Appendix C

DATA MANAGEMENT PROTOCOL FOR CALCULATING CRITICAL LOADS FOR SULFUR AND NITROGEN FOR UPLAND FORESTED ECOSYSTEMS IN THE UNITED STATES

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Publications/presentations using information presented in the *Data Management Protocol for Calculating Critical Loads for Sulfur and Nitrogen for Upland Ecosystems in the United States* must reference this document, prepared by USDA Forest Service Northeastern Research Station scientists.

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1 Introduction

The Data Management Protocol contains instructions for preparing data for simple mass balance calculations of critical loads. Correctly formatted data are entered into and extracted from the Critical Loads database, which was developed to support the calculation of critical loads at individual upland forest sites. The instructions (Section 2) are organized by data type (climate and deposition, vegetation, and soil), and include:

1. An overview of database calculations,
2. Options for data sources and details of the intermediate calculations required for calculating critical loads,
3. An overview of the database tables, and
4. Brief descriptions of data quality control issues.

Climate and deposition, vegetation, and soil data are required for calculating critical loads. Text boxes that appear after calculation instructions indicate which calculated data should be entered into database tables. Additional parameters are included in the Critical Loads database that allow more detailed assessment of current forest ecosystem conditions. **A summary table of the required and optional parameters is provided in Appendix A**. Full definitions of all database parameters, including required units, are provided in Appendix B. A summary of the data requirements and notes about data collection are provided in Appendix C.

2 Deposition and Climate Data and Calculations

2.1 Overview of Deposition and Climate Calculations

Data in the deposition and climate section are used for calculating the exceedance (how much the actual deposition exceeds the critical load) and for estimating soil mineral weathering rates. The deposition and climate section includes deposition, air temperature, precipitation, and annual evapotranspiration (AET) data. Deposition data are used to determine the mean annual total deposition. Precipitation volume and AET are used to calculate the soil percolation rate. Temperature, precipitation, and soil percolation are used with soil data to calculate mineral weathering rates. Soil mineral weathering rates are an important component in steady-state, simple mass-balance calculation of critical load. .

Deposition and climate data are measured at individual sites or are modeled based on latitude, longitude and elevation. Few intermediate calculations are necessary for deposition and climate data.

2.2 Overview of Deposition and Climate Tables

The deposition and climate section consists of six tables: **Deposition**, **Deposition Source**, **Precipitation**, **Air Temperature**, **AET**, and **Climate Source**. Measured or modeled data are entered into the **Deposition, Precipitation, Air Temperature,** and **AET** tables. Meta-data for deposition and climate data sources are in the **Deposition Source** and **Climate Source** tables. Overviews of these tables and descriptions of how they relate to one another are given here to provide context for climate and deposition data entry and calculations. Complete descriptions of all parameters in these tables are in the Critical Loads Database parameter list (Fig. 2.1; Appendix B).

2.2.1 The Deposition Table

The **Deposition** table contains wet, dry, cloud, throughfall, and bulk deposition values for Ca, Cl, H, K, Mg, Na, and for N and S containing compounds. The data presented for all N and S compounds represent nitrogen and sulfur only (e.g. NO_3-N or SO_4-S), and not the entire molecule. The **Deposition** table is linked to the **Site** table by the *Site ID* number, and to the **Deposition Source** table by the *Deposition Source ID* number. Because data from different sources (e.g., measured on site, region-specific models, NADP) are entered into separate rows of the **Deposition** table, a single site might have multiple entries in the table.

2.2.2 The Deposition Source Table

The **Deposition Source** table contains information on the source of the data provided in the deposition table. Included in the table is information on deposition data collection method, analysis method, quality assurance, and uncertainty. The **Deposition Source** table is connected to the **Deposition** table through the *Deposition Source ID* number.

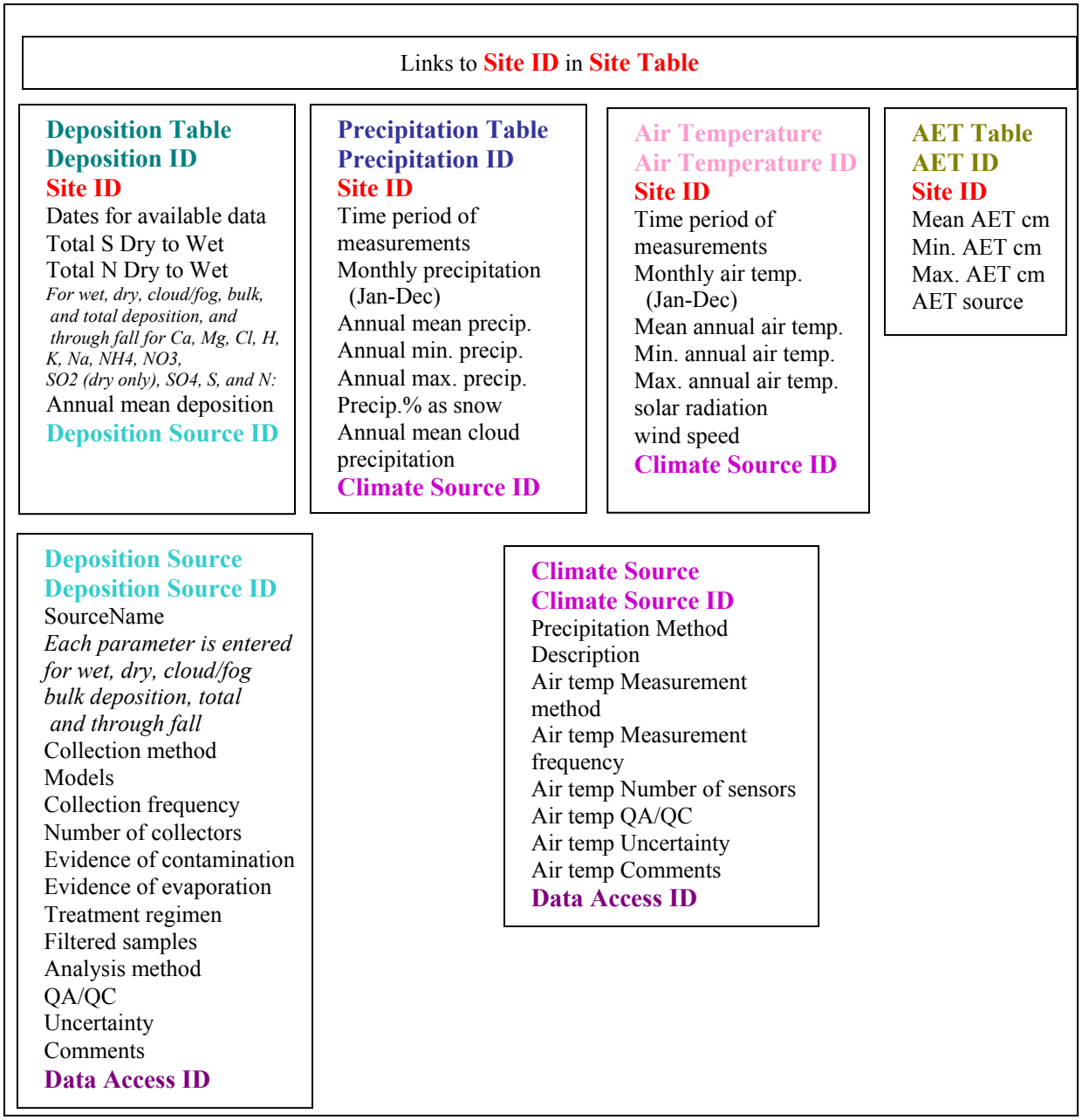

Figure 2.1 Deposition and Climate Tables

2.2.3 The Precipitation Table

The **Precipitation** table contains monthly and annual precipitation volume in cm. It is linked to the **Site** table through the *Site ID* number, and to the **Climate Source** table through the *Climate Source ID* number. Because data from separate sources (e.g., site, region-specific models, NADP) are entered into separate rows of the **Precipitation** table, a single site might have multiple entries in the table.

2.2.4 The Air Temperature Table

The **Air Temperature** table contains monthly and annual air temperature values in degrees Celsius, as well as solar radiation and wind speed values.

It is linked to the **Site** table through the *Site ID* number, and to the **Climate Source** table through the *Climate Source ID* number. Because data from separate sources (e.g., site, region-specific models, NADP) are entered into separate rows of the **Air Temperature** table, a single site might have multiple entries in the table.

2.2.5 The AET Table

The **AET** (annual evapotranspiration) table contains minimum, mean, and maximum evapotranspiration data. Evapotranspiration is the sum of evaporation and plant transpiration. AET is dependant primarily on precipitation volume, soil type (soil water holding capacity), and vegetation cover; other influencing factors include solar radiation, humidity, air temperature, and wind speed. Precipitation volume and AET are used to calculate the soil percolation rate. The **AET** table is connected to the **Site** table through the *Site ID* number. Because data from separate sources (e.g., site, region-specific models, NADP) are entered into separate rows of the **AET** table, a single site might have multiple entries in the table.

2.2.6 The Climate Source Table

The Climate Source Table contains measurement, quality assurance, and uncertainty information for data in the **Air Temperature** and **Precipitation** tables. The **Climate Source** table is linked to the **Air Temperature** and **Precipitation** tables by the **Climate Source ID** numbers.

2.3 Deposition and Climate Data Entry and Calculations

2.3.1 Deposition Data

On-site annual values are the preferred source of deposition data. If site values are unavailable, models, often based primarily on NADP data, can be used to estimate deposition rates. For New England and New York, ClimCalc (Ollinger, 1995) or HRDM (Miller, unpublished), can be used to generate deposition values.

Deposition data are annual values for either individual years or averages of multiple years, depending on the available data. If dry deposition is not available, wet: dry or wet: total

deposition ratios can be used to estimate the total load a site receives. Different ratios should be assigned based on region, forest type, and elevation. This approach takes into account the relative importance of dry and/or cloud-fog deposition.

Wet deposition data from a single location may be representative of the surrounding region, depending on the prevailing winds and landscape characteristics. Dry deposition data from a single location are not regionally representative, as the controlling factors are surface-driven and are not themselves regionally homogenous. If there are dry deposition data from a nearby site that has similar elevation and forest type, and is in the same air flowpath as the site for which calculations are being made.

2.3.1.1 Site Deposition Data

Measured deposition values come from NADP, CASNET, AIRMoN stations or other air quality or meteorological stations (often using NADP protocol). Another potential source of dry deposition data is IMPROVE haze monitoring stations, if the IMPROVE concentrations are converted into deposition rates.

2.3.1.2 Modeled Deposition Data

If measured deposition values are unavailable, modeled values from regional models can be used instead. Two models used in New England (and NY) are described here: the High Resolution Deposition Model (HRDM), and the ClimCalc model. See the VT NEG/ECP Site-specific Critical Loads Report (referred to from here on as the Vermont Technical Report; Duarte and Pardo, in preparation) for more details on the assumptions and use of the models. Other sources include NADP isopleths and Jim Lynch's model (Lynch et al., 1995), based on NADP data for non-glaciated eastern states.

Critical Loads Database Data Entry
If multiple models are available for a given site, make the deposition calculations using all models and enter the results into the database, adding information about the individual models in the **Deposition Source** table.

2.3.1.2.1 Deposition from the High Resolution Deposition Model (HRDM)

HRDM modeled values for wet, dry, and cloud deposition rates (1996-2003) are available for New England states. The HRDM model calculates multiple climatic parameters for a site based

on latitude, longitude, and elevation for multiple forest types. Prior to extracting data from the HRDM a forest type must be assigned. The forest type is determined based on species biomass distribution, which can be calculated from current biomass data (Section 2.3.1).

a. The percent biomass by species on a site is calculated by dividing the current biomass of each individual species by the total biomass values of all trees on the site (* 100).

b. The percent biomass distribution per species for the site is then compared to species distributions in the **HRDM Regional Forest Type** table in the database. The best match between on-site species distribution and regional forest type is determined. If none of the HRDM Regional Forest Types match the species distribution of a site, the HRDM Regional Forest Type is assigned based on percent hardwood and conifer at the site.

c. Deposition values for the assigned HRDM Regional Forest Type should be selected from model output values. If the assigned HRDM Regional Forest Type is not represented in the HRDM model output, there is a discrepancy of land classification between the Regional Forest Types. This may happen when a site falls close to the boundaries of two or more HRDM pixels. In these cases, the HRDM Regional Forest Type with the closest hardwood: conifer ratio can be used. HRDM Regional Forest Type flags should be entered in the database to identify if the assigned HRDM Regional Forest Type was unavailable.

Critical Loads Database Data Entry
Enter the assigned forest type code from the **Regional Forest Type** table into the RFT_dep_models column of the **Site** table. Enter the appropriate Regional Forest Type Flag into the RFT_dep_models_flag column of the **Site** table, if necessary.

2.3.1.2.2 Deposition from the ClimCalc Model

ClimCalc deposition values for New England States and New York can be calculated with a batch ClimCalc Excel file, which was obtained from Scott Ollinger at the University of New Hampshire. The regression coefficients for ClimCalc can be found in Ollinger, et al. (1995). A single site version of ClimCalc is also available online, at http://www.pnet.sr.unh.edu/climcalc/run.html. To run ClimCalc you must have site latitude, longitude, and elevation values. Unlike the HRDM model, the ClimCalc model assumes a single forest types (mature northern hardwoods). The ClimCalc model was originally developed using wet and dry deposition data from 1980-1991 and is currently being updated. As S deposition has

decreased since 1991, modeled S deposition rates from the present version are considered an overestimate.

ClimCalc provides wet and dry deposition concentration (mg/L/yr) and flux (kg/ha/yr); the flux values should be entered into the database.

Critical Loads Database Data Entry
Deposition data should be entered into the appropriate columns of the **Deposition** table; all data should be entered in units appropriate for the database. Data from two distinct time periods from the same site and measurement station should be entered into separate rows. The time period used should be entered into the *AvailableDataDates* column of the **Deposition** table.

2.3.2 Air Temperature Data

The preferred source of air temperature data are measured 30 year monthly averages. If measured data are unavailable, data from nearby meteorological stations or modeled values – either from NADP or NOAA isopleths, or accepted regional models – can be used for air temperature values.

2.3.2.1 Site Air Temperature Data

Measured air temperature values come from NADP, CASNET, AIRMoN stations or other air quality or meteorological stations. If it is available, air temperature data should come from on-site 30 year monthly averages. Long-term air temperature averages are used to capture the long-term trends for a given site and minimize single-year anomalies. Measured air temperature data for sites without 30 year measurements can be determined in two ways. If the dataset spans more than 10 years, the mean from the dataset can be used. Alternatively, the site data can be compared with the same time period in the 30 year dataset from the closest meteorological station and then the 30 year mean can be adjusted accordingly. For example, if 5 years of measured data are available and are, on average, 3% higher than the measured data from a nearby meteorological station for the same 5 years, the 30-year mean could be adjusted to reflect this difference.

2.3.2.2 Modeled Air Temperature Data

If on-site air temperature values are unavailable, modeled values from regional models can be used instead. Two models are described here: the High Resolution Deposition Model (HRDM),

and the ClimCalc model. See the Vermont Technical Report (Duarte, in preparation) for more details on the assumptions and use of the models. Other sources include NADP and NOAA isopleths and Jim Lynch's model (Lynch et al., 1995), based on NADP data for non-glaciated eastern states.

2.3.2.2.1 Air temperature from the High Resolution Deposition Model (HRDM)

HRDM modeled values for air temperatures (1974-2003) are available for New England states. The HRDM model calculates multiple climatic parameters for a site based on latitude, longitude, and elevation for multiple forest types. Prior to extracting data from the HRDM a forest type must be assigned. The forest type is determined based on species biomass distribution, which can be calculated from current biomass data (Section 2.3.1).

a. The percent biomass by species on a site is calculated by dividing the current biomass of each individual species by the total biomass values of all trees on the site (* 100).

b. The percent biomass distribution per species for the site is then compared to species distributions in the **HRDM Regional Forest Type** table in the database. The best match between on-site species distribution and regional forest type is determined. If none of the HRDM Regional Forest Types match the species distribution of a site, the HRDM Regional Forest Type is assigned based on percent hardwood and conifer at the site.

c. Air temperature for the assigned HRDM Regional Forest Type should be selected from model output values. If the assigned HRDM Regional Forest Type is not represented in the HRDM model output, there is a discrepancy of land classification between the Regional Forest Types. This may happen when a site falls close to the boundaries of two or more HRDM pixels. In these cases, the HRDM Regional Forest Type with the closest hardwood: conifer ratio can be used. HRDM Regional Forest Type flags should be entered in the database to identify if the assigned HRDM Regional Forest Type was unavailable.

Critical Loads Database Data Entry

Enter the assigned forest type code from the **Regional Forest Type** table into the RFT_dep_models column of the **Site** Table. Enter the appropriate Regional Forest Type Flag into the RFT_dep_models_flag column of the **Site** Table, if necessary.

2.3.2.2.2 Air Temperature from the ClimCalc Model

ClimCalc air temperature values (1950-1979) for New England states and New York can be calculated with a batch ClimCalc Excel file, which can be obtained from Scott Ollinger at the University of New Hampshire. The regression coefficients for ClimCalc can be found in Ollinger, et al. (1995). A single site version of ClimCalc is also available online, at http://www.pnet.sr.unh.edu/climcalc/run.html. To run ClimCalc you must have site latitude, longitude, and elevation values. Unlike the HRDM model, the ClimCalc model assumes a single forest types (mature northern hardwoods).

The batch version of ClimCalc provides monthly and annual air temperature values in degrees Celsius. The online version provides annual air temperature values, solar radiation, and wind speed.

Critical Loads Database Data Entry

Air temperature data should be entered into the appropriate columns of the **Air Temperature** table; all data should be entered in database appropriate units. Data from two distinct time periods from the same site and measurement station should be entered into separate rows. The time period used should be entered into the *MeasurementTimePeriod* column of the **Air Temperature** table.

2.3.3 Precipitation Data

The preferred source of precipitation volume data are measured 30 year monthly averages. If measured data are unavailable, data from nearby meteorological stations or modeled values – either from NADP or NOAA isopleths, or other accepted regional models – can be used for air temperature values.

2.3.3.1 Site Precipitation Data

Measured precipitation volume values come from NADP, CASNET, AIRMoN stations or other air quality or meteorological stations. If it is available, precipitation volume data should come from on-site 30 year monthly averages. Long-term precipitation volume averages are used to capture the long-term trends for a given site and minimize single-year anomalies. Measured precipitation volume data for sites without 30 year measurements can be determined in two ways. If the dataset spans more than 10 years, the mean from the dataset can be used. Alternatively, the site data can be compared with the same time period in the 30 year dataset from the closest meteorological station and then the 30 year mean can be adjusted accordingly.

For example, if 5 years of measured data are available and are, on average, 3% higher than the measured data from a nearby meteorological station for the same 5 years, the 30-year mean could be adjusted to reflect this difference.

2.3.3.2 Modeled Precipitation Data

If on-site precipitation values are unavailable, modeled values from regional models can be used instead. Two models are described here: the High Resolution Deposition Model (HRDM), and the ClimCalc model. See the Vermont Technical Report (Duarte, in preparation) for more details on the assumptions and use of the models. Other sources include NADP and NOAA isopleths and Jim Lynch's model (Lynch et al., 1995), based on NADP data for non-glaciated eastern states.

