# Surface Water Critical Loads for Acidity
# McDonnell et al., 2014

### Metadata for supporting GIS files:

NCLD_SW_GIS_McDonnell_v3.gdb

### Content

These geographic information system (gis) files contain only critical loads from McDonnell et al. 2014 that are part of the National Critical Load Database v3.0 (NCLD) for surface water (SW) acidification.

### Data and Project Citation

McDonnell, T.D., Sullivan, T. J., Hessburg, P.F., Reynolds, K.M., Povak, N.A., Cosby, B. J., Jackson, W., & Salter, R.B. 2014. Steady-state sulfur critical loads and exceedances for protection of aquatic ecosystems in the U.S. southern Appalachian Mountains. Journal of Environmental Management 146 (2014) 407-419. DOI:. http://dx.doi.org/10.1016/j.jenvman.2014.07.019

### NCLD Database Citation

Lynch, J.A., Phelan, J., Pardo, L.H., McDonnell, T.C., Clark, C.M., and Bell, M.D. 2020. Detailed Documentation of the National Critical Load Database (NCLD) for U.S. Critical Loads of Sulfur and Nitrogen, version 3.1, National Atmospheric Deposition Program, Wisconsin State Laboratory of Hygiene, Madison, WI.

### Critical Load Overview

For this study, CLS were derived using a modified form of the SSWC model that excluded the N terms. Building on the framework of Sullivan et al., (2012) and McDonnell et al., (2012), McDonnell et al. (2014) and Povak et al. (2014) expanded the study area and developed new statistical models to better predict $BC_w$ and evaluate CLs of S. Their study expanded the area to include the full Southern Appalachian Mountain (SAM) region and surrounding terrain from northern Georgia to southern Pennsylvania, and from eastern Kentucky and Tennessee to central Virginia and western North Carolina. As with Sullivan et al., (2012) and McDonnell et al., (2012), the MAGIC model was used to calculate watershed-specific $BC_w$ for 140 stream locations containing both measured soil chemistry and water chemistry data (see section above on page A-14 for a description of MAGIC). In addition, McDonnell et al., (2014) aggregated all known water quality data that totaled 933 sample locations in order to develop a statistical model to predict ANC and $BC_w$ for all streams in the SAM region. Water chemistry data were collected between 1986 and 2009, with stream ANC calculated as the equivalent sum of the base cation concentrations ($Ca^{2+}$, $Mg^{2+}$, $K^+$, $Na^+$, ammonium [$NH_4^+$]) minus the sum of the mineral acid anion concentrations (chloride [$Cl_-$], $NO_3^-$, $SO_4^{2-}$). $BC_w$ was estimated as the net internal source of base cations between weathering and base cation exchange for the watershed based on the MAGIC model calibrations, which used observed stream, soil, and atmospheric deposition data to match current observed stream and soil chemistry conditions. With the use of a random forest regression modeling technique, a continuous

$BC_w$ layer was regionalized using a suite of initial candidate predictor variables chosen to represent potential broad- to fine-scale climatic, lithologic, topoedaphic, vegetative, and S deposition variables that have the potential to influence ANC and $BC_w$. To represent the landscape conditions that influence specific locations along a stream, all candidate landscape predictor variables were expressed on a 30 m grid basis across the SAM's domain and were upsloped averaged based on the technique described in McDonnell et al., (2012). This resolution allowed for the creation of "flowpaths" for the development of a topographically determined stream network. This approach allowed for a total of 140,504 watersheds which were represented (i.e. delineated) with the use of a hydrologically conditioned DEM. CLs were calculated for all grid cells that had a predicted "low" ANC value (<300 μeq/L). If the grid value was predicted to be greater than 300 μeq/L, then the grid cell was considered well-buffered and assigned an arbitrarily large ANC and CL (e.g. 8888) value. CLs were then calculated with SSWC (Henriksen and Posch, 2001) with estimates of BCdep, $BC_w$ , $Bc_u$, $Q_s$ and an ANC chemical criteria set to an value of 50 μeq/L for each stream node.. See McDonnell et al., (2014) and Povak et al., (2014) for additional methods detail. A summary of model parameters is included in Table A2-8.

CLs exceedances can be calculated as total S deposition minus the CL. In McDonnell et al., (2014), estimates of S deposition were calculated for two time periods as three-year averages centered on 2001 and 2011. These deposition rates were used to evaluate changes in CL exceedance over the period 2001 to 2011.

