



Environmental
Chemistry, Inc.

Project Title: Geospatial Modeling of Critical Loads of Atmospheric Sulfur and Nitrogen Deposition and their Exceedance in Streams of the Appalachian Mountain Region in Virginia and West Virginia

Tim Sullivan, E&S Environmental Chemistry, Inc., P.O. Box 609 Corvallis, OR 97339, (541) 758-5777, tim.sullivan@esenvironmental.com

Todd McDonnell, E&S Environmental Chemistry, Inc., P.O. Box 609 Corvallis, OR 97339, (541) 758-1330, todd.mcdonnell@esenvironmental.com

Background

The critical load (CL) is defined as the level of sustained atmospheric deposition of sulfur (S) and nitrogen (N) below which significant harm to sensitive ecosystems does not occur according to current scientific understanding. For the sensitive receptor stream water, the most commonly selected chemical indicator is acid neutralizing capacity (ANC). Results are reported here for a pilot project that explores a new approach to CL modeling and mapping for the southeastern United States. This approach relies on the NHDPlus database for model parameterization and to express results across the regional landscape.

The Steady-State Water Chemistry (SSWC) model was used to calculate a simple balancing of watershed base cation (BC; e.g., calcium, magnesium, sodium, potassium) inputs and outputs with the atmospheric deposition of strong acids. The watershed supply of BC due to weathering (BC_w) is the CL model parameter that generally has the most influence in the CL calculation and the most uncertainty.

The NHDPlus database (Version 1) was used to develop the hydrologic framework used as the basis for modeling BC_w and CL throughout the regional landscape. The hydro-enforced digital elevation model (DEM) and resulting flow direction grid generated by NHDPlus were used to establish fine scale watersheds ($\sim 1\text{km}^2$) throughout the Appalachian Mountains of Virginia and West Virginia. The hydrologically conditioned flow direction data from NHDPlus resulted in a substantially more realistic representation of surface flow than was otherwise obtained using flow direction data generated from the raw unprocessed DEMs.

Calculation of Critical Load

The stream network generated from the NHDPlus data was based on a minimum contributing area threshold of 0.5 km^2 . The lower boundary of each watershed was determined on the basis of topographically determined stream junctions. This process resulted in generation of a synthetic stream network that was intermediate in stream size and density between the 1:100,000 National Hydrography Dataset (NHD) moderate

resolution stream network and the high resolution 1:24,000 NHD network.

Values for each of the terms in the SSWC model were calculated for every 30 m grid cell in the study region and the SSWC equation was solved to yield an estimate of CL for each 30 m grid cell. The representative watershed CL value was then calculated for each topographically determined watershed as an average of the CL values calculated at each stream cell (each grid cell that intersected a topographically determined stream) within the watershed. A regional watershed CL map was prepared for each critical ANC indicator value (ANC targets of 0, 20, 50, and 100 $\mu\text{eq/L}$).

Critical load results were also depicted for the network of streams that flow through these watersheds. The CL estimates for each watershed were intersected with high-resolution NHD stream data. This process yielded a regional stream coverage that was coded with CL according to the value given to its associated watershed.

For the study area as a whole, about 30% to 40% of the stream length (depending on selection of threshold ANC value) was classified as having CL above 200 $\text{meq/m}^2/\text{yr}$. The remainder of the stream length had lower calculated CL values, with about one-fourth of the stream length having CL below 100 $\text{meq/m}^2/\text{yr}$. For most CL classes, there was not much difference in the extent of stream length within the class as influenced by the threshold ANC value selected. For the lowest CL class (less than 50 $\text{meq/m}^2/\text{yr}$), however, choice of threshold ANC value made a substantial difference to the stream length calculations. The length of stream estimated to have $CL \leq 50\text{ meq/m}^2/\text{yr}$ across the study area varied by about a factor of four depending on which threshold ANC value was selected.

Critical loads were generally much lower and more heavily influenced by selection of the threshold ANC value for Wilderness streams as compared with non-Wilderness streams. About 70% of the Wilderness stream length had CL less than 100 $\text{meq/m}^2/\text{yr}$ to protect to stream ANC above 50 $\mu\text{eq/L}$. Nearly half of the Wilderness stream length had CL less than 100 $\text{meq/m}^2/\text{yr}$ to protect to stream ANC above 0 $\mu\text{eq/L}$.

Critical Load Exceedance

Watershed-averaged values of total ambient deposition of acidity (S + N) were overlaid with the CL maps to generate regional estimates of CL exceedance, to identify areas where ambient deposition exceeds the CL. Broad areas of the study region were found to be in CL exceedance when compared to the 5-year average deposition centered on 2005. Such areas are disproportionately associated with Wilderness and other public lands (Figure 1).