2.3.3.2.1 Precipitation from the High Resolution Deposition Model

HRDM modeled values for precipitation volumes (1974-2003) are available for New England states. The HRDM model calculates multiple climatic parameters for a site based on latitude, longitude, and elevation for multiple forest types. Prior to extracting data from the HRDM a forest type must be assigned. The forest type is determined based on species biomass distribution, which can be calculated from current biomass data (Section 2.3.1).

a. The percent biomass by species on a site is calculated by dividing the current biomass of each individual species by the total biomass values of all trees on the site (* 100).

b. The percent biomass distribution per species for the site is then compared to species distributions in the **HRDM Regional Forest Type** table in the database. The best match between on-site species distribution and regional forest type is determined. If none of the HRDM Regional Forest Types match the species distribution of a site, the HRDM Regional Forest Type is assigned based on percent hardwood and conifer at the site.

c. Precipitation volume for the assigned HRDM Regional Forest Type should be selected from model output values. If the assigned HRDM Regional Forest Type is not represented in the HRDM model output, there is a discrepancy of land classification between the Regional Forest Types. This may happen when a site falls close to the boundaries of two or more HRDM pixels. In these cases, the HRDM Regional Forest Type with the closest hardwood: conifer ratio can be used. HRDM Regional Forest Type flags should be entered in the database to identify if the assigned HRDM Regional Forest Type was unavailable.

Critical Loads Database Data Entry
Enter the assigned forest type code from the **Regional Forest Type** table into the RFT_dep_models column of the **Site** table. Enter the appropriate Regional Forest Type Flag into the RFT_dep_models_flag column of the **Site** table, if necessary.

2.3.3.2.2 Precipitation from the ClimCalc Model

ClimCalc precipitation volumes (1950-1979) for New England states and New York can be calculated with a batch ClimCalc Excel file, which can be obtained from Scott Ollinger at the University of New Hampshire. The regression coefficients for ClimCalc can be found in Ollinger, et al. (1995). A single site version of ClimCalc is also available online, at http://www.pnet.sr.unh.edu/climcalc/run.html. To run ClimCalc you must have site latitude, longitude, and elevation values. Unlike the HRDM model, the ClimCalc model assumes a single forest types (mature northern hardwoods).

The batch version of ClimCalc provides monthly and annual precipitation volume values in cm. The online version provides annual precipitation volume values, solar radiation, and wind speed.

Critical Loads Database Data Entry
Precipitation volume data should be entered into the appropriate columns of the **Precipitation** table; all data should be entered in database appropriate units. Data from two distinct time periods from the same site and measurement station should be entered into separate rows. The time period used should be entered into the *MeasurementTimePeriod* column of the **Precipitation** table.

2.3.4 Annual Evapotranspiration (AET) Data

AET (and precipitation volume) data are used to calculate soil percolation rates. The preferred source of AET data are measured data. If measured data are unavailable, modeled values – typically based on air temperature, precipitation volume and soil characteristics – can be used for AET values.

2.3.4.1 Site AET Data

In the absence of runoff or AET data measured at a site, simple models exist that provide estimates of AET rates. The required inputs include monthly long-term mean air temperature and precipitation volume, soil depth, field capacity, and the plant wilting point. The model outputs include potential evapotranspiration, annual evapotranspiration, runoff, and mean

volumetric soil moisture. The soil inputs required for this model are discussed in the soil data section (Section 4).

Critical Loads Database Data Entry
AET data should be entered into the appropriate columns of the **AET** table; all data should be entered in database appropriate units. Information about the data source (site or modeled) should be added to the **Climate Source** table.

2.4 Climate Metadata and QAQC

Some air quality and meteorological stations impose quality control assurances for precipitation volume data. For example, if there is only reliable data for 328 days in a year (less than 90% of the year), data for the entire year would be considered invalid.

Critical Loads Database Data Entry
All relevant metadata and QAQC procedures should be entered into the **Climate Source** table. Any additional information available should be entered into the *Comment* column.

2.5 Climate Unit Conversions

Although deposition is entered in the database as kg/ha/y, our critical load model requires the data to be in eq/ha/y. To convert data from kilograms to equivalents, use the following formula:

(kg element/ha/yr)*(1 mole/molecular weight (g))*(eq/mole)*(1000g/kg) = (eq element/ha/yr) [2.1]

Below are the equations for the specific elements we are concerned with:

N: (kg N/ha/yr)*(1 mole N/14.0067g)*(1 eq/mole N)*(1000g/kg) = eq N/ha/yr [2.2]

S: (kg S/ha/yr)*(1 mole S/32.044g)*(2 eq/mole S)*(1000g/kg) = eq S/ha/yr [2.3]

Ca: (kg Ca/ha/yr)*(1 mole Ca/40.08g)*(1 eq/mole Ca)*(1000g/kg) = eq Ca/ha/yr [2.4]

Mg: (kg Mg/ha/yr)*(1 mole Mg/24.3312g)*(1 eq/mole Mg)*(1000g/kg) = eq Mg/ha/yr [2.5]

K: (kg K /ha/yr)*(1 mole K /39.102g)*(1 eq/mole K)*(1000g/kg) = eq K /ha/yr [2.6]

Na: (kg Na/ha/yr)*(1 mole Na/22.9698g)*(1 eq/mole Na)*(1000g/kg) = eq Na/ha/yr [2.7]

Cl: (kg Cl /ha/yr)*(1 mole Cl /35.453g)*(1 eq/mole Cl)*(1000g/kg) = eq Cl /ha/yr [2.8]

2.6 Climate and Deposition References

Duarte, N and LH Pardo (In prep). VT NEG/ECP Site-Specific Critical Loads Report.

Lynch, J.A., J.W. Grimm, and V.C. Bowersox. 1995. Trends in precipitation chemistry in the United States: a national perspective, 1980-1992. Atmospheric Environment, 29(11):1231-1426.
Miller, EK. 2000. Atmospheric deposition to complex landscapes: HRDM – a strategy for coupling deposition models to high-resolution GIS. Page 74 in R. Arts, editor. NADP Proceedings of the NADP Technical Meeting, October 17-20, 2000. Illinois State Water Survey, Champaign, IL.
Miller et al. 1993a. Atmospheric deposition to a high-elevation forest at Whiteface Mountain, NY, USA. Tellus 45B: 209-227.
Miller et al. 1993b. Atmospheric deposition to forests along an elevational gradient at Whiteface Mountain, NY, USA. Atmospheric Environment. 27A: 2121-2136.
Ollinger, S.V., Aber, J.D., Federer, C.A., Lovett, G.M., Ellis, J.M. 1995. Modeling physical and chemical climate of the Northeastern United States for a geographic information system. Gen. Tech. Rep NE-191. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.
Ollinger, S.V., J.D. Aber, G.M. Lovett, S.E. Millham, R.G. Lathrop, and J.M. Ellis. 1993. A spatial model of atmospheric deposition for the northeastern U.S. Ecological Applications. 3(3): 459-472.

Web references

Air Resources Laboratory: http://www.arl.noaa.gov
AIRMoN: http://www.arl.noaa.gov/research/projects/airmon_data.html
CASTNET: http://www.epa.gov/CASTNET
ClimCalc: http://www.pnet.sr.unh.edu/climcalc
National Climate Data Center: http://www.ncdc.noaa.gov/oa/ncdc.html
National Trends Network:: http://nadp.sws.uicu.edu

3 Vegetation Data and Calculations

3.1 Overview of Vegetation Calculations

Data in the vegetation section are used to calculate nutrient removal from sites through forest harvesting or fire. The amount of nutrients removed is a component of simple mass balance calculations of critical load.

Nutrient removal rates depend on a variety of factors, including the type, intensity, and frequency of harvest or fire. These in turn depend on land ownership and conservation status. Private and public lands are often harvested at different rates. Harvesting may be prohibited on certain protected sites, such as wilderness areas, preserves, and sites above a designated elevation.

In order to calculate the nutrient uptake and removal due to harvest, the following sequence of calculations need to be made:

a. The *projected aboveground biomass*, or *harvestable biomass,* that would accumulate within the length of a rotation, or over several cutting cycles, must be estimated. Current tree diameter at breast height (DBH), projected DBH at the time of harvest, and DBH-based allometric equations are used to calculate the current and harvestable biomass. Included in the Critical Loads database are equations developed by Jenkins et al. (2003) from 2456 previously published DBH-based equations.

b. Calculation of *actual harvest biomass* from the harvestable biomass. The actual harvest biomass at a site varies according to harvest scenarios. For example, in Vermont, most trees are harvested as saw timber (merchantable stem wood and bark). For a saw timber harvest scenario, allometric equations from Jenkins et al. (2003) can be used to determine the ratio of merchantable stem wood and bark in the harvestable biomass.

c. Assignment of the appropriate percent *annual biomass extraction*, which is based on known removals from a site or assigned by county, land-ownership category, and forest type.

d. Calculation of *annual nutrient removal* from the forest ecosystem. The estimated actual harvest biomass data are combined with nutrient content and annual biomass extraction rates. When nutrient content is unavailable at a site, values are filled in from Tree Chemistry Database (TCDB) tables (Pardo et al., 2005). This database was developed to provide species- and genus-based nutrient values for tree stem wood, stem bark, branches, and foliage.

In order to calculate the nutrient uptake and removal due to fire, the following information is required:

a. The *projected aboveground biomass*, or *potential biomass,* that would accumulate within the length of a rotation, or over several cutting cycles, must be estimated. Current tree diameter at breast height (DBH), projected DBH at the time of harvest, and DBH-based allometric equations are used to calculate the current and harvestable biomass. Included in the Critical Loads database are equations developed by Jenkins et al. (2003) from 2456 previously published DBH-based equations.

b. The *aboveground biomass lost due to fire,* by species and tree compartment, for each fire occurring during a rotation, or over several cutting cycles must be estimated. The biomass

removed from each fire will be added together and divided by the number of years in the rotation (or 100 years as default) to result in an annual biomass removal rate.

c. Calculation of *annual nutrient removal* from the forest ecosystem. The estimated annual biomass removal rates are combined with nutrient content. When nutrient content is unavailable at a site, values are filled in from Tree Chemistry Database (TCDB) tables (Pardo et al., 2005) or from the literature.

Note that nutrient loss from fire is only considered when long-term fire interval is within the course of one rotation. For sites where harvesting and fire both occur, nutrient removal rates need to be calculated for both types of biomass removal, and then added together to result in the total nutrient removal.

3.2 Overview of Vegetation Tables in the Critical Loads Database

The vegetation section contains data necessary to calculate current biomass, projected biomass, harvestable biomass, annual biomass extraction rates, and annual nutrient extraction rates. Eight tables are included in the vegetation section: the **Vegetation** table, the **Tree** table, the **TCDB** (Tree Chemistry Database) **Bark, Bole, Branch**, and **Foliar Nutrient** tables, the **Jenkins Biomass Fractions** table, and the **Jenkins Species Group** table (table 3.2.6). Overviews of these tables and descriptions of how they relate to one another are provided here to provide context for vegetation calculations. Complete descriptions of all table contents are in the Critical Loads database parameter list (Figure 3.1; Appendix B).

3.2.1 The Vegetation Table

The **Vegetation** table contains data on individual trees or by species-group for each site. The data from this table are data measured at the site or are calculated using values from other tables in the Vegetation Section.

Figure 3.1 Vegetation Tables

The *VegetationID* parameter is a unique number assigned to each set of vegetation data. Numbering for new vegetation entries continues where the last entry left off. The *SiteID* and *PlotID* are important for linking vegetation data to Sites and original study

plots, respectively. Because each site has multiple trees and/or species, each *SiteID* and corresponding *PlotID* will occur multiple times in the **Vegetation** table.

The *TreeID* number links trees in the **Vegetation** table to species-specific parameters in the **Tree** table, which in turn links species to values in the **Jenkins Biomass Fractions**, **Jenkins Species Group**, and **TCDB** (Tree Chemistry Database) **Bark, Bole, Branch**, and **Foliar** nutrient values. These values are important in calculating site level biomass and nutrient values, as described in section 2.3.

Both measured and calculated data are entered into the **Vegetation** table.

3.2.1.1 Measured Data Entered into the Vegetation Table

All vegetation data measured on site should be entered into appropriate **Vegetation** table categories. Possible site-measured data include DBH (diameter at breast height), harvest DBH, height, MAI, wet to dry biomass ratio, fire nutrient loss, slash nutrient leaching, compartment sample variability, dry wood density, and compartment nutrient percentages.

3.2.1.2 Calculated Data Entered into the Vegetation Table

If certain data are not available from site measurements, they can be calculated using other database tables. These data include DBH, harvest DBH, current biomass, harvestable biomass, harvest bark, and harvest wood. Calculations are described in section 2.3.

3.2.2 The Tree Table

The **Tree** table links trees by genus, species, or hardwood/softwood category to biomass equations, vegetation, and nutrient values. The **Tree** table also contains minimum harvest DBH (diameter at breast height) by state and wood density values by species, genus, and hardwood/softwood category. The *TreeID* is unique for each entry in the **Tree** table, and is linked to entries in the **Vegetation** table. The *WoodDensityID* indicates if a tree is hardwood (h) or softwood (s), and also links to allometric equation parameter values in the **Jenkins Biomass Fractions** table. The *SpeciesGroupID* indicates Jenkins et al. (2003) species group assignments, and links to the **Jenkins Species Group** table. The *TCDB_BarkID, TCDB_BoleID, TCDB_BranchID,* and *TCDB_FoliarID* link to nutrient values in the **TCDB Bark, Bole, Branch,** and **Foliar Nutrient** tables, respectively. TCDB nutrient values are from the Tree

Chemistry Database (Pardo et al., 2005), which was developed to provide nutrient concentration information for tree species in the Northeastern United States.

The **Tree** table contains information for all tree species found on New England sites to date. If a desired species is missing from the tree table, either a new entry should be made in the Tree Table, with appropriate values entered into key linking fields, or genus or hardwood/softwood values should be used in place of species-specific values.

3.2.3 The TCDB Nutrient Tables

There are four **TCDB Nutrient** (Tree Chemistry Database) tables: the **TCDB Bark Nutrient, TCDB Bole Nutrient, TCDB Branch Nutrient,** and **TCDB Foliar Nutrient** table. The tables contain mean N, P, K, Ca, and Mg percent concentrations by species, genus, and hardwood/softwood, for stem bark, bole (stem wood), branch, and foliage, respectively. The values are derived from the Tree Chemistry Database (Pardo et al, 2005), which was developed to provide average nutrient concentrations for New England tree species.

The **TCDB Nutrient** tables are linked by the *TCDB_BarkID, TCDB_BoleID, TCDB_BranchID,* and *TCDB_FoliarID* to entries in the **Tree** table.

3.2.4 The Jenkins Biomass Fractions Table

This table contains biomass fraction equation values by hardwood and softwood from Jenkins, et al. (2003). The equations can be used to calculate biomass fractions (referred to as *ratios* in Jenkins et al., 2003) of foliage, roots, stem bark, and stem wood based on DBH (diameter at breast height) and softwood/hardwood category. Compartment biomass can be calculated by multiplying the compartment biomass fractions with the total aboveground biomass. The **Jenkins Biomass Fractions** table is linked to the **Tree** table by the *WoodDensityID*.

3.2.5 The Jenkins Species Group Table

This table contains species group codes, names, and associated allometric equation values from Jenkins et al., 2003. The equations can be used to calculate the aboveground biomass of a tree in kilograms based on its assigned species group category and its DBH (diameter at breast height). The **Jenkins Species Group** table is linked to the **Tree** table by the *SpeciesGroupID*. Detailed instructions for these intermediate calculations provided in section 3.3.1.1.2.

3.3 Intermediate Calculations for Vegetation Data

Data must be prepared for entry into the Critical Loads database before it can be used in critical loads calculations. If site data are not available for parameters, calculated or averaged data may be used in order of source preference. The following sections contains instructions for performing the calculations necessary for obtaining site nutrient removal rates based on site vegetation data.

Data collected from a site are the preferred source of vegetation data. Site data should be entered **before** calculated or averaged data. Data sources in descending order of preference are listed for DBH, biomass values, and nutrient concentrations.

If mean annual increment (MAI) data are available from a site, these data can be used with current biomass data to calculate the projected biomass accumulation within one rotation. Using site data is always preferred over modeled or extrapolated data.

3.3.1 Total Aboveground Current and Harvestable Biomass Calculations

Two types of site biomass are needed for critical loads calculations: current biomass and harvestable biomass. Current biomass refers to all aboveground biomass on a site at the time of sampling. Harvestable biomass refers to all biomass which could *potentially* be harvested from a site, i.e., the aboveground biomass of all trees that have attained a harvestable size. Site-based biomass is the preferred biomass for use in simple mass balance equations of critical load. However, if site-based biomass is unavailable, biomass values can be calculated. In order of descending preference, site biomass may be calculated using site-based allometric equations, using allometric equations from Jenkins et al. (2003), or using equations based on stand basal area values. In this section, calculations of current aboveground biomass and harvestable aboveground biomass using diameter at breast height (DBH)-based allometric equations from Jenkins et al. (2003; section 3.3.1.2.1) and using basal area values are described (section 3.3.1.2.2).

The DBH-based allometric equations calculations require site-based forest composition, site-based or assigned DBH values, and allometric equations to convert to volume and mass. The basal area-based calculations require site-based basal area by species, height by species or stand, and specific wood density by species.

3.3.1.1 DBH-based Current and Harvestable Biomass Calculations

To perform DBH-based current and harvestable biomass calculations, ideally you should have the following information: forest composition (number of trees of each species), current DBH, DBH at the time of harvest (harvest DBH), and appropriate allometric equations for calculating biomass. The minimum information you must have from a site in order to perform biomass calculations is the number of trees of each species. DBH and allometric equations can be assigned to trees from Critical Loads database values, as explained below.

3.3.1.1.1 DBH assignment

Site-based current and harvest DBH are the preferred source of DBH data. However, if site-based values are unavailable for a tree, current and/or harvest DBH can be assigned from the *HarvestDBH_cm* in the **Tree** table of the Critical Loads database. DBH values should be assigned by species; if species values are not available in the database, they should be assigned next by genus and finally by hardwood/softwood category.

The *HarvestDBH_cm* is the species minimum DBH for the dominant state harvest scenario. These harvest DBH values are assigned with the assumption that the tree is no larger than the *HarvestDBH_cm*. If the site-based current DBH of a tree is greater than the database *HarvestDBH_cm,* the current DBH is assumed to be the harvest DBH.

3.3.1.1.2 Allometric equations for biomass calculations

Site-based current biomass and harvestable biomass are the preferred sources of biomass information.

If site biomass data are not available, aboveground biomass should be calculated using the allometric equation variables BM_β_0 and BM_β_1 from the **Jenkins Species Group** table. Equation variables are assigned by species group; the *SpeciesGroupID* links species, genus, or other entries in the **Tree** table to variables in the **Jenkins Species Group** table.

To calculate current aboveground biomass, use BM_β_0, BM_β_1 and DBH_cm, in the equation

$$BM = \text{Exp}\,(\beta_0 + \beta_1 \ln DBH) \qquad [3.1]$$

where BM equals aboveground biomass in kg.

To calculate harvestable aboveground biomass, use BM_β_0, BM_β_1 and HarvestDBH_cm, in the equation

$$BM = \text{Exp}\,(\beta_0 + \beta_1 \ln DBH) \qquad [3.2]$$

where BM equals aboveground biomass in kg.

Biomass is calculated in kg/tree, and should be calculated individually for every tree at the site. To obtain site level biomass data, sum the biomass for all trees on site (sum separately for current biomass and harvestable biomass), then divide by the site area in hectares.

Critical Loads Database Data Entry
All site-based vegetation data should be entered into the **Vegetation** table of the Critical Loads Database. Assigned DBH values and calculated current biomass and harvestable biomass should also be entered into the **Vegetation** table of the Critical Loads database. The appropriate biomass units, DBH comment, Biomass Source (site, allometric from Jenkins et al., 2003, basal area, or other), and biomass comment should also be entered into the database.

3.3.1.2 Basal Area-based Current and Projected Biomass Calculations

Current and harvestable biomass measured at the site are the preferred sources of biomass values, followed by DBH-based allometric equations. Calculations of biomass based on basal area should be made only if other sources of biomass data are unavailable. To calculate biomass using basal area, you must have basal area values by individual tree or by species, tree height, and wood density values. The minimum data you must have for a site are basal area and height. Wood density can be assigned from values in the Critical Loads database.