**Table 1. Description of Variables in the Database for Surface Water Critical Load of Acidity Calculations for McDonnell et al., 2014.**

| Variable | Criterion (Units) | Description of the Variable | Data Source | Data | Assumptions and value |
|---|---|---|---|---|---|
| ChemCriterion/ ChemThreshold | ANC μeq/L | Critical value for chemical criterion | n/a | n/a | ANClimit = 50 μeq/L |
| $BC_{dep}$ | $meq/m^2$-yr | BC; Ca+Mg+K+Na | NADP-Grimm (wet) Grimm and Lynch, 2005. Baker, 1991 (dry), using dry:wet ratio. | 3-year average centered at 2002 | Wet and Dry deposition |
| $CL_{dep}$ | $meq/m^2$-yr | Wet deposition of chloride | n/a | n/a | |
| $BC_w$ | eq/ha-yr or $meq/m^2$-yr | BC; Ca+Mg+K+Na | Regionalization of BCw based on Random Forest (RF) modeling techniques. | | |
| $Bc_u$ | $meq/m^2$-yr | Bc; Ca+Mg+K | McNulty et al., 2007. | | |
| $N_i$ | $meq/m^2$-yr | Acceptable nitrogen immobilized in soil | n/a | n/a | |
| $N_{de}$ | $meq/m^2$-yr | Denitrification rate in catchment | n/a | n/a | |
| $N_{ni}$ | $meq/m^2$-yr | Nitrification rate in the catchment | n/a | n/a | |
| $N_{leach}$ | $meq/m^2$-yr | N leaching from the watershed as $[NO_3]*Q_R$ | n/a | n/a | |
| $Q_S$ | m/yr | Annual runoff flux | McCabe & Wolock, 2011 | n/a | |

| | | | | | |
|---|---|---|---|---|---|
| Watershed/stream reaches | $km^2$ | Watersheds | Watersheds were delineated based on hydrologically conditioned DEM derivatives from the National Hydrography Dataset (NHDPlus; USEPA and U. S. Geological Survey [USGS], 2005). This process delineated a total of 140,504 watersheds within the study region, with an average size of approximately 1 $km^2$. | | |

**Critical load exceedance**

Critical load exceedance here can be considered with respect to S deposition (Eq. 1). The maximum CL of S (CLmaxS) is the CL for acidity expressed in terms of S when N deposition is zero.

$$Ex(S) = \text{Total S deposition} - \text{ClmaxS} \qquad (1)$$

**See NCLD Database v3 0 document for more details.**

## Projection

| USA_Contiguous_Albers_Equal_Area_Conic_USGS_version | |
|---|---|
| Projection: Albers | Geographic Coordinate System: GCS_North_American_1983 |
| False_Easting: 0.00000000 | Datum: D_North_American_1983 |
| False_Northing: 0.00000000 | Prime Meridian: Greenwich |
| Central_Meridian: -96.00000000 | Angular Unit: Degree |
| Standard_Parallel_1: 29.5.00000000 | |
| Standard_Parallel_2: 45.00000000 | |
| Latitude_of_Origin: 23.00000000 | |
| Linear_Unit: Meter | |

## No Data Values

The values -9999, -9999.99, -9999.999 are used in numeric fields and “(no data)” or “(n/a)” is used in text fields within the database to represent “no data” or “does not apply.”

## Attribute Descriptions

| Variable | Explanation | Format |
|---|---|---|
| CLID | Unique(!) identifier across all three CL grouping: Forest Ecosystem, Surface Waters, and Empirical Nitrogen. | Text |
| PRID | Unique(!) identifier of the CL project. | Integer |
| LOCID | Unique(!) identifier of a particularly location as defined as a lake body or stream reach as classified by NHD+2.0. In many cases, a single waterbody (lake or stream reach) may have more than one CL value because more than one source estimated a CL for it. The LOCID can be used to aggregate CLs for a particularly lake or stream reach. | Integer |
| CL_Class | Critical load class across all tables:<br>Forest Soil Acidity<br>Surface Water Acidity<br>Empirical | Text |
| SiteID | Project specific identifier of the site. | Text |
| LatDD | Latitude (decimal degrees). | Double |
| LongDD | Longitude (decimal degrees). | Double |
| CL_Type | Critical load type:<br>Steady-state<br>Target-load<br>Empirical. | Text |
| CLmaxS | Maximum CL of S (eq/ha-yr). | Double |
| CLminN | Minimum CL of N (eq/ha-yr). See Appendix 2 for a summary of the minimum CL of N. | Double |
| CLmaxN | Maximum CL of N (eq/ha-yr). | Double |
| ChemCriterion | Chemical criterion used:<br>ANC. | Text |
| ChemThreshold | Value of the chemical threshold used. | Long |
| PrimRef | Publication citation for primary study for the CL. | Text |
| CL_Unit | $meq/m^2$-yr | Text |

### Linking/Joining to Database Tables

NCLD Tables (1B, 2B, and 3B) can be joined using the CLID.