Half of the stream length within the study region was calculated to receive current acidic deposition in exceedance of the CL to protect against stream ANC below 0 $\mu\text{eq/L}$. That percentage increased to 53% for the threshold ANC value of 20 $\mu\text{eq/L}$, to 57% for the threshold ANC value of 50 $\mu\text{eq/L}$, and 63% for the threshold ANC value of 100 $\mu\text{eq/L}$. Nearly one-fourth of the stream length in the study region was estimated to be receiving acidic deposition that is more than double the CL for protecting stream ANC from going below 50 $\mu\text{eq/L}$. Exceedance of the CL was most prevalent in the Blue Ridge ecoregion, followed by the Central Appalachian ecoregion.

Summary

The SSWC steady-state CL model was applied in a regional pilot study to estimate CLs and exceedances for aquatic resources in streams in the southeastern United States. A computationally efficient and robust method for estimating weathering on a continuous basis across a regional landscape was developed using the NHDPlus database. It was based on weathering estimates extracted from a well-tested process-based watershed model of drainage water acid-base chemistry and also on features of the landscape that are available as regional spatial data coverages. This approach avoids many of the uncertainties associated with other common methods for estimating BC_w for input into SSWC and other steady-state CL models.

Results indicate that more than half of the streams within the study region receive current acidic deposition that is higher than the steady state CLs. Furthermore, results indicate that most of the modeled watersheds will likely not reach the steady-state condition for hundreds of years after continuous constant deposition at the CL levels are established.

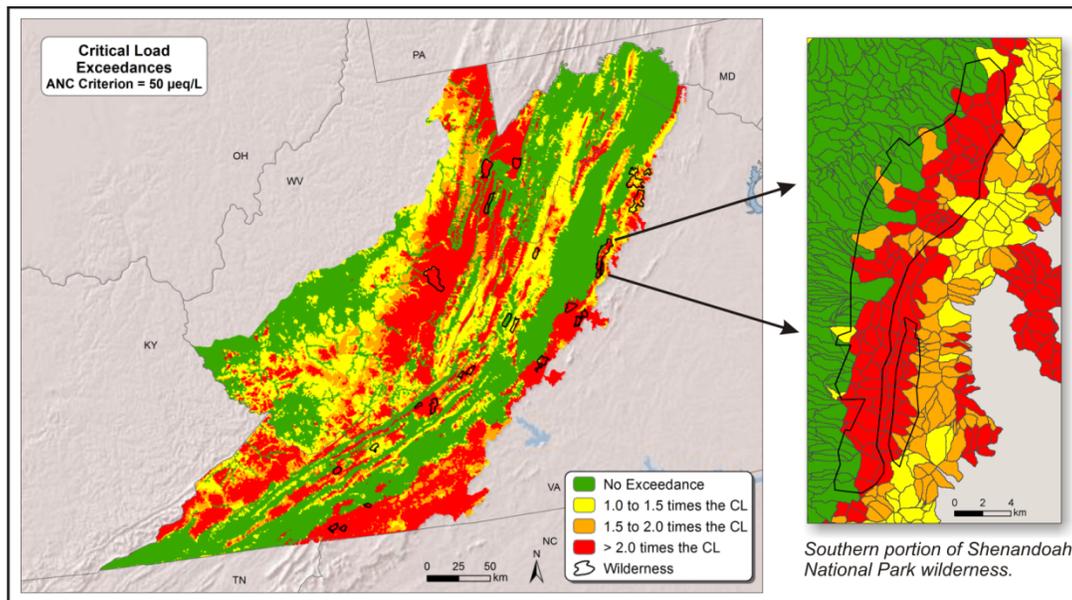


Figure 1. Critical load exceedance map for the ANC criterion 50 $\mu\text{eq/L}$.

Related Information

- McDonnell, T.C., B.J. Cosby, and T.J. Sullivan. 2012. Regionalization of soil base cation weathering for evaluating stream water acidification in the Appalachian Mountains, USA. *Environmental Pollution*. 162:338-344.
- Sullivan, T.J., B.J. Cosby, T.C. McDonnell, E. Porter, T. Blett, R. Haeuber, C.M. Huber, and J. Lynch. In Press. Critical Loads of Acidity to Protect and Restore Acid-Sensitive Streams in Virginia and West Virginia. *Water, Air, and Soil Pollution*. DOI: 10.1007/s11270-012-1312-4.