3.3.1.2.1 Wood density assignment

If you do not have wood density values, these should be assigned from *SpecificWoodDensity_kg_m3* in the **Tree** table of the Critical Loads database. Wood density values should be assigned by species; if species values are not available in the database, they should be assigned next by genus or finally by hardwood/softwood category.

3.3.1.2.2 Parabolic equation for biomass calculations

If vegetation data are given as basal area, biomass should be calculated as follows (http://www.hubbardbrook.org/yale/watersheds/w6/biomass-stop/how-to-quantify.htm):

1. Calculate the parabolic volume (VolP) using the given basal area (BA) and height (H):

   $$\text{VolP } (m^3/ha) = \tfrac{1}{2}\ \text{BA } (m^2/ha) \times \text{H } (m) \qquad [3.3]$$

2. Calculate the biomass (BM) using species-specific wood density (WD) and parabolic volume:

   $$\text{BM } (kg/ha) = \text{VolP } (m^3/ha) \times \text{WD } (kg/m^3) \qquad [3.4]$$

This biomass value serves as both the Current and Harvestable Biomass value. Note that the units are kg/ha, and that basal area may be calculated by individual tree or by species group.

3.3.1.2.3 DBH assignment

Although DBH is not needed for basal area biomass calculations, it is necessary for calculations of harvest biomass made using harvestable biomass values (introduced in section 3.3.1.1.1). Assign DBH and Harvest DBH for each tree or species group from the state appropriate *HarvestDBH_cm*, which can be found in the **Tree** table of the Critical Loads database. DBH values should be assigned by species; if species values are not available in the database, they should be assigned next by genus and finally by hardwood/softwood category.

Critical Loads Database Data Entry
All site-based vegetation data should be entered into the **Vegetation** table of the Critical Loads Database. Assigned DBH values and calculated current biomass and harvestable biomass should also be entered into the **Vegetation** table of the Critical Loads database. The appropriate biomass units, DBH comment, Biomass Source (site, allometric from Jenkins et al., 2003, or basal area), and biomass comment should also be entered into the database.

3.3.2 Actual Harvest Biomass Calculations

Actual harvest biomass should be calculated from the harvestable biomass by individual tree or by species. The actual harvest biomass is contingent upon harvest scenarios. In order to accurately calculate actual harvest biomass, you must know the harvest DBH, harvestable biomass, and the harvest scenario. Specifically, you must know which tree components – stem wood, stem bark, branches, and/or foliage – are removed from the site. With this information, you can use allometric equations to determine the fraction of harvestable biomass that is actually harvested.

3.3.2.1 Calculations of Harvestable Biomass Fractions based on DBH

Allometric equation variables for calculating biomass fractions (stem bark, stem wood, coarse roots, and foliage) are in the **Jenkins Biomass Fractions** table of the Critical Loads database. Branch biomass fractions are calculated by subtracting the sum of bark, wood, coarse roots, and foliage from total aboveground biomass. Equation variables are assigned by hardwood (h) or softwood (s) category, and are linked to species in the **Tree** table by the *WoodDensityID.*

Biomass fractions for each tree or species group should be calculated separately, and then summed to obtain the actual harvest biomass.

3.3.2.1.1 Bark fraction and biomass calculations

To calculate the biomass contributed from the bark, you need Harvest DBH, Bark_ β_0 and Bark_ β_1 from the **Jenkins Biomass Fractions** table, and the harvestable biomass.

To obtain the bark fraction, enter the appropriate values into the equation

Bark fraction=Exp ($Bark_\beta_0 + Bark_\beta_1$/DBH) [3.5]

Where Bark fraction= fraction of component to total aboveground biomass.

Multiply the bark fraction by the harvestable biomass to obtain the bark biomass.

3.3.2.1.2 Wood fraction and biomass calculations

To calculate the biomass contributed from the wood, you need Harvest DBH, Wood_ β_0 and Wood_ β_1 from the **Jenkins Biomass Fractions** table, and the harvestable biomass.

To obtain the wood fraction, enter the appropriate values into the equation

Wood fraction =Exp ($Wood_\beta_0 + Wood_\beta_1$/DBH) [3.6]

Where Wood fraction = fraction of component to total aboveground biomass.

Multiply the wood fraction by the harvestable biomass to obtain the wood biomass.

3.3.2.1.3 Foliage fraction and biomass calculations

To calculate the biomass contributed from the foliage, you need Harvest DBH, Foliage_ β_0 and Foliage_ β_1 from the **Jenkins Biomass Fractions** table, and the harvestable biomass.

To obtain the foliage fraction, enter the appropriate values into the equation

Foliage fraction =Exp ($Foliage_\beta_0 + Foliage_\beta_1$/DBH) [3.7]

Where Foliage fraction = fraction of component to total aboveground biomass.

Multiply the foliage fraction by the harvestable biomass to obtain the foliage biomass.

3.3.2.1.4 Coarse root fraction and biomass calculations

To calculate the biomass contributed from coarse root, you need Harvest DBH, Root_ β_0 and Root_ β_1 from the **Jenkins Biomass Fractions** table, and the harvestable biomass.

To obtain the root fraction, enter the appropriate values into the equation

Root fraction =Exp ($Root_\beta_0 + Root_\beta_1$/DBH) [3.8]

Where Root fraction = fraction of component to total aboveground biomass.

Multiply the root fraction by the harvestable biomass to obtain the root biomass.

3.3.2.1.5 Branch and treetop biomass calculations

Branch biomass values are obtained by subtracting bark, wood, foliage, and coarse root biomass values from total aboveground biomass. Therefore, to calculate branch biomass values, you must first calculate bark, wood, foliage, and coarse root biomass values as described above.

Critical Loads Database Data Entry
Harvest biomass fraction values (stem wood, stem bark, branches, and/or foliage) should be entered into the **Vegetation** table of the Critical Loads database.

3.3.3 Annual Biomass Extraction Calculations

Annual biomass extraction data measured at the site are the preferred source of biomass extraction values. If site data are unavailable, annual biomass extraction rates are assigned on a site-level basis by state, county, land-ownership category, and forest type. County and land-ownership category (public or private) should be known for each site. Biomass extraction forest type is assigned based on hardwood and softwood percentages as follows: softwood = 70% or more current biomass softwood, hardwood = 70% or more current biomass hardwood, mixed wood = everything else.

3.3.3.1 Assigning forest type through biomass calculations

Hardwood and softwood (or coniferous) biomass percentages should be determined by summing current biomass values (site –based or calculated as described in section 2.3.1) for all softwoods and all hardwoods on a site. Softwood and hardwood classification is indicated by species in the *WoodDensityID* column of the **Tree** table (h = hardwood; s = softwood).

Hardwood biomass percentage = total hardwood biomass/current biomass; softwood biomass percentage = total softwood biomass/current biomass.

3.3.3.2 Assigning biomass extraction rates

Biomass extraction rates should be assigned by site from the **Biomass Extraction** table in the Critical Loads database. Biomass extraction rates are given by county, ownership status (public or private) and biomass extraction forest type.

Critical Loads Database Data Entry
The percent hardwood and softwood (coniferous) composition of each site should be entered into the **Site** table of the critical loads database.

3.3.4 Annual Nutrient Extraction Calculations

Annual nutrient extraction rates measure at the site are the preferred source of nutrient extraction values. If site data are unavailable, annual nutrient extraction is calculated for a site using harvest biomass values, the annual biomass extraction rate, and species-based nutrient concentrations. To perform nutrient extraction calculations, you must have either site-based or calculated harvest biomass values broken down by tree compartment (stem wood, stem bark, branches, foliage), and the assigned biomass extraction rate. Nutrient concentrations can be either site values or values obtained from the **TCDB** (Tree Chemistry database) **Bole, Bark, Branch**, and/or **Foliar** tables in the Critical Loads Database. The TCDB tables are derived from the Tree Chemistry Database, which was developed to provide species-based average nutrient percentages for New England tree species. Nutrient values in the **TCDB** tables are linked to species in the **Tree** table by the *TCDB_BoleID, TCDB_BarkID, TCDB_BranchID,* and *TCDB_FoliarID.*

3.3.4.1 Calculating Harvestable Nutrients

Before calculating the annual nutrient extraction rate, you must calculate harvestable nutrients. To do this you need biomass data for all harvestable tree components, e.g., harvestable bark or harvestable wood. Instructions for calculating these values are given in section 2.3.2.1.

1. For each tree or species group, match species-based nutrient concentrations with the appropriate biomass fraction. For example, match harvestable bark biomass with *Bark_N_%, Bark_K_%, Bark_Ca_%,* and *Bark_Mg_%* values from the **TCDB_Bark** table by matching the *TCDB_BarkID* for the desired species in the **Tree** table with the *TCDB_BarkID* in the **TCDB Bark** table.
2. Multiply the harvestable biomass with the nutrient concentration. Repeat this procedure for each tree or species group and for each harvestable component.
3. Sum all of the harvestable values for each nutrient on a site to obtain the harvestable value of that nutrient. For example, harvestable N = ($tree_1$ bark N) + ($tree_1$ wood N) + ($tree_2$ bark N) + ($tree_2$ wood N) + ($tree_n$ bark N) + ($tree_n$ wood N). Depending on your biomass values, you

should now have site nutrients in kg/ha or kg/site. If your values are in kg/site, divide by ha/site to obtain kg/ha.

3.3.4.2 Calculating the Annual Nutrient Extraction Rate

To calculate the annual nutrient extraction rate, you must have the site nutrients in kg/ha and the annual biomass extraction rate. Multiply the site nutrients by the annual extraction rate to obtain the potential nutrient removal in kg/ha/yr.

3.4 Vegetation Metadata and Quality Assurance and Control

We accepted data in any format available and performed unit conversions and QA/QC; our primary QA/QC issue was vegetation data without units. We made no assumptions about the units assigned to any data, as inconsistencies sometimes exist within a single dataset. Questionable data and data entered from hard copy should always be double checked.

For the DBH data, once units are determined, it is helpful to sort the vegetation data by DBH. By looking at the data in this way, missed decimal places become obvious. It is also important to note that different studies use different minimum DBH. For example, FIA only measures trees with a DBH equal to or greater than 1 inch, whereas other studies may use a 10 cm cutoff (2.54 inches).

3.5 Vegetation References

Jenkins, J.C., Chojnacky, D.C., Heath, L.S., and Birdsey, R.L. 2003. National Scale Biomass Estimators for United States Tree Species. Forest Science 49(1): 12-35.

4 Soil Data and Calculations

4.1 Overview of Soil Calculations

Soil mineral weathering rates are a component of the simple mass balance equation for critical loads. Soil mineral weathering is the primary means of replenishing the base cations lost from the soil due to leaching caused by acidic deposition. The soil mineral weathering rate is determined by the types of minerals present in the bedrock or substrate, soil physical properties, and the local climate (temperature and precipitation). There are different ways of estimating soil

mineral weathering rates. Data availability typically determines which methods are most appropriate to use.

Soil data may undergo intermediate calculations, data filling, or formatting prior to use in calculating soil mineral weathering rates. Ultimately, soil mineral weathering is calculated from soil data combined with precipitation, temperature, and annual evapotranspiration. Soil data necessary for these calculations may include soil substrate, soil depth, bulk density, texture, moisture, mineralogy, and organic matter content. Additional data including exchangeable cations, base saturation, and CEC, are not required, but increase the accuracy of the weathering rate calculations. These data, as well as soil solution chemistry data, are required for dynamic models and can also be used as "common sense" checks on estimates of soil mineral weathering rates.

4.2 Overview of Soil Tables in the Critical Loads Database

Tables in the soil section of the Critical Loads database are the **Soil** table, the **Soil Horizon** table, the **Additional Soil Data** table, the **Soil Moisture** table, the **Soil Horizon Flag** table, the **Brady Moisture** table, and the **Lysimeter Data** table. Overviews of these tables and descriptions of how they relate to one another are discussed here to provide context for soil calculations. Complete descriptions of all table contents are in the Critical Loads database parameter list (Fig. 4.1; Appendix B).

4.2.1 The Soil Table

The **Soil** table contains depth-weighted mean soil physical, textural, and mineralogical content values as reported or calculated for soil samples. These values represent soil as a single layer, for either the depth of the soil through the B horizon or to a soil layer through which roots cannot penetrate (this depth is referred to as the *rooting zone*). The **Soil** table is linked to sites in the **Site** table by the *Site ID* number, and to original study plots by the *Plot ID* number. The unique identification number for each soil sample, *Soil ID,* links to entries in the **Soil Horizon, Additional Soil Data,** and **Soil Moisture** tables. If there are data for multiple soil types for the same site, those data should be entered into separate rows.

Soil Table
Soil ID
Site ID
PlotID
FMGName
County
SoilSampleDates
SoilNutrientsDates
SoilMap
SoilSeries
SoilTaxonomy
RootingHorizonDepth
SoilPercolationRate
RootingDepth and SoilPercolation:
method, QA/QC, uncertainty, comments
PercentClay
PercentSilt
PercentSand
AdjustedBulkDensity
TextFC
Texture name
SoilCollectionMethod
SoilDataSource
SoilDataComment
NutrientSampleSize
ODBulkDensity_method
OrganicMatterPercent_method
ParentMaterialAnalysis_method
Estimated_%_change
Minerals:
Albite%, Anthorite%, Apatite%, Biotite%, Calcite%, Chlorite%, Dolomite%, Epidote%, Garnet%, Hornblend%, Kaolinite%, KFeldspar%, Muscovite%, PagioclaseFeldspar%, Pyroxene%, Quartz%, VemicMica%, Vermiculite%
Mineralogy_[source, comment, method]
CEC_[cmoles/kg, source, comment, method]
Soil Ions (Ca, K, Mg, Na, Al):
cmoles/kg
Al: CEC ratio
Al: BC ratio
AlSaturationPercent
BaseSaturation
BaseSaturationComment
OrganicMatter
OrganicMatterComment
Data Access ID

Soil Horizon Table
Soil Horizon ID
Soil ID
State
County
SoilSeries
pedon_key
layer_key
HorizonDesignation
hzn_thickness
PercentSand
PercentSilt
PercentClay
PercentFineClay
TextureClass
Texture flag
PercentCoarseFractions
C frag flag
BulkDensity
Bulk Density Flag
BulkDensityAdjusted
OMPercent
OMSource
OMComment
pHH2O
pHCaCl2
Minerals:
Albite%, Anthorite%, Apatite%, Biotite%, Calcite%, Chlorite%, Dolomite%, Epidote%, Garnet%, Hornblend%, Kaolinite%, KFeldspar%, Muscovite%, PagioclaseFeldspar%, Pyroxene%, Quartz%, VemicMica%, Vermiculite%
Mineralogy_source
CEC_cmoles/kg
CEC_Flag
Soil Ions (Ca, K, Mg, Na, Al):
Exchangeable ions (cmoles/kg)
Exchangeable ions Method
AlSaturationPercent
BaseSaturation
BaseSaturationComment
Ctot
Ntot
OC
BradyMoistureID

Additional Soil Data
Additional Soil ID
Soil temperature
Soil temperature depth
Soil temperature method
For each parameter below, rates, methods, QA/QC, uncertainty, and comments are entered:
Nutrient leaching: Ca, K, Mg, NO3
H+ and Al leaching
Flux values
Flux calculations
Denitrification rates
N fixation rates
N immobilization rates
Soil ID

Soil Moisture Table
Soil Moisture ID
Dates for available data
Collection method
Sample depths
Sample frequency
Sample size
Calibration method
QA/QC
Uncertainty
Comments
For volumetric moisture:
Moisture % at each depth
Field capacity
Wilting point
Plant available water
Saturation
Soil ID

Soil Horizon Flag Table
FlagID
Flag Description

Brady Moisture Table
BradyMoistureID
SoilTexture
VolumetricMoisture_FC
VolumetricMoisture_PWP

Fig. 4.1 Soil Tables in the Critical Loads Database

Data entered into the **Soil** table can be either measured or calculated. Soil data calculations are described in section 4.3.

4.2.2 The Soil Horizon Table

The **Soil Horizon** table contains soil physical, textural, and mineralogical data for individual soil horizons within a pedon. This table may also include horizon data not associated with a particular site; these horizon data are used to calculate mean values for individual soil series when site-specific data are not available. The **Soil Horizon** table is linked to entries in the **Soil** table by the *Soil ID* and to entries in the **Site** table by the *Site ID.* The *Brady Moisture ID* links soil horizon entries to moisture values in the **Brady Moisture** table.

4.2.3 The Additional Soil Data Table

The **Additional Soil Data** table contains measured soil data parameters not included in the **Soil** table. These parameters provide supplemental information and are not used directly in SMB calculations of critical loads, but may be required for dynamic models. These parameters include: soil temperature, leaching rates for Al, Ca, H, K, Mg, and NO_3^-, denitrification rates, N fixation rates, N immobilization rates, and associated metadata.

4.2.4 The Soil Moisture Table

The **Soil Moisture** table contains measured soil moisture data, such as field capacities, plant wilting points, and saturation points, by depth.

4.2.5 The Soil Horizon Flag Table

The **Soil Horizon Flag** table details the source of calculated or estimated values in the **Soil Horizon** table. The *Flag ID,* which is unique for each type of calculation or fill scenario in the **Soil Horizon Flag** table, links to the *Texture Flag, C Frag Flag,* and *Bulk Density Flag* identification numbers in the **Soil Horizon** table. These calculations and the methods for filling in missing data are detailed in section 4.3.1.2.5.

4.2.6 The Brady Moisture Table

The Brady moisture values (field capacity and plant wilting points) contained in this table are taken from a soil texture versus moisture curve presented in Brady (1990). These values can be

used when site-specific soil moisture data are unavailable. Field capacity and the plant wilting point are used to model AET rates when measured AET rates are unavailable. The **Brady Moisture** table is linked to entries in the **Soil Horizon** table.

4.3 Intermediate Calculations and Data Filling for Soil Data

Intermediate calculations, formatting, and data filling may need to occur before soil data are entered into the Critical Loads database. In the following sections, methods for preparing soil data for entry into the database are described. Soil data associated with a site are the preferred source of information. Soil data extracted from the Natural Resources Conservation Service (NRCS) soil database (Soil Survey Staff, 2003) may also be used if geographic coordinates and associated climate and vegetation data are available. Because NRCS data are available nationally, specific instructions for data extraction are provided.

4.3.1 Soil Horizon Data Calculations

Data measured at the site are the preferred source for soil horizon data. If data for a horizon are unavailable, data from a related horizon in the same soil sample are the preferred substitute (i.e., if data from Bsh is missing, data from Bh in the same sample should be used instead). If no data for an entire soil horizon (i.e., B horizon) are available, averaged data for that horizon from the soil series should be used. Finally, averaged data for the entire soil series should be used for soil horizon data if no other information is available. Steps for these calculations are discussed further in section 4.3.2.1.5.

4.3.1.1 Natural Resources Conservation Service (NRCS) Soil Horizon Data

Soil horizon data from study pits throughout the United States are available from the Natural Resources Conservation Service (Soil Survey Staff, 2003). These data can be used for site data, or for both soil horizon and soil data calculation and filling. In this section, the process of extracting NRCS data from their online database for use in the Critical Loads database is described.

4.3.1.1.1 Selecting and Extracting NRCS data

NRCS data are downloaded from the NRCS website (http://ssldata.nrcs.usda.gov/). To identify appropriate NRCS SSL sites and extract soil horizon data, follow these steps:

1. Open http://ssldata.nrcs.usda.gov/ and select "characterization data".

2. Select the desired *state admin div*. The page will refresh; select a county, then click *execute query*.

3. A list of pedons will be returned. Select *check all* and *generate report*, then click *continue*.

4. A new page is returned with a list of options. Select *Soil Characteristics* and *NASIS Pedon Description* using the control key, then click *get report*.

5. Pedons that are described should be evaluated for database inclusion. Included sites should be forested and moderately or better drained. The following criteria should be used to determine database inclusion:

- the *vegetation description* should be forested OR the soil should have an O horizon. Sites that have no O horizon but that are forested should be included.

-the *drainage class* should not be "poorly drained"[1].