### Critical Load Database and Information Use Conditions

## Disclaimer

The National Atmospheric Deposition Program (NAPD) Critical Loads of Atmospheric Deposition (CLAD) Science Committee National Critical Loads Database (NCLD) for Nitrogen (N) and Sulfur (S) was developed cooperatively with individuals or groups sharing critical load (CL) data and is NOT intended to be comprehensive of all known CLs for the U.S. While substantial efforts are made to ensure the accuracy of data and documentation contained in the NCLD, complete accuracy of the information cannot be guaranteed. The qualities and accuracy of the CLs are best described in the associated research publication(s). It is important to review material and information in the cited papers prior to using the CL data within the NCLD. In addition, any opinions, findings, conclusions, or recommendations as part of these datasets do not necessarily reflect the views of CLAD, NADP, and/or respective members' affiliations.

## Use Condition and Citation

The intended use of the NCLD is for scientific, policy-related, and/or educational purposes. Any published use of the database information must acknowledge the original source(s) of the data. Each CL value is linked to its origin source(s) through the RefID field. The proper citations for each RefID can be found in Table 6 of the database. In addition, whenever the Data User presents and/or publishes research based on CLs in the database, NADP and CLAD must be acknowledged. A suggested Acknowledgement is:
"We acknowledge the Critical Loads of Atmospheric Deposition (CLAD) Science Committee of the National Atmospheric Deposition Program (NADP) for their role in making available NCLD_v3.0 datasets"

and please cite:

Lynch, J.A., Phelan, J., Pardo, L.H., McDonnell, T.C., Clark, C.M., and Bell, M.D. 2020. Detailed Documentation of the National Critical Load Database (NCLD) for U.S. Critical Loads of Sulfur and Nitrogen, version 3.1, National Atmospheric Deposition Program, Wisconsin State Laboratory of Hygiene, Madison, WI.

We request one copy of any printed publications using data from the NCLD to be sent to the NADP Program Office at the address below. Citations or electronic copies are acceptable. For online uses, we request that the author notify the Program Office of the URL address of the online publications or website that includes NCLD data. We encourage teachers and professors to send the program office a brief description of how they have used the NCLD in their curriculum. Students who use the NCLD to complete academic assignments are not required to seek permission from the Program Office, but must acknowledge NADP and CLAD in any publications (e.g., a thesis).

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### *Questions, Errors and Corrections*
Please contact NCLD manager, Jason Lynch (US EPA) with any questions about the NCLD or to report errors or corrections at lynch.jason@epa.gov or 202-343-9257.

## References

McDonnell, T.C., Cosby, B. J., & Sullivan, T. J. 2012. Regionalization of soil base cation weathering for evaluating stream water acidification in the Appalachian Mountains, USA. Environmental Pollution, 162: 338-344.

McDonnell, T.D., Sullivan, T. J., Hessburg, P.F., Reynolds, K.M., Povak, N.A., Cosby, B. J., Jackson, W., & Salter, R.B. 2014. Steady-state sulfur critical loads and exceedances for protection of aquatic ecosystems in the U.S. southern Appalachian Mountains. Journal of Environmental Management 146 (2014) 407-419. DOI:. http://dx.doi.org/10.1016/j.jenvman.2014.07.019

Povak, N.A., Hessburg, P.F., McDonnell, T.C., Reynolds, K.M., Sullivan, T.J., Salter, R.B., & Cosby, B.J. 2014. Machine learning and linear regression models to predict catchment-level base cation weathering rates across the southern Appalachian Mountain region, USA. Water Resources Research, 50: 2798–2814. DOI: http://dx.doi.org/10.1002/2013WR014203.

Sullivan, T.J., Cosby, B.J., McDonnell, T.C., Porter, E.M., Blett, T., Haeuber, R., Huber, C.M., & Lynch, J. 2012. Critical loads of acidity to protect and restore acid-sensitive streams in Virginia and West Virginia. Water Air Soil Pollution, 223:5759-5771.

## Document Information

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|---|---|
| Author: | Jason Lynch |
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