</td>
<td>% Siliciclastic (-)</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Carbonate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation (-)</td>
<td></td>
</tr>
<tr>
<td>Blue Ridge</td>
<td>26</td>
<td>% Siliciclastic (-)</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil % Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil Depth (-)</td>
<td></td>
</tr>
</tbody>
</table>
Steady State Water Chemistry Model (SSWC)

\[ CL(A) = BC_{dep} + BC_w - Bc_{up} - ANC_{limit} \]
Time to Steady State ANC (μeq/L) Starting 2020 Using SSWC Critical Loads

- ANC 20  (n = 45)
- ANC 50  (n = 54)
Things to move from the back of your mind to the front of your mind when addressing critical and target loads

1. Time frame matters.

2. There are multiple possible chemical indicators; each relates somehow to biology.

3. Do you want to base policy on one lake or one stream? You need to know about the broader population of lakes and/or streams.
4. Most lakes or streams in a given region are generally NOT acid-sensitive (critical load is very high). Focus on the relatively small number of waters that are sensitive.

5. Some acidified lakes and streams are not projected to recover to critical criteria values even if deposition is reduced to zero because they were not that high to begin with.

6. It’s important to separate the science (objective) from the policy (judgment). The science is reflected in the modeling. There are MANY policy judgments to be made, and they should be clearly documented.