-the soil horizons should not be gleyed (an indication of wetness)– the letter "g" should not be part of any horizon name.

6. Return to the page listing pedons by county.

7. Select the *user_pedon_ID* for sites that meet database inclusion criteria, then click *Download data*.

8. A page of download options should appear. Select *include site information* and *include pedon information*. From layer data tiers, select *PSDA and rock fragments*, *Bulk density and moisture*, *Carbon and extractions*, *CEC and bases*, and *pH and carbonates*. From trace and dash notation, select *replace trace and dash notation with zero*. Click *download*, and save the file.

9. Repeat these steps for all counties in a given state.

The NRCS data files download as one Winzip file per county, with separate files for each data tier (e.g., bulk density, pH and carbonates, etc.). In addition, each parameter file has a *dict*, or dictionary, file associated with it. The *dict* files contain important metadata that need to be summarized in the Critical Loads Database because data from more than one type of analysis may be available.

4.3.1.1.2 Formatting NRCS Data for the Critical Loads database

1. Open the Winzip files extracted from the NRCS database as described in section 4.3.1.1.1, then open the non-dictionary files and save them as Excel files. Add and populate a county column for each file.

[1]In these critical loads calculations, it is assumed that soils do not receive acid-buffering seepage water from higher ground or from upwelling subsurface flows. See VT NEG/ECP Site-Specific Critical Loads Report (Duarte et al, In prep), page 2 for more discussion of this assumption.

2. For the *Bulk density and moisture*, *Carbon and extractions*, and *pH and carbonates* data tiers, combine the data from all of the counties per state into one file. Make sure that all parameter columns are aligned; not all counties will have the same parameter column labels. Data for parameters that appear under slightly different column headings, specifically various *DBOD*, *Cly*, *Snd* and *wpG2_d-1_S* columns, should be combined under common headings – respectively, *Bulk density*, *Clay*, *Sand* and *Coarse fragment*.

3. For the *CEC and Bases* and *Carbon and Extractants* files, create the following parameter and method columns: *Al cmoles/kg, Base Saturation %, Total C %, CN ratio, Ca cmoles/kg, CEC sum, ECEC, Extractable Acidity, Fe %, K cmoles/kg, Mg cmoles/kg, Mn, Total N %, Na cmoles/kg, Organic C%, S %*, and *Si %.* Combine elemental data by method and element, filling in the method column with the appropriate method (the complete method associated with each parameter name should be obtained from the *CEC and Bases* and *Carbon and Extractants dict* files). The following restrictions apply when combining element and method data: only use Al data that was extracted by KCl (Al_kcl); use base saturation measured at pH 8.2; use CEC calculated at pH 8.2; use Fe and Mn extracted by Dithionite-citrate; and use all organic carbon values except those obtained by sodium pyrophosphate (pyp) extraction.

4. Combine *PSDA and rock fragments*, *Bulk density and moisture*, *Carbon and extractions*, *CEC and bases*, and *pH and carbonates* data for each state into one file. Make sure that the *layer_key* for all data rows aligns.

5. Eliminate parameters from the combined data file so that the following parameters remain: *county, pedon_key, layer_key, layer_sequence, layer_field_label_1, hzn_top, hzn_bot, hzn_depth* (obtained from subtracting the *hzn_bot* from *hzn_top*), *hzn_dsgn, texture_description, pH CaCl, pH H2O, Clay, Silt, Sand, Coarse Fragment, Bulk density, Al cmoles/kg, Base Saturation %, Total C %, CN ratio, Ca cmoles/kg, CEC sum, ECEC, Extractable Acidity, Fe %, K cmoles/kg, Mg cmoles/kg, Mn, Total N %, Na cmoles/kg, Organic C%, S %,* and *Si %*, as well as associated method columns for *CEC and Bases* and *Carbon and Extractants* data.

6. Eliminate parameters from the *Pedon* data tier so the parameters *User_site_ID, pedon_key, county*, and *sampled_taxon_name* remain. The parameters *User_site_ID* and *sampled_taxon_name* should be renamed *PlotID* and *SoilSeries*, respectively.

7. Join the combined data file created in steps 4 and 5 with the *Pedon* data file on the *Pedon_Key* (this can be done in Microsoft Access), so that the new file includes *PlotID* and *SoilSeries*.

8. Create a Site file from the *Site* data tier that contains *user_site_ID*, *county*, and *latitude* and *longitude* in decimal degrees. The parameter *User_site_ID* should be renamed *PlotID*.

Critical Loads Database Data Entry

The combined soil horizon data from NRCS should be entered into the **Soil Horizon** table. Each Soil Horizon should be assigned a unique *Soil Horizon ID*. The site data should be entered into the **Site** table and assigned a unique *Site ID* number. The associated *Site ID* for each soil horizon should be entered into the *Site ID* column of the **Soil Horizon** table.

4.3.1.2 Soil Horizon Data Coding and Calculation

Some parameters in the Soil horizon table may be missing and need to be assigned or calculated. Parameters that may need to be assigned or calculated are *Rooting zone codes*, *Adjusted Bulk Density, Soil Texture,* and *Brady Moisture ID.* In addition, *Bulk Density, Coarse Fragment,* and *Soil Texture* may need to be filled in with values calculated from adjacent horizons or a soil series. Filled data are indicated by a flag column.

4.3.1.2.1 Assigning Rooting Zone Codes

The rooting zone is defined as the volume of mineral soil from which (we assume) the majority of nutrients are accessed by tree roots. The rooting zone is defined as starting at the top of the mineral soil and continuing through the bottom of the B horizon, excluding the BC horizon. Depending on the site characteristics, the BC horizon may also be included. *Rooting zone* codes are assigned to soil horizons in order to facilitate calculation of soil averages from soil horizons. In the Critical Loads database, the horizons are currently coded as follows:

1 = included in the rooting zone (A, E, and B horizons)

2 = excluded from the rooting zone (O, (L, F, H), Bx, BC, C, and R)

Only horizons coded as *1* are included in soil average calculations from soil horizon data.

4.3.1.2.2 Calculating Adjusted Bulk Density

The bulk density of NRCS soil horizon data needs to be adjusted for the presence of coarse fragments. To adjust any bulk density value for coarse fragments, use the following equations:

Given: Coarse fragment (wt %); Bulk Density (BD) fine fraction (g/cm^3)

Assumed: BD of coarse fraction = 2.6 g/cm^3

Calculations:

X = fine fraction (wt %) =100 – coarse fragment (wt %) [4.1]

Y = Fine fraction volume = (fine fraction %)/100/(BD fine fraction) [4.2]

Z = Coarse fraction volume = coarse fraction%/100/(2.6 g/cm^3) [4.3]

V = total effective volume = Y + Z [4.4]

Adjusted bulk density (BD*)

BD* = X/V [4.5]

The bulk density may not need to be adjusted in non-NRCS data. If the bulk density data are already adjusted for course fragments, the data should be assigned to the A*djusted Bulk Density* column.

4.3.1.2.3 Assigning Soil Texture Values

The texture of a soil is determined by relative percentage of sand, silt, and clay. If soil texture values have not already been assigned for a soil horizon, they should be assigned using a soil texture triangle (Fig. 4.2). If all or many soil texture values have not been assigned, they can be done in batch using resources available at http://nowlin.css.msu.edu/software/triangle_form.html.

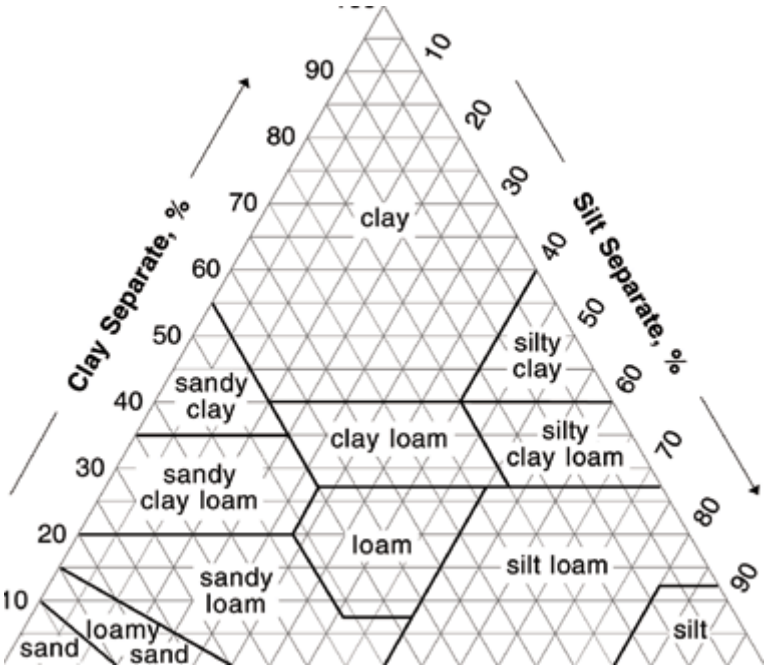

Figure 4.2 Soil texture triangle. (from: http://www.pedosphere.com/resources/texture/triangle_us.cfm).

4.3.1.2.4 Assigning the Brady Moisture ID

If measured soil moisture data are unavailable, the *Brady Moisture ID* is assigned to horizons in the **Soil Horizon** table based on soil texture values (section 4.3.1.2.3.). *Brady Moisture ID* codes and their correlated soil texture values are given in Appendix B. If a soil has been assigned a soil texture that does not appear in the **Brady Moisture ID** table, assign the next best fit. For example, if the soil texture assigned to a horizon was "fine sandy loam", the *Brady Moisture ID* for sandy loam should be assigned to the soil horizon.

Critical Loads Database Data Entry
Rooting Zone code, *Adjusted Bulk Density*, *Soil texture,* and *Brady Moisture ID* should be entered into the appropriate rows and columns of the **Soil Horizon** table.

4.3.1.2.5 Soil Horizon Data Filling for Bulk Density, Coarse Fragments, and Soil Texture

If bulk density, coarse fragments, and/or soil texture data are missing from a rooting zone (see section 4.3.1.2.1) horizon, they should be filled in from calculated data. The following list provides methods for filling in missing data, from most desirable to acceptable:

1. from the same *pedon*, same horizon designation (e.g., B1 data used for B2 data);
2. from the same *series*, same horizon designation (e.g., B1 data used for B2 data);
3. from the same *pedon*, average of primary horizon designation (e.g., Bs data for Bsh data); and finally,
4. from the same *series*, average of primary horizon designation (e.g., Bs data for Bsh data).

Bulk density, *Coarse fragment*, and *Soil Texture* data filled in this fashion should be marked with a *Soil Horizon Flag ID* code (Appendix B) in *Bulk Density Flag*, *C Frag Flag*, and *Texture Flag* columns respectively.

Critical Loads Database Data Entry
Filled data values and Flag codes should be entered into the appropriate rows and columns of the **Soil Horizon** table.

4.3.2 Soil Data Calculations

Soil data consist of physical, textural, and mineralogical data for soil rooting zones at a sample site. Soil data values may be previously measured averages or may be calculated from soil horizon data. Values measured at the site are the preferred source of soil data. If data from the site are unavailable, averaged data for the soil series may be used. If measured mineralogy data are unavailable, regionally modeled values for soil mineralogy may be used if they exist.

4.3.2.1 Calculating Depth-Weighted Soil Data from Soil Horizon Data

Soil input values used in calculating critical loads represent a single depth-weighted average for the rooting zone. If soil data for a site have not been previously calculated from rooting zone averages, this can be done by taking depth-weighted averages of numerical data, as described below.

1. Extract all soil horizon data for the desired soil sample/site with a *Rooting zone* code of *1* from soil horizon data or the **Soil Horizon** table. Instructions for assigning the *Rooting zone* code are given in section 4.3.1.2.

2. Multiply numeric parameter values by depth to generate depth-weighted numeric parameter columns (e.g., multiply bulk density value 1.5 by horizon depth 4 to obtain a depth-weighted bulk density value of 6).

3. Sum all numeric parameters (this can be done using a Pivot table in Microsoft Excel), including horizon depth, by site/pedon.

4. Divide the summed parameter values by the summed horizon depth to obtain depth-weighted averages for each site/pedon. These depth weighted averages are the soil values for a site.

5. Combine the calculated numeric values with non-numeric values – *Plot ID, SoilSeries, County,* and *pedon_key* to create a file for input into the **Soil** table.

Critical Loads Database Data Entry

The soil data should be assigned a unique *Soil ID* number per pedon/site and entered into appropriate columns of the **Soil Table.** The associated *Site ID* for each **Soil** table entry should be entered into the *Site ID* column of the **Soil** table. The newly created *Soil ID* should be entered into the *Soil ID* column of the **Soil Horizon** table. In the case of NRCS data, this may be done by matching on the *pedon_key.*

4.3.3 Data Filling for Missing Soil Data

Values measured at the site are always the preferred source of soil data. Soil data for sites without site-measured soil data are filled in from soil series averages by county, state, or region. If the soil series for a site is not included in site data, the series can be assigned by overlaying site coordinates onto soil maps (e.g., County Soil Survey maps). If the soil map of the site indicates a soil complex or associations of two or more soil series, the soil series identified become multiple soil scenarios, with different unique *Soil ID* numbers, in order to capture the potential range of soil weathering that may occur at a given site.

4.3.3.1 Estimating minimum and maximum potential weathering rates

For sites without soil data, it is important to try to capture a range of potential weathering rates. In addition to using the mean soil data as described above, two additional soil scenarios may be used for sites without soil data: a minimum potential weathering rate scenario and a maximum potential weathering rate scenario. These are developed from information taken from the Official Soil Series Descriptions (OSDs), which can be found at http://soils.usda.gov/technical/classification/osd/index.html by clicking on "View OSDs by List of Series Names (with FTP option)" and typing in the soil series name. Minimum and maximum values for clay % (based on soil texture, if not listed explicitely) and depth to root limiting laye can be found in the Official Soil Series Description. Before extracting these values, double check the drainage class. If the soil series associated with the site tends to be poorly drained, exclude this site from the analysis unless you know that the site is well-drained (from field experience).

If the soil series is well drained, the required information is located in the range of characteristics section of the OSD. The range of soil depth that is needed is often expressed as solum depth or mineral soil depth, as opposed to the depth to bedrock, which sometimes includes C horizons (which are excluded from the rooting zone). Note that depth is most often given in inches in OSDs and must be converted to cm. Also, if information is given regarding depth to a limiting or cemented horizon, this is the depth to use.

Also from the range of characteristics, extract information regarding possible soil textures for all horizons. This is used to determine the minimum and maximum clay percents.

The Geographic Setting section of the OSD lists the typical bedrock from which the soil series is formed. This information allows us to categorize the substrate as acidic, intermediate, or basic. Lastly, from the Use and Vegetation section, it is interesting to note the common trees that grow on individual types of soil. For the NRCS sites, this can sometimes be used to assign a likely regional forest type.

4.3.3.2 Soil Metadata and Quality Assurance and Control

As with all datasets, it is important to understand how the data were gathered (or modeled) in order to determine if the data are appropriate for use in making critical loads calculations. Soil mineralogy data are available from NRCS, but in many instances the data do not represent the bulk soil but only specific particle size fractions of the soil (e.g., fine sand). More information

about the calculation of weathering rates can be found in the VT NEG/ECP Site-Specific Critical Loads Report (Duarte and Pardo, In prep).

The Soil Climate Analysis Network (SCAN; http://www.wcc.nrcs.usda.gov/scan/) is a potential source for soil temperature and moisture data. These datasets need to be carefully reviewed, however. In Vermont, capacitance probes are used to measure soil moisture data; however, the probes are not calibrated in the field at this time, organic matter content is not accounted for, and the algorithms available are limited to only three soil textures (which may or may not be appropriate for the site). While SCAN provides useful data for some projects, it may not be appropriate for use in the critical loads calculations at the single-site scale. In absence of soil temperature and moisture data from a site, air temperature is often used as a proxy for soil temperature, and soil moisture can be estimated based on texture (see section 4.2.6).

4.4 Soil References

Soil Survey Staff. 2003. National Soil Survey Characterization Data, Soil Survey Laboratory. National Soil Survey Center. USDA-NRCS -Lincoln, NE.

Appendix A: Summary of the required and optional parameters for making critical loads calculations.

Site Name: **Contact Person:** **Contact Information:**	**Mandatory or Optional**	**Check if available**		**Mandatory or Optional**	**Check if available**
1. Site Description Data			**2. Atmospheric/Climate Data**		
Latitude and longitude (center point)	M		Total deposition (N, S, Ca, Mg, K, Na)		
Elevation	M		Wet deposition	M	
Polygon file and/or plot radius	M		Dry Deposition	M	
Principle investigators	O		Bulk deposition	O	
Size of site	O		Throughfall	M	
Land-use history	O		Precipitation volume (long-term)	M	
Disturbance history	O		Mean annual temperature (long term)	M	
Political jurisdiction	O		Mean annual evapotranspiration	M	
Publications associated with site	O		Runoff	M	
			Other	O	
3. Tree Data			**4. Soil Data**[1]		
Stand composition	M		Number of soil pits/site	M	
DBH	M		Soil depth	M	
Number of stems by species	M		Soil texture	M	
Nutrient concentration (N, Ca, Mg, K) by biomass fraction by species	M		Soil bulk density (and course fragment content)	M	
Annual biomass removal rate	M		Parent material	M	
Biomass by species	M		Soil series	M	
Average height by species	O		Mineralogy	O	
MAI	O		Soil profile descriptions	O	
Volume	O		Soil Map	O	
Nutrient uptake by species	O		Organic matter percent	M	
Nutrient ratios	O		Extractable nutrients (Ca, Mg, K, Na)	M	
Other	O		Cation exchange capacity	M	
			Base saturation	M	
			Volumetric soil moisture	M	
			Lysimeter data (see section 5 for parameter list)	M	
			pH	O	
			Other	O	
5. Forest Health Data			**6. Stream Water Data**		
Foliage transparency	O		Size of catchment	O	
Crown density	O		Alkalinity, pH, conductivity	O	
Mortality	O		Base cations (Ca, Mg, K, Na)	O	
Dieback	O		NH4-N, NO3-N	O	
Insect damage and disease	O		SO4-S	O	
Areas of forest decline	O		Cl	O	
Vegetation structure	O		DOC	O	
Other (lichens, …)	O		Al (reactive)	O	

[1]If soil depth, texture, bulk density, and parent material are unknown, soil series must be known

Appendix B: CLDB Parameter List with Full Definitions

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AET Table

The annual evapotranspiration (AET) table contains evapotraspiration data. Evapotranspiration is the total water transferred from the earth's surface to the atmosphere. It includes the evaporation of water from bodies of water and land as well as transpiration from plants.

AETID

The annual evapotranspiration identification number is unique for each AET scenario.

SiteID

The site identification number links AET scenarios to specific sites.

Mean_AET_cm

Modeled mean AET. Measured AET, when available, is included in this column.

Min_AET_cm

Modeled minimum annual AET.

Max_AET_cm

Modeled maximum annual AET.

AET_source

The source of annual AET calculations. This refers to a climate model or to an actual collection site.

Air Temperature Table

The air temperature table contains average air temperature data as collected at measuring stations over a given time period.

AirTemperatureID

The air temperature identification number is unique for each air temperature scenario.

SiteID

The site identification number links air temperature scenarios to specific sites.

FMGSite

A Forest Mapping Group name is assigned to each site. This number is correlated with the Site ID number.

MeasurementTimePeriod

The time span over which temperature measurements occurred.

Jan_temp_C

Average January temperature in degrees Celsius.

Feb_temp_C

Average February temperature in degrees Celsius.

Mar_temp_C

Average March temperature in degrees Celsius.

Apr_temp_C

Average April temperature in degrees Celsius.

May_temp_C

Average May temperature in degrees Celsius.

Jun_temp_C

Average June temperature in degrees Celsius.

Jul_temp_C
Average July temperature in degrees Celsius.
Aug_temp_C
Average August temperature in degrees Celsius.
Sep_temp_C
Average September temperature in degrees Celsius.
Oct_temp_C
Average October temperature in degrees Celsius.
Nov_temp_C
Average November temperature in degrees Celsius.
Dec_temp_C
Average December temperature in degrees Celsius.
AnnualAirTemp_mean_C
Average annual air temperature in degrees Celsius, by calendar year.
AnnualAirTemp_min_C
Minimum annual air temperature in degrees Celsius, by calendar year.
AnnualAirTemp_max_C
Maximum annual air temperature in degrees Celsius, by calendar year.
SolarRadiation_W/m2
Mean annual solar radiation in watts per square meter.
WindSpeed_m/s
Mean annual wind speed in meters per second.
ClimateSourceID
The climate source identification number links to air temperature value modeling methods.

Additional Soil Data Table

The additional soil data table contains soil data values not included in the soil table.

AdditionalSoilDataID
The additional soil data identification number is unique for each data set.
SoilID
The soil identification number links additional soil data sets to specified soils.
SoilTempByDepth
Soil temperature by depth.
Ca_leaching _eq/m/y
Calcium leaching rate through the soil in equivalents per meter per year.
K_leaching _eq/m/y
Potassium leaching rate through the soil in equivalents per meter per year.
Mg_leaching _eq/m/y
Magnesium leaching rate through the soil in equivalents per meter per year.
NO3_leaching _eq/m/y
Nitrate leaching rate through the soil in equivalents per meter per year.
H_leaching _eq/m/y
Hydrogen leaching rate through the soil in equivalents per meter per year.

Al_leaching _eq/m/y
Aluminum leaching rate through the soil in equivalents per meter per year.
Flux_values

Flux_calulation

Al:CEC
Ratio of soil aluminum to cation exchange capacity.
Al:BC
Ratio of soil aluminum to base cations.
Denitrification_rates_eq/m/y
Rate of denitrification in the soil in equivalents per meter per year.
N_fixation_rates _eq/m/y
Rate of nitrogen fixation in the soil in equivalents per meter per year.
N_immobilization_rates_eq/m/y
Rate of nitrogen immobilization in the soil in equivalents per meter per year.
SoilTempByDepth_methods
Method for measuring the soil temperature at different depths.
Ca_leaching_methods
Method for measuring calcium leaching rates.
K_leaching_methods
Method for measuring potassium leaching rates.
Mg_leaching_methods
Method for measuring magnesium leaching rates.
NO3_leaching_methods
Method for measuring nitrate leaching rates.
H_leaching_methods
Method for measuring hydrogen leaching rates.
Al_leaching_methods
Method for measuring aluminum leaching rates.
Flux_values_methods
Method for measuring flux values.
Flux_calulations_methods
Method for calculating flux values.
Al:CEC_methods
Method for measuring soil aluminum to cation exchange capacity ratio.
Al:BC_methods
Method for measuring soil aluminum to base cation ratio.
Denitrification_rates_methods
Method for measuring soil denitrification rates.
N_fixation_rates_methods
Method for measuring soil nitrogen fixation rates.
N_immobilization_rates_methods
Method for measuring soil nitrogen immobilization rates.
SoilTempByDepth_QAQC
Quality assurance and control mechanisms for soil temperature by depth measurements.

Ca_leaching_QAQC
Quality assurance and control mechanisms for calcium leaching measurements.
K_leaching_QAQC
Quality assurance and control mechanisms for potassium leaching measurements.
Mg_leaching_QAQC
Quality assurance and control mechanisms for magnesium leaching measurements.
NO3_leaching_QAQC
Quality assurance and control mechanisms for nitrate leaching measurements.
H_leaching_QAQC
Quality assurance and control mechanisms for hydrogen leaching measurements.
Al_leaching_QAQC
Quality assurance and control mechanisms for aluminum leaching measurements.
Flux_values_QAQC
Quality assurance and control mechanisms for flux values.
Flux_calulations_QAQC
Quality assurance and control mechanisms for flux calculations.
Al:CEC_QAQC
Quality assurance and control mechanisms for aluminum to cation exchange capacity ratio calculations.
Al:BC_QAQC
Quality assurance and control mechanisms for Aluminum to base cation ratio calculations.
Denitrification_rates_QAQC
Quality assurance and control mechanisms for denitrification rates.
N_fixation_rates_QAQC
Quality assurance and control mechanisms for nitrogen fixation rates.
N_immobilization_rates_QAQC
Quality assurance and control mechanisms for nitrogen immobilization rates.
SoilTempByDepth_uncertainty
Uncertainty associated with soil temperature by depth values.
Ca_leaching_uncertainty
Uncertainty associated with calcium leaching rate values.
K_leaching_uncertainty
Uncertainty associated with potassium leaching rate values.
Mg_leaching_uncertainty
Uncertainty associated with magnesium leaching rate values.
NO3_leaching_uncertainty
Uncertainty associated with nitrate leaching rate values.
H_leaching_uncertainty
Uncertainty associated with hydrogen leaching rate values.
Al_leaching_uncertainty
Uncertainty associated with aluminum leaching rate values.
Flux_values_uncertainty
Uncertainty associated with flux values.
Flux_calculations_uncertainty
Uncertainty associated with flux calculation values.

Al:CEC_uncertainty
Uncertainty associated with aluminum to cation exchange capacity ratio values.

Al:BC_uncertainty
Uncertainty associated with aluminum to base cation ratio values.

Denitrification_rates_uncertainty
Uncertainty associated with denitrification rate values.

N_fixation_rates_uncertainty
Uncertainty associated with nitrogen fixation rates values.

N_immobilization_rates_uncertainty
Uncertainty associated with nitrogen immobilization rates values.

SoilTempByDepth_comments
Comments on irregularities or calculations associated with soil temperature by depth values.

Ca_leaching_comments
Comments on irregularities or calculations associated with calcium leaching rate values.

K_leaching_comments
Comments on irregularities or calculations associated with potassium leaching rate values.

Mg_leaching_comments
Comments on irregularities or calculations associated with magnesium leaching rate values.

NO3_leaching_comments
Comments on irregularities or calculations associated with nitrate leaching rate values.

H_leaching_comments
Comments on irregularities or calculations associated with hydrogen leaching rate values.

Al_leaching_comments
Comments on irregularities or calculations associated with aluminum leaching rate values.

Flux_values_comments
Comments on irregularities or calculations associated with flux values.

Flux_calulations_comments
Comments on irregularities associated with flux calculations values.

Al:CEC_comments
Comments on irregularities or calculations associated with aluminum to cation exchange capacity ratio values.

Al:BC_comments
Comments on irregularities or calculations associated with aluminum to base cation ratio values.

Denitrification_rates_comments
Comments on irregularities or calculations associated with denitrification rate values.

N_fixation_rates_comments
Comments on irregularities or calculations associated with nitrogen fixation rate values.

N_immobilization_rates_comments
Comments on irregularities or calculations associated with nitrogen immobilization rate values.

Biomass Extraction Table

The biomass extraction table contains biomass extraction values by county. Values for hardwood, softwood, and mixed-wood on public and private land are provided.

BiomassExtractionID
Unique identification number for each County-based biomass extraction scenario.

County
County name

PrivateSoftwood%
Percent of private softwood biomass extracted annually.

PrivateHardwood%
Percent of private hardwood biomass extracted annually.

PrivateMixedwood%
Percent of private mixed-wood biomass extracted annually.

PublicSoftwood%
Percent or public softwood biomass extracted annually.

PublicHardwood%
Percent of Public hardwood biomass extracted annually.

PublicMixedwood%
Percent of Public mixed-wood biomass extracted annually.

BradyMoisture

The Brady moisture values contained in this table are taken from a soil texture versus moisture curve developed by Brady (Brady, 1990).

BradyMoistureID
Unique identification number for each soil texture classification.

SoilTexture
Soil texture classification, based the percent of sand, silt, and clay in a soil sample.

VolumetricMoisture_FC
Average volumetric moisture at field capacity for soil texture classification.

VolumetricMoisture_PWP
Average volumetric moisture at the plant wilting point for soil texture classification.

Climate Source Table

The Climate Source Table contains information on the source of data provided in the Air Temperature and Precipitation tables.

ClimateSourceID
The climate source identification number is unique for each climate information source.

PreciptationMethod
Method for measuring precipitation.

AirTempMeasurementMethod
Method for measuring air temperature.

AirTempMeasurementFrequency
Frequency of air temperature measurements.
AirTempNumberOfSensors
Number of sensors used to take air temperature measurements.
AirTempQAQC
Quality assurance and control mechanisms for air temperature measurements.
AirTempUncertainty
Uncertainty associated with air temperature measurements.
AirTempComments
Comments on irregularities or calculations associated with air temperature measurements.

Deposition Source Table

The deposition source table contains information on the source of data provided in the deposition table. Definitions of the different types of deposition – wet, dry, bulk, cloud, and throughfall – can be found in the Deposition Table description.

DepositionSourceID
The deposition source identification number is unique for each set of deposition source values.
SourceName
The name of the study or station providing deposition data.
CollectionMethod_wet
Method of collecting wet deposition.
Model_wet
Method of modeling wet deposition values.
CollectionFrequency_wet
Frequency of wet deposition collection.
NumberOfCollectors_wet
Number of wet deposition collectors.
EvidenceOfContamination_wet
Any evidence of the sample contamination for wet deposition.
EvidenceOfEvaporation_wet
Any evidence of evaporation of wet deposition.
TreatmentRegimen_wet
Wet deposition sample treatment regimen.
FilteredSamples_wet
Wet deposition sample filtration method.
AnalysisMethod_wet
Wet deposition sample analysis method.
QAQC_wet
Quality assurance and control mechanisms for wet deposition samples..
Uncertainty_wet
Uncertainty associated with wet deposition sample collection and analysis.
Comments_wet
Comments on irregularities or calculations associated with wet deposition samples.

CollectionMethod_dry
Method for collecting dry deposition samples.
Model_dry
Method for modeling dry deposition.
CollectionFrequency_dry
Frequency of dry deposition sample collection.
NumberOfCollectors_dry
Number of dry deposition sample collection stations.
EvidenceOfContamination_dry
Any evidence of contamination of dry deposition samples.
TreatmentRegimen_dry
Dry deposition sample treatment regimen.
FilteredSamples_dry
Dry deposition sample filtration method.
AnalysisMethod_dry
Dry deposition sample analysis method.
QAQC_dry
Quality assurance and control mechanisms for dry deposition samples.
Uncertainty_dry
Uncertainty associated with dry deposition sample collection and analysis.
Comments_dry
Comments on irregularities or calculations associated with dry deposition samples.
CollectionMethod_cloud
Method for collecting cloud deposition samples.
Model_cloud
Method for modeling cloud deposition.
CollectionFrequency_cloud
Frequency of cloud deposition sample collection.
NumberOfCollectors_cloud
Number of cloud deposition sample collection stations.
EvidenceOfContamination_cloud
Any evidence of cloud deposition sample contamination.
EvidenceOfEvaporation_cloud
Any evidence of cloud deposition sample evaporation.
TreatmentRegimen_cloud
Cloud deposition sample treatment regimen.
FilteredSamples_cloud
Cloud deposition sample filtration method.
AnalysisMethod_cloud
Cloud deposition sample analysis method.
QAQC_cloud
Quality assurance and control mechanisms for cloud deposition samples.
Uncertainty_cloud
Uncertainty associated with cloud deposition sample collection and analysis.
Comments_cloud
Comments on irregularities or calculations associated with cloud deposition samples.

CollectionMethod_bulk
Method for collecting bulk deposition samples.
Model_bulk
Method for modeling bulk deposition.
CollectionFrequency_bulk
Frequency of bulk deposition sample collection frequency.
NumberOfCollectors_bulk
Number of bulk deposition sample collection stations.
EvidenceOfContamination_bulk
Any evidence of contamination of bulk deposition samples.
EvidenceOfEvaporation_bulk
Any evidence of evaporation of bulk deposition samples.
TreatmentRegimen_bulk
Bulk deposition sample treatment regimen,
FilteredSamples_bulk
Bulk deposition sample filtration method.
AnalysisMethod_bulk
Bulk deposition sample analysis method.
QAQC_bulk
Quality assurance and control mechanisms for bulk deposition samples.
Uncertainty_bulk
Uncertainty associated with bulk deposition sample collection and analysis.
Comments_bulk
Comments on irregularities or calculations associated with bulk deposition samples.
CollectionMethod_throughfall
Method for collecting throughfall samples.
Model_throughfall
Method for modeling throughfall.
CollectionFrequency_throughfall
Frequency of throughfall sample collection.
NumberOfCollectors_throughfall
Number of throughfall sample collection stations.
EvidenceOfContamination_throughfall
Any evidence of contamination of throughfall samples.
EvidenceOfEvaporation_throughfall
Any evidence of evaporation of throughfall samples.
TreatmentRegimen_throughfall
Throughfall sample treatment regimen.
FilteredSamples_throughfall
Throughfall sample filtration method.
AnalysisMethod_throughfall
Throughfall analysis method.
QAQC_throughfall
Quality assurance and control mechanisms for throughfall samples.
Uncertainty_throughfall
Uncertainty associated with throughfall sample collection and analysis.

Comments_throughfall

Comments on irregularities or calculations associated with throughfall samples.

Deposition Table

The deposition table contains wet, dry, cloud, throughfall, and bulk deposition values for multiple elements. The mass data presented for all nitrogen and sulfur containing molecules are for the nitrogen and sulfur only, and not for the entire molecule (e.g. NO_3-N or SO_4-S). **Wet deposition** refers to the deposition of atmospheric particles to the earth's surfaces through rain or snow. **Dry deposition** is the deposition of gasses and atmospheric particles to the earth's surfaces without the aid of rain, snow, fog, or clouds. **Cloud deposition** is the deposition of atmospheric particles to the earth's surfaces by clouds; this form of deposition can be very important at high elevations. **Bulk deposition** refers to all atmospheric particles collected at a measuring station, and does not differentiate between wet, dry, or cloud deposition. **Throughfall** is precipitation that passes through the forest canopy. The chemical composition of throughfall can be very different from that of precipitation, since it interacts with leaves and substances on the leaves.

DepositionID

The deposition identification is unique for each site-deposition scenario.

SiteID

The site identification number is a unique number that links deposition scenarios to specific sites.

AvailableDataDates

Dates for which data is available.

NH4_N_wet_kg/ha/yr

The amount of nitrogen deposited per year, in kilograms per hectare, as a result if wet ammonium deposition.

NO3_N_wet_kg/ha/yr

The amount of nitrogen deposited per year, in kilograms per hectare, as a result of wet nitrate deposition.

N_tot_wet_kg/ha/yr

The total amount of nitrogen deposited, in kilograms per hectare per year, as a result of wet deposition.

NH4_N_dry_kg/ha/yr

The amount of nitrogen deposited per year, in kilograms per hectare, as the result of dry ammonium deposition.

NO3_N_dry_kg/ha/yr

The amount of nitrogen deposited per year, in kilograms per hectare, as the result of dry nitrate deposition.

HNO3_N_dry_kg/ha/yr

The amount of nitrogen deposited per year, in kilograms per hectare, as the result of dry nitric acid deposition.

N_tot_dry_kg/ha/yr

The total amount of nitrogen deposited per year, in kilograms per hectare, as the result of dry deposition.

N_tot_cloud_kg/ha/yr
The total amount of nitrogen deposited per year, in kilograms per hectare, as the result of cloud deposition.

N_total_kg/ha/yr
The total amount of nitrogen deposited per year, in kilograms per hectare, in all forms of deposition.

SO4_S_wet_kg/ha/yr
The amount of sulfur deposited per year, in kilograms per hectare, as the result of wet sulfate deposition.

S_tot_wet_kg/ha/yr
The total amount of sulfur deposited per year, in kilograms per hectare, as the result of wet deposition.

SO4_S_dry_kg/ha/yr
The amount of sulfur deposited per year, in kilograms per hectare, in dry sulfate deposition.

SO2_S_dry_kg/ha/yr
The amount of sulfur deposited per year, in kilograms per hectare, as the result of dry sulfide deposition.

S_tot_dry_kg/ha/yr
The total amount of sulfur deposited per year, in kilograms per hectare, as the result of dry deposition.

S_tot_cloud_kg/ha/yr
The total amount of sulfur deposited per year, in kilograms per hectare, as the result of cloud deposition.

S_total_kg/ha/yr
The total amount of sulfur deposited per year, in kilograms per hectare, in all forms of deposition.

Total_S_dry_to_wet
The dry to wet ratio of total sulfur deposition.

Total_N_dry_to_wet
The dry to wet ration of total nitrogen deposition.

Ca_wet_kg/ha/yr
The total amount of calcium deposited per year, in kilograms per hectare, in wet deposition.

Ca_dry_kg/ha/yr
The total amount of calcium deposited per year, in kilograms per hectare, in dry deposition.

Ca_cloud_kg/ha/yr
The total amount of calcium deposition per year, in kilograms per hectare, in cloud deposition.

Ca_bulk_kg/ha/yr
The total amount of calcium deposited per year, in kilograms per hectare, in bulk deposition.

Ca_throughfall_kg/ha/yr
The total amount of calcium deposited per year, in kilograms per hectare, in throughfall.

Ca_total_kg/ha/yr
The total amount of calcium deposited per year, in kilograms per hectare, in all forms of deposition.

Cl_wet_kg/ha/yr
The total amount of chloride deposited per year, in kilograms per hectare, in wet deposition.

Cl_dry_kg/ha/yr
The total amount of chloride deposited per year, in kilograms per hectare, in dry deposition.

Cl_cloud_kg/ha/yr
The total amount of chloride deposited per year, in kilograms per hectare, in cloud deposition.

Cl_bulk_kg/ha/yr
The total amount of chloride deposited per year, in kilograms per hectare, in bulk deposition.

Cl_throughfall_kg/ha/yr
The total amount of chloride deposited per year, in kilograms per hectare, in throughfall.

Cl_total_kg/ha/yr
The total amount of chloride deposited per year, in kilograms per hectare, in all forms of deposition.

H_wet_kg/ha/yr
The total amount of hydrogen deposited per year, in kilograms per hectare, in wet deposition.

H_dry_kg/ha/yr
The total amount of hydrogen deposited per year, in kilograms per hectare, in dry deposition.

H_cloud_kg/ha/yr
The total amount of hydrogen deposited per year, in kilograms per hectare, in cloud deposition.

H_bulk_kg/ha/yr
The total amount of hydrogen deposited per year, in kilograms per hectare, in bulk deposition.

H_throughfall_kg/ha/yr
The total amount of hydrogen deposited per year, in kilograms per hectare, in throughfall.

H_total_kg/ha/yr
The total amount of hydrogen deposited per year, in kilograms per hectare, in all forms of deposition.

K_wet_kg/ha/yr
The total amount of potassium deposited per year, in kilograms per hectare, in wet deposition.

K_dry_kg/ha/yr
The total amount of potassium deposited per year, in kilograms per hectare, in dry deposition.

K_cloud_kg/ha/yr
The total amount of potassium deposited per year, in kilograms per hectare, in cloud deposition.

K_bulk_kg/ha/yr
The total amount of potassium deposited per year, in kilograms per hectare, in bulk deposition.

K_throughfall_kg/ha/yr
The total amount of potassium deposited per year, in kilograms per hectare, in throughfall deposition.

K_total_kg/ha/yr
The total amount of potassium deposited per year, in kilograms per hectare, in all forms of deposition.

Mg_wet_kg/ha/yr
The total amount of magnesium deposited per year, in kilograms per hectare, in wet deposition.

Mg_dry_kg/ha/yr
The total amount of magnesium deposited per year, in kilograms per hectare, in dry deposition.

Mg_cloud_kg/ha/yr
The total amount of magnesium deposited per year, in kilograms per hectare, in cloud deposition.

Mg_bulk_kg/ha/yr
The total amount of magnesium deposited per year, in kilograms per hectare, in bulk deposition.

Mg_throughfall_kg/ha/yr
The total amount of magnesium deposited per year, in kilograms per hectare, in throughfall.

Mg_total_kg/ha/yr
The total amount of magnesium deposited per year, in kilograms per hectare, in all forms of deposition.

Na_wet_kg/ha/yr
The total amount of sodium deposited per year, in kilograms per hectare, in wet deposition.

Na_dry_kg/ha/yr
The total amount of sodium deposited per year, in kilograms per hectare, in dry deposition.

Na_cloud_kg/ha/yr
The total amount of sodium deposited per year, in kilograms per hectare, in cloud deposition.

Na_bulk_kg/ha/yr
The total amount of sodium deposited per year, in kilograms per hectare, in bulk deposition.

Na_throughfall_kg/ha/yr
The total amount of sodium deposited per year, in kilograms per hectare, in throughfall.

Na_total_kg/ha/yr
The total amount of sodium deposited per year, in kilograms per hectare, in all forms of deposition.

Fire History Table

The Fire History table contains information on the fire histories. This table is supplemental to the Site table.

FireHistoryID

The fire history identification number is unique for each distinct fire history scenario.

FireDate

The date of the fire event.

FireDescription

A description of the fire event – the intensity, duration, and acreage.

SiteID

The site identification number links fire histories to specific sites.

Jenkins Biomass Fractions

This table contains a hardwood/softwood code and associated biomass equation values as found in Jenkins, et al. (2003). The equations can be used to calculate biomass ratios of foliage, roots, stem bark, and stem wood based on DBH (diameter at breast height) and softwood/hardwood category. Component biomass can be calculated by multiplying the component biomass ration with the aboveground biomass.

WoodDensityID

The wood density identification code is a unique identifier for hardwood and softwood value sets.

WoodType

The wood type names the wood type (h=hardwood; s=softwood) associated with the WoodDensityID.

Foliage_β_0

Assigned β_0 value in the foliar ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Foliage_ β_1

Assigned β_1 value in the foliar ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Roots_ β_0

Assigned β_0 value in the roots ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Roots_ β_1

Assigned β_1 value in the roots ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Bark_ β_0

Assigned β_0 value in the bark ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Bark_ β_1

Assigned β_1 value in the bark ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Wood_ β_0

Assigned β_0 value in the wood ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Wood_ β_1

Assigned B_1 value in the wood ratio calculation *ratio*=Exp($\beta_0 + \beta_1/dbh$), where *ratio* = ratio of component to total aboveground biomass for trees > 2.5 cm dbh, and *dbh* = diameter at breast height.

Jenkins Species Group

This table contains species group codes and associated biomass equation values as found in the following reference Jenkins, et al, 2003. The equations can be used to calculate the aboveground biomass of a given tree in kilometers based on its assigned species group category and its DBH (diameter at breast height).

SpeciesGroupID

The species group identification code is a two letter code used to identify species group as determined by Jenkins, et. al.

JenkinsName

Name assigned to Jenkins species group.

BM_ β_0 Biomass equation β_0 value

β_0 value used in the Jenkins equation *bm* = Exp($\beta_0 + \beta_1 \ln dbh$), where *bm* equals aboveground biomass in kg for trees 2.5 cm dbh or larger and where *dbh* equals the diameter at breast height.

BM_ β_1 Biomass equation β_1 value

β_1 value used in the Jenkins equation *bm* = Exp($\beta_0 + \beta_1 \ln dbh$), where *bm* equals aboveground biomass in kg for trees 2.5 cm dbh or larger and where *dbh* equals the diameter at breast height.

Land Use Table

The Land Use table contains land use codes and histories, and is supplemental to the Site table.

LandUseID

Identification number for unique land use patterns

LandUseDescription

Description of historical land use patterns.

Lysimeter Table

The Lysimeter table contains information from lysimeter soil water samples, and is supplemental to the Site table.

LysimeterID
Identification number for unique lysimeter samples.

SiteID
The site identification number links lysimeter samples to specific sites.

DataDatesAvailable
Dates for which lysimeter data are available.

DON_flux _eq/m2/y
Dissolved organic nitrogen flux, in equivalents per meter squared per year, in the lysimeter sample.

DON_concentration
Dissolved organic nitrogen concentration in the lysimeter sample.

DOC_flux _eq/m2/y
Dissolved organic carbon flux, in equivalents per meter squared per year, in the lysimeter sample.

DOC_concentration
Dissolved organic carbon concentration in the lysimeter sample.

Al_flux _eq/m2/y
Aluminum flux, in equivalents per meter squared per year, in the lysimeter sample.

Al_concentration
Aluminum concentration in the lysimeter sample.

Ca_flux _eq/m2/y
Calcium flux, in equivalents per meter squared per year, in the lysimeter sample.

Ca_concentration
Calcium concentration in the lysimeter sample.

H_flux _eq/m2/y
Hydrogen flux, in equivalents per meter squared per year, in the lysimeter sample.

H_concentration
Hydrogen concentration in the lysimeter sample.

K_flux _eq/m2/y
Potassium flux, in equivalents per meter squared per year, in the lysimeter sample.

K_concentration
Potassium concentration in the lysimeter sample.

Mg_flux _eq/m2/y
Magnesium flux, in equivalents per meter squared per year, in the lysimeter sample.

Mg_concentration
Magnesium concentration in the lysimeter sample.

Na_flux _eq/m2/y
Sodium flux, in equivalents per meter squared per year, in the lysimeter sample.

Na_concentration
Sodium concentration in the lysimeter sample.

NH4_flux _eq/m2/y
Ammonium flux, in equivalents per meter squared per year, in the lysimeter sample.

NH4_concentration
Ammonium concentration in the lysimeter sample.
NO3_flux _eq/m2/y
Nitrate flux, in equivalents per meter squared per year, in the lysimeter sample.
NO3_concentration
Nitrate concentration in the lysimeter sample.
SO4_flux _eq/m2/y
Sulfate flux, in equivalents per meter squared per year, in the lysimeter sample.
SO4_concentration
Sulfate concentration in the lysimeter sample.
FluxConversion
Flux conversion factors.
LysimeterType
Type of lysimeter used to collect lysimeter sample
CollectionFrequency
Frequency of lysimeter sample collection.
LysimeterNumber
Number of lysimeters used per site.
SampleDepth
Lysimeter sampling depth (distance below the soil surface).
SamplesFiltered
Indicates if lysimeter samples were filtered prior to analysis.
AnalysisMethod
Method of lysimeter sample analysis.
QAQC_lysimeter
Quality assurance and control mechanisms for lysimeter samples.
Uncertainty_lysimeter
Uncertainty associated with lysimeter data.
Comments_lysimeter
Comments on irregularities or calculations associated with lysimeter data values.

Precipitation Table

The Precipitation table contains monthly and annual precipitation values in centimeters. It is supplemental to the Site table.

PrecipitationID
Identification number for each unique precipitation sample.
SiteID
The site identification number links precipitation samples to specific sites
MeasurementTimePeriod
Time period over which precipitation samples were collected.
Jan_precip_cm
January precipitation in centimeters.
Feb_precip_cm
February precipitation in centimeters

Mar_precip_cm
March precipitation in centimeters.
Apr_precip_cm
April precipitation in centimeters.
May_precip_cm
May precipitation in centimeters.
Jun_precip_cm
June precipitation in centimeters.
July_precip_cm
July precipitation in centimeters.
Aug_precip_cm
August precipitation in centimeters.
Sep_precip_cm
September precipitation in centimeters.
Oct_precip_cm
October precipitation in centimeters.
Nov_precip_cm
November precipitation in centimeters.
Dec_precip_cm
December precipitation in centimeters.
AnnualPrecip_mean_cm
Mean annual precipitation in centimeters.
AnnualPrecip_min_cm
Minimum annual precipitation in centimeters.
AnnualPrecip_max_cm
Maximum annual precipitation in centimeters.
PercentPrecipSnow
Percent of precipitation falling as snow.
CloudPrecip_mean_cm
Mean annual cloud precipitation in centimeters.
ClimateSourceID
The Climate Source Identification code links sets of precipitation values to precipitation and climate measurement methods.

Publications

The Publications table contains information on any publications related to specific studies and sites, and is supplemental to the Study table.

PublicationsID
The Publications identification number is unique for each publication.
Author
Author name, with the last name appearing first.
CoAuthors
Publication Co-Authors; last name appears first.

Year
Year of publication.
Title
Title of publication.
Citation
Publication source data: journal or book source, [publisher], volume number, page numbers.
SiteID
The site identification number links publications to specific sites.
StudyID
The study identification code links publications to specific studies.

Regional Forest Type Table

The Regional Forest Type table contains codes and forest type descriptions as assigned by Eric K. Miller, Ecosystems Research Group, Inc., FMG.

Regional_FT
The regional forest type code number is unique to each forest type.
RegionlForestTypeDescription
Principal component trees associated with each Regional_FT code.

SAF Forest Type Table

The Society of American Foresters (SAF) Forest Type table contains codes and forest types for north and central regions as assigned by the Society of American Foresters.

SAF_FT
The Society of American Foresters code number is unique to each forest type.
SAF_FT_Description
Principal component trees associated with each SAF_FT code.

Site Table

The Site table contains site level geographic and vegetative cover information for individual sites.

SiteID
The site identification number is unique for each site.
StudyID
The study identification code links sites to specific studies.
FMGSite
The Forest Mapping Group code name is a unique name assigned to each site.

PlotID

The plot identification number is a unique code created from site codes assigned by study investigators. For example, FHM study sites were assigned hexagon ID numbers. These are listed in the PlotID column.

StateOrProvince

State or province where the site is located.

County

County where the site is located.

Latitude_dec_degrees

Site latitude in decimal degrees.

Longitude_dec_degrees

Site longitude in decimal degrees.

PreciseCoordinates

Indicates if the provided coordinates are precise.

SiteArea (ha)

The area of the site in hectares.

Min_elevation

The minimum site elevation in meters.

Mean_elevation

The mean site elevation in meters.

Max_elevation

The maximum site elevation in meters.

SiteMap

Y (yes) and N (no) indicate if a map of the site is available.

StartDate

Date that the site was incorporated into the study.

EndDate

Date that the site was no longer part of the study.

Principal_investigators

The main researchers/investigators at the study site.

Other_personnel

Other personnel involved in collecting, compiling, or disseminating study details.

Institute

Institute with which study personnel are associated.

DataAccess

Indicates site data may be shared.

SiteURL

Web address associated with the study site.

Jurisdiction

Indicates if site land is publicly or privately owned.

PercentConiferous

Percent of site forest cover that is coniferous.

PercentDeciduous

Percent of site forest cover that is deciduous.

StandAge

The average age of the entire site/stand.

StandAgeComment

Any irregularities or notes about stand age determinations.

Regional_FT

The site's regional forest type as assigned for the ecological unit analysis. The Regional FT code links to a description in the Regional FT table.

RFT_SpeciesComposition

The site's regional forest type as assigned based on site-specific species composition. The RFT_SpeciesComposition code links to a description in the Regional FT table.

RFT_SpeciesComposition B

An alternative site regional forest type as assigned based on site-specific species composition. The RFT SpeciesComposition B code links to a description in the Regional FT table.

RFT_SpeciesComp_Flag

The regional forest type flag indicates irregularities in regional forest types assigned to individual sites.

SAF_FT

The site's forest type as assigned based on basal area composition and Society of American Foresters forest type categories. The SAF_FT code links to a description in the SAF Forest Type table.

RFT_bm_xtxn

The regional forest type code from the ecological unit analysis that was used to determine biomass extraction rate. This code links to a description in the Regional FT table.

RFT_dep_models

The regional forest type values used to extraction deposition data from HRDM (High Resolution Deposition Model) (Miller, 2000). The RFT_dep_models code links to a description in the Regional FT table.

FoliageTransparency_%

The foliar transparency is an indication of the amount of sunlight seen through branch foliage.

CrownDensity_avg_%

An average visual estimate of the fullness of the crown, as based on the amount of sunlight blocked by leaves, branches, the bole, fruit, etc.

CrownDensity_low_%

A low visual estimate of the fullness of the crown, as based on the amount of sunlight blocked by leaves, branches, the bole, fruit, etc.

Defoliation

An estimate of the amount of crown defoliation, or leaf loss.

Vigor

An estimate of the vigor, or relative health of a tree or stand.

Decline

An estimate of the amount of decline in a tree or stand.

Mortality

Indicates the amount of mortality, or tree death, within a stand.

IncidenceOfDisease

Indicates the prevalence of disease within a stand.

IncidenceOfPestDamage
Indicates the prevalence of pest damage within the stand.
StemCountLive
Number of live trees on site.
StemCountDead
Number of dead trees on the site.
SiteComment
Notes of site data irregularities.
BS_factor
Base saturation factor
BS_factor_ClimSourceID
The base saturation factor climate source identification code links sites to the Climate Source table.
LandUseID
This ID links each site to specific land use scenarios in the Land Use table.

Soil Table

The Soil table contains soil physical, textural, and mineralogical content information as reported and/or calculated for individual soil pits. The Soil table is supplemental to the Site table.

SoilID
The soil identification number is unique to each soil sample.
SiteID
The site identification number links soil samples to specific sites.
PlotID
The plot identification number is the number assigned in the original soil survey.
FMGName
Forest Mapping Group name associated with each soil sample.
County
The county in which the soil sample is located.
SoilSampleDates
Dates that soil samples were taken.
SoilNutrientsDates
Dates that soil nutrient samples were taken.
SoilMap
Indicates if a site-specific soil map exists: Y=Yes, N=No.
SoilSeries
The official soil series name for the sampled soil, assigned based on soil physical and chemical properties.
SoilTaxonomy
The major taxonomic group to which a soil sample belongs.
RootingZoneDepth_cm
Depth from the surface to the bottom of the B horizon, excluding Bc and Bx layers.
SoilPercolationRate_m/y
Percolation rate through the soil in meters per year.

PercentClay
In soil texture analysis, percent of the soil sample that is clay.
PercentSilt
In soil texture analysis, percent of the soil sample that is silt.
PercentSand
In soil texture analysis, percent of the soil sample that is sand.
AdjustedBulkDensity_g/cm^3
Bulk density of the sample, in grams per cubic centimeter, adjusted for coarse fragments.
WeightedFC
The field capacity, defined as water remaining in a saturated soil after gravitational water has drained, weighted by horizon depth.
Texture name
Name of the soil texture class as determined by soil texture analysis.
Comments
Comments on irregularities and calculations associated with soil texture and classification parameters.
SoilCollectionMethod
Method for collecting the soil sample.
SoilPercolationRate_methods
Method for measuring the soil percolation rate.
Rooting_depth_measurements_methods
Method for taking rooting depth measurements.
SoilPercolationRate_QAQC
Quality assurance and control mechanisms for Soil percolation rate.
Rooting_depth_measurements_QAQC
Quality assurance and control mechanisms for rooting depth measurements.
SoilPercolationRate_uncertainty
Uncertainty associated with soil percolation rate values.
Rooting_depth_measurements_uncertainty
Uncertainty associated with rooting depth measurements values.
SoilPercolationRate_comments
Comments on irregularities or calculations associated with soil percolation rate.
Rooting_depth_measurements_comments
Comments on irregularities or calculations associated with rooting depth measurements.
SoilDataSource
Source of soil data information.
NutrientSampleSize
Size of the sample used to obtain soil nutrient values.
ODBulkDensity_method
Method used to determine oven dried bulk density.
OrganicMatterPercent_method
Method used to determine the organic matter percent within the sample.
ParentMaterialAnalysis_method
Method used to determine parent material composition.
Estimated_%_change_for_repeated_sampling
The estimated change resulting from repeated sampling.

Ca_analysis_method
Method for analyzing soil calcium concentration.
Ca_QAQC
Quality assurance and control mechanisms for calcium values.
Ca_uncertainty
Uncertainty associated with calcium measurements.
Ca_comments
Comments on irregularities or calculations associated with calcium values.
K_analysis_method
Method for analyzing soil potassium concentration.
K_QAQC
Quality assurance and control mechanisms for potassium values.
K_uncertainty
Uncertainty associated with potassium measurements.
K_comments
Comments on irregularities or calculations associated with potassium values.
Mg_analysis_method
Method for analyzing soil magnesium concentration.
Mg_QAQC
Quality assurance and control mechanisms for magnesium values.
Mg_uncertainty
Uncertainty associated with magnesium values.
Mg_comments
Comments on irregularities or calculations associated with magnesium values.
Na_analysis_method
Method for analyzing soil sodium concentration.
Na_QAQC
Quality assurance and control mechanisms for sodium values.
Na_uncertainty
Uncertainty associated with sodium measurements.
Na_comments
Comments on irregularities or calculations associated with sodium values.
Albite%
Percent albite in the soil sample.
Anthorite%
Percent anthorite in the soil sample.
Apatite%
Percent apatite in the soil sample.
Amphibole%
Percent amphibole in the soil sample.
Beryl%
Percent beryl in the soil.
Biotite%
Percent biotite in the soil.
Calcite%
Percent calcite in the soil.

Cassiterite%
Percent cassiterite in the soil.
Chlorite%
Percent chlorite in the soil.
Dolomite%
Percent dolomite in the soil.
Epidote%
Percent epidote in the soil.
feldspar%
Percent feldspar in the soil.
Garnet%
Percent garnet in the soil.
Glass%
Percent glass in the soil.
Hornblende%
Percent hornblende in the soil.
IronOxides%
Percent iron oxides in the soil.
Kaolinite%
Percent kaolinite in the soil.
KFeldspar%
Percent potassium feldspar in the soil.
Mica%
Percent mica in the soil.
Monazite%
Percent monazite in the soil.
Muscovite%
Percent muscovite in the soil.
Opaques%
Percent opaques in the soil.
PlagioclaseFeldspar%
Percent plagioclase feldspar in the soil.
Pyroxene%
Percent pyroxene in the soil.
Quartz%
Percent quartz in the soil.
Rutile%
Perecnt rutile in the soil.
Sericite%
Percent sericite in the soil.
Sohene%
Percent sohene in the soil.
Tourmaline%
Percent tourmaline in the soil.
VemicMica%
Percent vermiculite/mica in the soil.

Vermiculite%
Percent vermiculite in the soil.
WthrAggregates%
Percent weathered aggregates in the soil.
Zircon%
Percent zircon in the soil.
SoilMineralogy_datasource
Source of soil mineralogy data.
SoilMineralogy_method
Method for obtaining soil mineralogy data.
SoilMineralogy_comment
Comments on irregularities or calculations associated with soil mineralogy data.
CEC_cmoles/kg
Soil cation exchange capacity, in centimoles per kilogram.
CEC_method
Method for obtaining cation exchange capacity values.
CECSource
Source of cation exchange capacity values.
CECComment
Comments on irregularities or calculations associated with cation exchange capacity values.
Exhangeable_Ca_cmoles/kg
Exchangeable calcium in the soil, in centimoles per kilogram.
Exchangeable_Ca_method
Method for obtaining exchangeable calcium values.
Exchangeable_Ca_source
Source of exchangeable calcium values.
Exchangeable_Ca_comment
Comments on irregularities or calculations associated with exchangeable calcium values.
Exhangeable_K_cmoles/kg
Exchangeable potassium in the soil, in centimoles per kilogram.
Exchangeable_K_method
Method for obtaining exchangeable potassium values.
Exchangeable_K_source
Source of exchangeable potassium values.
Exchangeable_K_comment
Comments on irregularities or calculations associated with exchangeable potassium values.
Exhangeable_Mg_cmoles/kg
Exchangeable magnesium in the soil, in centimoles per kilogram.
Exchangeable_Mg_method
Method for obtaining exchangeable magnesium values.
Exchangeable_Mg_source
Source of exchangeable magnesium values.

Exchangeable_Mg_comment
Comments on irregularities or calculations associated with exchangeable magnesium values.

Exhangeable_Na_cmoles/kg
Exchangeable sodium in the soil, in centimoles per kilogram.

Exchangeable_Na_method
Method for obtaining exchangeable sodium values.

Exchangeable_Na_source
Source of exchangeable sodium values.

Exchangeable_Na_comment
Comments on irregularities or calculations associated with exchangeable sodium values.

Exchangeable_Al_cmoles/kg
Exchangeable aluminum in the soil, in centimoles per kilogram.

Exchangeable_Al_method
Method for obtaining exchangeable aluminum values.

Exchangeable_Al_source
Source of exchangeable aluminum values.

Exchangeable_Al_comment
Comments on irregularities or calculations associated with exchangeable aluminum values.

AlSatPercent
Percent aluminum saturation of the soil.

BaseSaturationPercent
Percent base cation saturation of the soil.

BaseSaturationComment
Comments on base cation saturation values.

OrganicMatterPercent
Percent of the soil sample composed of organic matter.

OrganicMatterComment
Comments on organic matter values or measurement techniques.

Soil Horizon Table

The Soil Horizon table contains soil physical, textural, and mineralogical data at the horizon level. This table includes horizons not associated with a particular site; these horizons are used to calculate mean soil data when site-specific data are not available.

SoilHorizonID
The Soil Horizon identification number is unique for each set of soil horizon values.

State
State in which the soil horizon was sampled.

County
County in which the soil horizon was sampled.

SoilSeries
Official soil series name as determined by soil physical and chemical characteristics.

PlotID
The plot identification number is the number assigned in the original soil survey.

Pedon_key
Pedon key assigned by field researchers to a soil pit sample.

Layer_key
Unique identification code assigned by field researchers to each soil horizon in individual soil pit samples.

HorizonDesignation
Horizon designation, assigned based on horizon location within the soil profile.

horizon_thickness_cm
Thickness of the horizon in centimeters.

PercentSand
In soil texture analysis, percent of the soil horizon sample that is sand.

PercentSilt
In soil texture analysis, percent of the soil horizon sample that is silt.

PercentClay
In soil texture analysis, percent of the soil horizon sample that is clay.

PercentFineClay
In soil texture analysis, percent of the soil horizon sample that is fine clay.

TextureClass
Name of the soil horizon texture class as determined by soil texture analysis.

TextureFlag
The texture flag number links to the Soil Horizon Flag table, which contains an explanation of calculations or irregularities associated with soil texture class values.

PercentCoarseFractions
Percent of the soil horizon sample composed of coarse fractions.

CFragFlag
The coarse fraction flag number links to the Soil horizon Flag table, which contains an explanation of calculations or irregularities associated with coarse fragment values.

BulkDensity_g/cm3
Bulk density of the soil horizon sample in grams per cubic centimeter.

BulkDensityFlag
The bulk density flag number links to the Soil Horizon Flag table, which contains an explanation of calculations or irregularities associated with bulk density values.

BulkDensityAdjusted
Bulk density values in grams per cubic centimeter adjusted for coarse fragments.

OMPercent
Percent of the soil horizon sample composed of organic matter.

OMSource
Source of organic matter values.

OMComment
Comments on organic matter values.

pHH2O
Soil horizon pH as measured in a water extracted soil solution.

pHCaCl2
Soil horizon pH as measured in a calcium chloride extracted soil solution.

Albite%
Percent albite in the soil horizon sample.
Anthorite%
Percent anthorite in the soil horizon sample.
Apatite%
Percent apatite in the soil horizon sample.
Amphibole%
Percent amphibole in the soil horizon sample.
Beryl%
Percent beryl in the soil horizon.
Biotite%
Percent biotite in the soil horizon.
Calcite%
Percent calcite in the soil horizon.
cassiterite%
Percent cassiterite in the soil horizon.
Chlorite%
Percent chlorite in the soil horizon.
Dolomite%
Percent dolomite in the soil horizon.
Epidote%
Percent epidote in the soil horizon.
feldspar%
Percent feldspar in the soil horizon.
Garnet%
Percent garnet in the soil horizon.
Glass%
Percent glass in the soil horizon.
Hornblende%
Percent hornblende in the soil horizon.
IronOxides%
Percent iron oxides in the soil horizon.
Kaolinite%
Percent kaolinite in the soil horizon.
KFeldspar%
Percent potassium feldspar in the soil horizon.
Mica%
Percent mica in the soil horizon.
Monazite%
Percent monazite in the soil horizon.
Muscovite%
Percent muscovite in the soil horizon.
Opaques%
Percent opaques in the soil horizon.
PlagioclaseFeldspar%
Percent plagioclase feldspar in the soil horizon.

Pyroxene%
Percent pyroxene in the soil horizon.
Quartz%
Percent quartz in the soil horizon.
Rutile%
Perecnt rutile in the soil horizon.

Sericite%
Percent sericite in the soil horizon.
Sohene%
Percent sohene in the soil horizon.
Tourmaline%
Percent tourmaline in the soil horizon.
VemicMica%
Percent vermiculite/mica in the soil horizon.
Vermiculite%
Percent vermiculite in the soil horizon.
WthrAggregates%
Percent weathered aggregates in the soil horizon.
Zircon%
Percent zircon in the soil horizon.
SoilHorizonMineralogy_datasource
Source of soil mineralogy data.
SoilHorizonMineralogy_method
Method for obtaining soil mineralogy data.
SoilHorizonMineralogy_comment
Comments on irregularities or calculations associated with soil mineralogy data.
CEC_cmoles/kg
Soil cation exchange capacity, in centimoles per kilogram.
CEC_method
Method for obtaining cation exchange capacity values.
CECSource
Source of cation exchange capacity values.
CECComment
Comments on irregularities or calculations associated with cation exchange capacity values.
Exhangeable_Ca_cmoles/kg
Exchangeable calcium in the soil, in centimoles per kilogram.
Exchangeable_Ca_method
Method for obtaining exchangeable calcium values.
Exchangeable_Ca_source
Source of exchangeable calcium values.
Exchangeable_Ca_comment
Comments on irregularities or calculations associated with exchangeable calcium values.
Exhangeable_K_cmoles/kg
Exchangeable potassium in the soil, in centimoles per kilogram.

Exchangeable_K_method
Method for obtaining exchangeable potassium values.

Exchangeable_K_source
Source of exchangeable potassium values.

Exchangeable_K_comment
Comments on irregularities or calculations associated with exchangeable potassium values.

Exhangeable_Mg_cmoles/kg
Exchangeable magnesium in the soil, in centimoles per kilogram.

Exchangeable_Mg_method
Method for obtaining exchangeable magnesium values.

Exchangeable_Mg_source
Source of exchangeable magnesium values.

Exchangeable_Mg_comment
Comments on irregularities or calculations associated with exchangeable magnesium values.

Exhangeable_Na_cmoles/kg
Exchangeable sodium in the soil, in centimoles per kilogram.

Exchangeable_Na_method
Method for obtaining exchangeable sodium values.

Exchangeable_Na_source
Source of exchangeable sodium values.

Exchangeable_Na_comment
Comments on irregularities or calculations associated with exchangeable sodium values.

Exchangeable_Al_cmoles/kg
Exchangeable aluminum in the soil, in centimoles per kilogram.

Exchangeable_Al_method
Method for obtaining exchangeable aluminum values.

Exchangeable_Al_source
Source of exchangeable aluminum values.

Exchangeable_Al_comment
Comments on irregularities or calculations associated with exchangeable aluminum values.

AlSatPercent
Percent aluminum saturation of the soil horizon.

BaseSaturationPercent
Percent base cation saturation of the soil horizon.

BaseSaturationComment
Comments on base cation saturation values.

Ctot
Total carbon in the soil horizon sample.

Ctot_method
Method for obtaining total carbon values.

Ntot
Total nitrogen in the soil horizon sample.

Ntot_method
Method for obtaining total nitrogen values.
OC
Organic carbon content of the soil horizon sample.
OC_method
Method for obtaining organic carbon content values.
BradyMoistureID
The Brady moisture identification number links soil horizons to values in the Brady Moisture table.
SoilID
The soil identification number links soil horizons to specific soil samples.
SiteID
The site identification number links soil horizons to specific sites.

Soil Horizon Flags Table

The Soil Horizon Flags table provides descriptive information for flag columns in the Soil Horizon table.

FlagID
The flag identification number is unique for each soil horizon flag, and links to flag columns in the Soil Horizon table.
FlagDescription
Comments on data irregularities and calculations associated with the flag.

Soil Moisture Table

The Soil Moisture table is provides information supplemental to the Soil table.

SoilMoistureID
Unique identification number for each set of soil moisture values.
DataDatesAvailable_volumetric
Dates for which soil volumetric moisture values are available.
Moisture%_volumetric
Percent volumetric moisture in the soil sample.
FieldCapacity%_volumetric
Percent volumetric field capacity, or water holding capacity, of the soil sample.
WiltingPoint%_volumetric
Percent volumetric water content at which plants can no longer obtain moisture from the soil.
PlantAvailableWater%_volumetric
Percent volumetric amount of water in the soil that is plant available.
Saturation%_volumetic
Percent volumetric amount of water when the soil is considered saturated.
CollectionMethod_volumetric
Method of collecting volumetric water samples.

SampleDepth_volumetric_cm
Sampling depth, in centimeters, for volumetric water samples.
SampleFrequency_volumetric
Frequency of volumetric water sample collection.
SampleSize_volumetric_ml
Size of volumetric water samples in milliliters.
CalibrationMethod_volumetric
Method for calibrating volumetric soil water values.
QAQC_volumetric
Quality assurance and control mechanisms for soil volumetric water measurements.
Uncertainty_volumetric
Uncertainty associated with soil volumetric water measurements.
Comments_volumetric
Comments on irregularities or calculations associated with soil volumetric water measurements.
SoilID
The soil identification number links sets of soil moisture values to values in the Soil table.

Stream Chemistry Table

The Stream Chemistry Table is supplemental to the Site table.

StreamChemistryID
The stream chemistry identification number is unique for each set of stream chemistry values.
SiteID
The site identification number links stream chemistry values to specific sites.
CatchmentSize
Size of the catchment used to collect stream chemistry samples.
SamplesFiltered
Indicates if the stream chemistry samples were filtered prior to analysis.
FluxCalcComment
Comments on stream chemistry flux calculations.
CollectionFrequency
Frequency of stream chemistry sample collection.
AnnualStreamFlow_m/y
Annual rate of stream flow in meters per year.
DON_volume_wtd_annual_mean
A volume weighted mean of annual dissolved organic nitrogen values.
DON_episodic_concentrations_eq/l
Episodic concentrations of dissolved organic nitrogen in equivalents per liter.
DON_flux_values_eq/l/y
Dissolved organic nitrogen flux values in equivalents per liter per year.
DOC_volume_wtd_annual_mean
A volume weighted mean of annual dissolved organic carbon values.

DOC_episodic_concentrations_eq/l
Episodic concentrations of dissolved organic carbon in equivalents per liter.

DOC_flux_values_eq/l/y
Dissolved organic carbon flux values in equivalents per liter per year.
ANC_volume_wtd_annual_mean
A volume weighted mean of annual acid neutralizing capacity values.
ANC_episodic_concentrations_eq/l
Episodic concentrations of acid neutralizing capacity in equivalents per liter.
ANC_flux_values_eq/l/y
Acid neutralizing capacity flux values in equivalents per liter per year.
pH_volume_wtd_annual_mean
A volume weighted mean of annual pH values.
pH_episodic_concentrations_eq/l
Episodic concentrations of pH in equivalents per liter.
pH_flux_values_eq/l/y
pH flux values in equivalents per liter per year.
Al_volume_wtd_annual_mean
A volume weighted mean of annual aluminum values.
Al_episodic_concentrations_eq/l
Episodic concentrations of aluminum in equivalents per liter.
Al_flux_values_eq/l/y
Aluminum flux values in equivalents per liter per year.
Ca_volume_wtd_annual_mean
A volume weighted mean of annual calcium values.
Ca_episodic_concentrations_eq/l
Episodic concentrations of calcium in equivalents per liter.
Ca_flux_values_eq/l/y
Calcium flux values in equivalents per liter per year.
H_volume_wtd_annual_mean
A volume weighted mean of annual hydrogen values.
H_episodic_concentrations_eq/l
Episodic concentrations of hydrogen in equivalents per liter.
H_flux_values_eq/l/y
Hydrogen flux values in equivalents per liter per year.
K_volume_wtd_annual_mean
A volume weighted mean of annual potassium values.
K_episodic_concentrations_eq/l
Episodic concentrations of potassium in equivalents per liter.
K_flux_values_eq/l/y
Potassium flux values in equivalents per liter per year.
Mg_volume_wtd_annual_mean
A volume weighted mean of annual magnesium values.
Mg_episodic_concentrations_eq/l
Episodic concentrations of magnesium in equivalents per liter.

Mg_flux_values_eq/l/y
Magnesium flux values in equivalents per liter per year.
Na_volume_wtd_annual_mean
A volume weighted mean of annual sodium values.
Na_episodic_concentrations_eq/l
Episodic concentrations of sodium in equivalents per liter.
Na_flux_values_eq/l/y
Sodium flu values in equivalents per liter per year.
NH4_volume_wtd_annual_mean
A volume weighted mean of annual ammonium values.
NH4_episodic_concentrations_eq/l
Episodic concentrations of ammonium in equivalents per liter.
NH4_flux_values_eq/l/y
Ammonium flux values in equivalents per liter per year.
NO3_volume_wtd_annual_mean
A volume weighted mean of annual nitrate values.
NO3_episodic_concentrations_eq/l
Episodic concentrations of nitrate in equivalents per liter.
NO3_flux_values_eq/l/y
Nitrate flux values in equivalents per liter per year.
SO4_volume_wtd_annual_mean
A volume weighted mean of annual sulfate values.
SO4_episodic_concentrations_eq/l
Episodic concentration of sulfate in equivalents per liter.
SO4_flux_values_eq/l/y
Sulfate flux values in equivalents per liter per year.
TOC_volume_wtd_annual_mean
A volume weighted mean of total organic carbon values.
TOC_episodic_concentrations_eq/l
Episodic concentrations of total organic carbon in equivalents per liter.
TOC_flux_values_eq/l/y
Total organic carbon flux values in equivalents per liter per year.
Methods
Methods for obtaining stream chemistry values.
QAQC
Quality assurance and control mechanisms for stream chemistry values.
Uncertainty
Uncertainty associated with stream chemistry values.
Comments
Comments on irregularities or calculations associated with stream chemistry values.

Study Table

The Study table contains information on the original studies from which database values were obtained.

StudyID
Unique study identification code
StudyName
Full study name.
StudySites
Geographic location of study sites.
StudyDescription
Description of study parameters: indicates if the study includes vegetation, soil, climate, or other data.
StudyScale
The landscape scale at which the study was conducted.
StartDate
Date that the study began.
EndDate
Date that the study ended.
StudyURL
Website, if available, that provides more study details.

TCDB Bark Table

The Tree Chemistry Database Bark table contains bark N, P, K, Ca, and Mg values for species, genus, or hardwood/softwood categories. The nutrient values are derived from the Tree Chemistry Database version 1.0, which can be found on the web at www.hubbardbrook.org/treechem/index.htm.

TCDB_BarkID
Unique identification number for each set of bark nutrient values.
TreeCategory
Species, Genus, or hardwood/softwood category associated with nutrient values.
Bark_Ca
Percent calcium as calculated using the Tree Chemistry Database version 1.
Bark_K
Percent potassium as calculated using the Tree Chemistry Database version 1.
Bark_Mg
Percent magnesium as calculated using the Tree Chemistry Database version 1.
Bark_N
Percent nitrogen as calculated using the Tree Chemistry Database version 1.
Bark_P
Percent phosphorus as calculated using the Tree Chemistry Database version 1.

TCDB Bole Table

The Tree Chemistry Database Bole table contains bole N, P, K, Ca, and Mg values for species, genus, or hardwood/softwood categories. The nutrient values are derived from the Tree Chemistry Database version 1.0, which can be found on the web at www.hubbardbrook.org/treechem/index.htm.

TCDB_BoleID
Unique identification number for each set of bole nutrient values.
TreeCategory
Species, Genus, or hardwood/softwood category associated with nutrient values.
Bole_Ca
Percent calcium as calculated using the Tree Chemistry Database version 1.
Bole_K
Percent potassium as calculated using the Tree Chemistry Database version 1.
Bole_Mg
Percent magnesium as calculated using the Tree Chemistry Database version 1.
Bole_N
Percent nitrogen as calculated using the Tree Chemistry Database version 1.
Bole_P
Percent phosphorus as calculated using the Tree Chemistry Database version 1.

TCDB Branch Table

The Tree Chemistry Database Branch table contains branch N, P, K, Ca, and Mg values for species, genus, or hardwood/softwood categories. The nutrient values are derived from the Tree Chemistry Database version 1.0, which can be found on the web at www.hubbardbrook.org/treechem/index.htm.

TCDB_BranchID
Unique identification number for each set of branch nutrient values.
TreeCategory
Species, Genus, or hardwood/softwood category associated with nutrient values.
Branch_Ca
Percent calcium as calculated using the Tree Chemistry Database version 1.
Branch_K
Percent potassium as calculated using the Tree Chemistry Database version 1.
Branch_Mg
Percent magnesium as calculated using the Tree Chemistry Database version 1.
Branch_N
Percent nitrogen as calculated using the Tree Chemistry Database version 1.
Branch_P
Percent phosphorus as calculated using the Tree Chemistry Database version 1.

TCDB Foliar Table

The Tree Chemistry Database Foliar table contains foliar N, P, K, Ca, and Mg values for species, genus, or hardwood/softwood categories. The nutrient values are derived from the Tree Chemistry Database version 1.0, which can be found on the web at www.hubbardbrook.org/treechem/index.htm.

TCDB_FoliarID
Unique identification number for each set of foliar nutrient values.

TreeCategory
Species, Genus, or hardwood/softwood category associated with nutrient values.
Foliage_Ca
Percent calcium as calculated using the Tree Chemistry Database version 1.
Foliage_K
Percent potassium as calculated using the Tree Chemistry Database version 1.
Foliage_Mg
Percent magnesium as calculated using the Tree Chemistry Database version 1.
Foliage_N
Percent nitrogen as calculated using the Tree Chemistry Database version 1.
Foliage_P
Percent phosphorus as calculated using the Tree Chemistry Database version 1.

Tree Table

The Tree table links trees by genus, species, or hardwood/softwood category to biomass equations, vegetation, and nutrient values.

TreeID
The tree identification number is unique for value sets assigned by tree species, genus, and category.
TreeName
Name of the tree species, genus, or other category.
TreeLatin
The latin name of the tree.
TreeAlternate
Alternate names for the tree.
WoodDensityID
The wood density identification code links tree species or groups to values in the Jenkins Biomass Fractions table.
VTHarvestDBH
The minimum diameter at breast height at which trees are harvested for saw timber in Vermont.
SpeciesGroupID
The species group identification code links tree species or groups to values in the Jenkins Species Group table.
TCDB_BarkID
The tree chemistry database bark identification number links tree species or groups to nutrient values in the TCDB Bark table.

TCDB_BoleID
The tree chemistry database bole identification number links tree species or groups to nutrient values in the TCDB Bole table.
TCDB_BranchID
The tree chemistry database branch identification number links tree species or groups to nutrient values in the TCDB Branch table.

TCDB_FoliarID

The tree chemistry database foliar identification number links tree species or groups to nutrient values in the TCDB Foliar table.

Vegetation Table

The Vegetation table contains measurement, biomass, and nutrient data for individual trees. This information is linked to specific sites.

VegetationID

The vegetation identification number is unique for each set of vegetation values. Vegetation values are presented for individual trees or for a group of trees of the same species within a plot.

SiteID

The site identification number links vegetation values to specific sites.

Study

Forest Mapping Group acronym for the study associated with vegetation values.

PlotID

The plot identification number was assigned by study researchers; it is correlated with the Forest Mapping Group assigned Site ID.

Plot

The plot number refers to a subdivided sampling location within a site.

Individual_or_Plot_level

Indicates if the vegetation sample values are for an individual tree (individual) or for a species group on a plot (plot).

TreeID

The tree identification number links vegetation values to a specific tree species or group in the tree table.

TreeName

Common name of the tree associated with vegetation values.

DBH_cm

Measured tree diameter at breast height. For some plot level data, where individual tree diameters were not measured, DBH is based on the state average harvest DBH for that species.

DBH_harvest_cm

The assumed tree diameter at breast height at harvest. This value is used to calculate biomass extraction values. If the measured DBH is under the state harvest minimum, the assumed harvest DBH is the state harvest minimum. If the measured DBH is above the state harvest minimum, the assumed harvest DBH is the measured DBH.

DBH_comment

Comments on diameter at breast height values or year of measurement.

Height_m

Tree height in meters.

MAI

Mean Annual Increment.

Current_Biomass_Kg

The current biomass of the vegetation. This is either the biomass provided by the study investigators or a biomass calculated using tree species, DBH, and equations from Jenkins, J.C., Chojnacky, D.C., Heath, L.S., and Birdsey, R.L. 2003. National Scale Biomass Estimators for United States Tree Species. Forest Science 49(1): 12-35. The equations are explained in more detail in the Jenkins Species Group section.

Biomass_source

Source of current biomass values.

Harvest_Biomass_Kg

The harvestable biomass of the vegetation. This is either a biomass provided by the study investigators or a biomass calculated using the tree species, harvest DBH, and equations from Jenkins et al., 2003. The equations are explained in more detail in the Jenkins Species Group section.

HarvestBark_Kg

The harvestable bark biomass of the vegetation. . This is either a biomass provided by the study investigators or a biomass calculated using the tree species, harvest biomass, and equations from Jenkins et al., 2003. The equations are explained in more detail in the Jenkins Biomass Fractions section.

HarvestWood_Kg

The harvestable wood biomass of the vegetation. . This is either a biomass provided by the study investigators or a biomass calculated using the tree species, harvest biomass, and equations from Jenkins et al., 2003. The equations are explained in more detail in the Jenkins Biomass Fractions section.

Biomass_comment

Comments on biomass calculations.

Wet_to_dry_biomass_ratio

Ratio of wet, or green, biomass to dry biomass.

FireNutrientLoss

Vegetation nutrient losses due to fire.

FireNutrientLoss_comment

Comment on fire nutrient loss calculations or values.

SlashNutrientLeaching

Vegetation nutrient losses due to leaching from slash left behind from logging.

SlashNutrientLeaching_comment

Comments on slash nutrient loss calculations or values.

DryWoodDensity

Density of dry wood as provided by study investigators.

BarkSampleVariability

Degree of variability in bark sample data.

BarkSampleComment

Comment on bark sample variability.

BoleSampleVariability

Degree of variability in bole sample data.

BoleSampleComment

Comment on bark sample variability.

BranchSampleVariability
Degree of variability in branch sample data.
BranchSampleComment
Comment on variability of branch sample data.
FoliageSampleVariability
Degree of variability in foliar sample data.
FoliageSampleComment
Comment on variability of foliar sample data.
Bark_Ca
Bark calcium percentage.
Bark_K
Bark potassium percentage.
Bark_Mg
Bark magnesium percentage.
Bark_N
Bark Nitrogen percentage.
Bole_Ca
Bole calcium percentage.
Bole_K
Bole potassium percentage.
Bole_Mg
Bole magnesium percentage.
Bole_N
Bole nitrogen percentage.
Branch_Ca
Branch calcium percentage.
Branch_K
Branch Potassium percentage.
Branch_Mg
Branch magnesium percentage.
Branch_N
Branch nitrogen percentage.
Foliage_Ca
Foliage calcium percentage.
Foliage_K
Foliage potassium percentage.
Foliage_Mg
Foliage magnesium percentage.

Foliage_N
Foliage nitrogen percentage.

Weathering Rates Table

The Weathering Rates table contains site associated soil weathering rates.

WeatheringID
The weathering identification number is unique for each weathering scenario.
SiteID
The site identification number links weathering scenarios to specific sites.
SubstrateAcidityClass
The substrate acidity class indicates whether the soil substrate is acidic (A), intermediate (I), or basic (B).
SoilSeries
The soil series is assigned based on soil physical and chemical characteristics.
%Clay
Clay percent present in the soil sample analyzed for weathering rates.
Weathering_BC_eq/ha/y
The estimated mineral soil weathering rate for base cations in equivalents per hectare per year.
Weathering_Ca_eq/ha/y
The estimated mineral soil weathering rate for calcium in equivalents per hectare per year.
Weathering_Mg_eq/ha/y
The estimated mineral soil weathering rate for magnesium in equivalents per hectare per year.
Weathering_K_eq/ha/y
The estimated mineral soil weathering rate for potassium in equivalents per hectare per year.
Weathering_Na_eq/ha/y
The estimated mineral soil weathering rate for sodium in equivalents per hectare per year.
Weathering_method
Method for obtaining weathering rates
WeatheringClimateSourceID
The climate source identification number links weathering rate scenarios to data in the Climate Source table.
SubstrateAcidityClass_methods
Methods used to obtain substrate acidity class values.
SubstrateAcidityClass_QAQC
Quality assurance and control mechanisms for substrate acidity class values.
SubstrateAcidityClass_uncertainty
Uncertainty associated with substrate acidity class values.
SubstrateAcidityClass_comments
Comments on irregularities or calculations associated with substrate acidity class values.

Bibliography

Jenkins, J.C., Chojnacky, D.C., Heath, L.S., and Birdsey, R.L. 2003. National Scale Biomass Estimators for United States Tree Species. Forest Science 49(1): 12-35.

Appendix C: Instructions to accompany the data requirement check list for calculating critical loads for N and S for forest ecosystems

C1. Introduction

The data checklist (attached) is organized into six categories: the first four correspond with the data inputs required for the Steady State Mass Balance Method approach for calculating critical loads and exceedance (site data, atmospheric/climate data, vegetation data, soil data). The fifth and sixth categories (forest health and surface water) include data that are used in further analysis of the model output.

A summary parameter table is provided for each data category. The parameters are categorized as:

1. *Model Input*, these parameters are required for input directly into the Steady State Mass Balance model;
2. *Intermediate calculations*, these parameters are required for calculating model inputs;
3. *Background data*; and
4. *Additional analysis*, data used for analysis of the model outputs

The parameters are labeled mandatory (M) or optional (O) according to the requirements of the US critical loads protocol. Note that there are some differences between these designations of mandatory and optional and those used in the ICP protocol. For more information regarding ICP protocol, please see http://www.icp-forests.org/Manual.htm.

In this document, we have also provided information meant to aid researchers in assembling the required data and, where appropriate, we have included lists ranking data sources, from most to least preferred.

Because these critical load calculations are made for the steady state, the climate parameters ideally represent long-term means (e.g. 30 years). In all cases, data should be provided for as long a time period as possible (after 1950), even if there are breaks in time. This allows us better understanding of the long-term conditions at each site.

C2. Site description parameters

Site Description Parameters	Model input	Intermediate calculations	Background	Additional analysis
Latitude and longitude (decimal degrees)		M		
Elevation (m)		M		
Size of site (m or ha)		M		
Map of site			O	
Principle investigators			O	
Land-use history			O	
Disturbance history				O
Political jurisdiction			O	
Publications associated with site			O	

C2.1 Explanation of the site description parameters

2.1.1 Latitude and longitude (decimal degrees)

2.1.1.1 For a plot: Coordinates should be for the center point of the site

First choice: GPS'ed to 5 decimal places

Second choice: If GPS coordinates are unavailable, please identify how the coordinates were determined

2.1.1.2 For a watershed or large site

First choice: GPS'ed center point coordinates should be accompanied by a GIS polygon file of the site

Second choice: GPS'ed center point coordinates should be accompanied by corner coordinates and a paper map of the site

Third choice: If GPS coordinates are unavailable, please identify how the coordinates were determined

2.1.2 Elevation (meters)

If applicable, include the minimum and maximum elevation of the site (m)

2.1.3 Size of site

First choice: The area of the site (meters or hectares)

Second choice: Plot radius (meters or hectares)

2.1.3.1 Is the site at the watershed or plot level?

2.1.4. Map of site

First choice: GIS files

a. Of site, showing sample locations
b. Of site
c. Of broader site area, showing proximity to other sites, weather stations, etc.

Second choice: paper maps

a. Of site, showing sample locations
b. Of site
c. Of broader site area, showing proximity to other sites, weather stations, etc.

2.1.5 Principal investigator(s)

a. Please include the names and contact information of the PIs
b. Please include the names and contact information for all individuals who handle the data, by data type

2.1.6 Land-use history

What management practices are in place? If there have been changes in management practices, what management practices were in place? Please provide details regarding the rotation length, harvest frequency, controlled burning, etc.

2.1.7. Disturbance history
Please provide as many details as possible regarding each major disturbance event, including when the event occurred, the severity, the extent of effect within the site, and any additional information about the disturbance that may be available.
Also note any anomalous weather events that need to be taken into account (e.g. an ice storm) and the time period of expected influence on the data (or identify any suspect data).

2.1.8 Political jurisdiction

2.1.9 Publications
In addition to publications and reports, please provide web site addresses if available.

C3. Atmospheric and Climate data

Atmospheric/Climate Data	Model input	Intermediate calculations	Background	Additional analysis
Total deposition (kg/ha-yr and eq/ha-yr)) (N, S, Ca, Mg, K, Na, Cl, pH, total alkalinity)				
Wet deposition	M			
Dry Deposition	M[1]			
Bulk deposition	O			
Throughfall (additional parameters: conductivity and total N)	M[2]			
Precipitation volume (long-term; m)	M			
Mean annual temperature (long term, deg C)		M		
Mean annual evapotranspiration (m)	M			
Runoff (m/yr)	M			
Other				O

[1]May be modeled
[2]Throughfall deposition is assumed to be a measurement of total deposition

C3.1 Explanation of the deposition and climate parameters

3.1.1 Total deposition (kg/ha-yr)
Total deposition is required, which can be estimated in various ways (i.e., wet + dry, throughfall, modeled)

3.1.1.1 General information

i. Data should be reported as annual means, for as many individual years as available
ii. NH4 and NO3 data should be reported as NH4-N and NO3-N
iii. SO4 data should be reported as SO4-S?

3.1.1.2 Preferred sources of data

First choice: air quality station on site

Second choice: air quality station determined to be representative of the site

Third choice: modeled deposition

3.1.1.3 Sample collection and analysis

i. If established sampling protocol is used, identify protocol (NADP, CASTNET, AIRMoN, …)
ii. If site has unique sampling protocol, answer the following:
    1) How are samples collected, how many samples are collected, and at what frequency?
    2) How are the samples analyzed?
    3) How are the data dealt with if below the analytical detection limit?
    4) What QA/QC are in place?
    5) Where on the site (relative to other measurements) is the deposition measured?

3.1.1.4 Modeled data

i. Identify model
ii. Identify model assumptions
iii. What type of deposition was modeled?
iv. What uncertainty is associated with the model used?
v. What is the year or range of years represented by model output

3.1.1.5 Additional data (including, but not limited to)

i. Deposition data for any other elements
ii. Cloud and or fog deposition
iii. Ozone concentration data

3.1.2. Precipitation volume (m)

3.1.2.1 Type of data

First choice: 30-year mean monthly and annual precipitation volume

Second choice: monthly and annual means for as many individual years as available

3.1.2.2 Data source preferences

First choice: air quality station on site

Second choice: air quality station determined to be representative of the site

Third choice: modeled precipitation volume

3.1.2.3 Sample collection and analysis

i. How are samples collected?
ii. How many samples are collected?
iii. At what frequency?
iv. Is there or has there been any evidence of evaporation?
v. What QA/QC are in place?

3.1.2.4 Modeled data

i. What model was used?

ii. What uncertainty is associated with the model used?

3.1.2.5 Additional data (including, but not limited to)

i. Percentage of precipitation as snow
ii. Snow-free period of year (fraction of year): defined as the period between the first appreciable snowfall to last appreciable snowfall

3.1.3 Air temperature (degrees C)

3.1.3.1 Type of data

First choice: 30-year mean monthly and annual precipitation volume

Second choice: monthly and annual means for as many individual years as available

3.1.3.2 Data source preferences

First choice: air quality station on site

Second choice: air quality station determined to be representative of the site

Third choice: modeled air temperature

3.1.3.3 Data collection and analysis

i. At what frequency is temperature measured?
ii. What is the entire date range for available data?
iii. What QA/QC are in place?

3.1.3.4 Modeled data

i. What model was used?
ii. What uncertainty is associated with the model used?

3.1.3.5 Additional data

i. Growing season (fraction of year): defined as the period between five consecutive days above 0°C and five consecutive days below 0°C. If there are more than one such period, report the longest period.

3.1.4 Runoff (m/yr)

3.1.4.1 Type of data

First choice: 30-year mean annual runoff

Second choice: Mean annual runoff for as many individual years as available

3.1.4.2 General information

i. How is runoff measured?
ii. Is this a gauged watershed?
iii. Where on the site (relative to other measurements) is the runoff measured?
iv. Is there any missing data? If so, how is this accounted for?
v. Any other comments regarding runoff data?

3.1.5 Mean annual actual evapotranspiration (m/yr)

3.1.5.1 Type of data

First choice: calculated from 30-year mean annual runoff

Second choice: Mean annual runoff for as many individual years as available

3.1.5.2 Data source preferences

First choice: Calculated as measured precipitation minus measured runoff

Second choice: modeled deposition

3.1.5.3 Modeled data

i. What model was used?

ii. What uncertainty is associated with the model used?

3.1.6 Additional climate data (including, but not limited to)

3.1.6.1 Mean annual solar radiation

3.1.6.2 Mean annual wind speed

3.1.6.3 Mean annual air humidity

C4. Tree data

Tree data	Model input	Intermediate calculations	Background	Additional analysis
Stand composition		M		
DBH (cm)		M		
Number of stems by species		M		
Nutrient concentration (N, Ca, Mg, K, P, S) by biomass compartment by species		M[1]		
Annual biomass removal rate		M		
Biomass by species (kg/ha)		M[2]		
Average height by species (m)			O	
MAI by species (kg/ha/yr)		O		
Volume (m^3/ha)		O		
Nutrient removal by species				O
Nutrient ratios				O
Stand age (yrs)				O
Other				O

[1]Can be estimated from literature

[2]Can be calculated using allometric equations

C4.1 Explanation of the tree data

4.1.1 General information

The primary data that we need from the tree data section are nutrients lost from the site due to harvest or fire. Additionally, depending on how dry deposition is estimated, forest type may be required. For sites where loss of nutrients is not already calculated, the following provides the basic information required to estimate these losses.

4.1.2 Nutrient removal by species (mg/kg)

i. Data required include Ca, K, Mg, N
ii. How is this measured or calculated?

4.1.2 Nutrient concentration by biomass compartment by species (mg/kg)

i. How are samples measured?
ii. Is heartwood included in the bole samples?
iii. How representative are the samples?
iv. Can you provide any quantitative assessment of the variability?

4.1.3 Total biomass (kg/ha) by species

i. Biomass by species: How is this calculated? What allometric equations are used?
ii. Biomass fractions by species (bark, bole, branch, foliage): How is this calculated? What allometric equations are used?
iii. Wet-to-dry biomass conversions, if available

4.1.3 Biomass removal rate by species (kg/ha-yr)

4.1.3.1 Removal rate by harvest

i. What type of harvest (e.g. whole tree, stem only, clear cut)?
ii. What is the cutting cycle?
iii. How was this biomass removal rate determined?

4.1.3.2 Removal rate by fire

We are only interested in biomass removal by fire if the fires occur regularly (at least once) within a rotation.

i. Are the fires controlled burns, wildfires, or both?
ii. What is the fire cycle?
iii. What was the intensity of the fire?
iv. Which biomass compartments were lost?
v. How was this biomass removal rate determined?

4.1.4 Additional information (including but not limited to)

i. Nutrient leaching from slash
ii. Wood density of dry biomass

C5. Soil data

Soil Data	Model input	Intermediate calculations	Background	Additional analysis
Number of soil pits/site			M	
Soil depth		M		
Soil texture (by horizon)		M		
Soil bulk density (by horizon)		M		
Course fragments (by horizon)				
Parent material		M		
Soil series		M		
Mineralogy (by horizon)		O		
Soil profile descriptions			O	
Soil Map			O	
Organic matter percent or organic C (by horizon)		M		
Total N (by horizon)				
Extractable Al, Ca, Mg, K, Na (by horizon)		M		
Cation exchange capacity (by horizon)		M		
Base saturation (by horizon)		M		
Volumetric soil moisture (by horizon)		M		
pH ($CaCl_2$ and H_2O)				O
Other				O
Soil Lysimeter Data (by depth)	**Model input**	**Intermediate calculations**	**Background**	**Additional analysis**
pH				M
Alkalinity				M
DOC				M
Base cations (Ca, Mg, K, Na)				M
Al (total)				M
Al (labile)				M
NO_3-N				M
SO_4-S				M
NH_4-N				M
Cl				M
Other				O

C5.1 Explanation of the soil data

5.1.1 General information

i. How many soil pits are on the site?
ii. What soil series are present on the site?
iii. What is the dominant series?
iv. What area percent does each soil series make up?
v. Is there a soil map for the site?
vi. Where on the site (relative to other measurements) are the soil pit(s) located?

5.1.2 For all chemical analysis

i. What method was used?
ii. How are the data dealt with if below the analytical detection limit?
iii. What QA/QC are in place?

5.1.3 Soil Lysimeter data

i. What type of lysimeter was used?
ii. How many samples are collected and at what depth and frequency?
iii. Are the samples filtered?
iv. How are the samples analyzed?
v. How are data dealt with if below the analytical detection limit?
vi. What QA/QC procedures are in place?

5.1.4 Soil moisture

5.1.4.1 Data sources:

First choice: measured data
Second choice: generalized data based on soil texture

5.1.4.2 Sample collection and analysis

i. How many samples are taken and at or across what depths?
ii. What is the frequency of sampling?
iii. What method is used?
iv. What calibration is used?
v. Any notes on landscape position
vi. Any notes on concerns or limitations of measurements (limited choice of algorithms, sampling inconsistencies, etc.)

5.1.5 Additional information (including but not limited to).
Please indicate methodology where appropriate.

i. Mean annual soil temperature
ii. Water holding capacity
iii. Flow rate through soil
iv. Leaching rates of H, Ca, K, Mg, Na, NO3, …
v. Proportion of CEC occupied by Al
vi. Al: BC ratio
vii. Denitrification
viii. Nitrogen fixation rates
ix. Soil N immobilization, biotic and/or abiotic
x. Rooting depth (is this measured or an approximation based on field observation?)
xi. Weathering rates

C6. Forest health data

Forest Health Data	Model input	Intermediate calculations	Background	Additional analysis
Foliage transparency				O
Crown density				O
Dieback				O
Mortality				O
Insect damage and disease				O
Areas of forest decline				O
Vegetation structure				O
Other (lichens, …)				O

C7. Surface water chemistry

Surface Water Data	Model input	Intermediate calculations	Background	Additional analysis
Size of catchment				O[1]
Alkalinity				O[1]
pH				O[1]
Conductivity				O[1]
Base cations (Ca, Mg, Na, K)				O[1]
NH_4-N				O[1]
NO_3-N				O[1]
SO_3-S				O[1]
Cl				O[1]
Al (reactive)				O[1]
DOC				O[1]
Other				O

[1]These data are the mandatory paramters for ICP Waters (http://www.iis.niva.no/ICP-waters/)

C7.1 Explanation of the surface water data

7.1.1 General information

i. Provide volume-weighted mean and maximum annual concentrations
ii. Provide fluxes and details of how flux calculations were made
iii. If annual means are unavailable, please provide raw data
iv. Are measurements made at regular time interval or by event?
v. How are samples collected?
vi. How many samples are collected?
vii. How are the samples analyzed?
viii. How are the data dealt with if below the analytical detection limit?
ix. What QA/QC procedures are in place?
x. Please include any other measured variables

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