August 12, 2014

Critical Load Exceedance Metrics

Step 6 of the CL Implementation Strategy examines exceedance patterns across forests to better characterize the extent and severity of potential air pollutant deposition impacts to resources. This document provides instructions on creating summary "metrics" that will be used in the assessment, as well as information on reliability of the various critical loads. In addition to calculating exceedance metrics across the National Forest or Grassland, if the Forest manages any wilderness with Class I area designation, the same metrics could be recalculated based only on areas within the wilderness boundary.

These instructions assume the user has GIS files (and associated attribute tables) with gridded exceedance values and exceedance class information for each CL of concern or interest. CL exceedance data for the conterminous US are hosted on the Air Quality Portal and available on the Data Page. Remember that a critical load is the level of atmospheric deposition below which no detrimental ecological effects occur over the long term, based on current scientific knowledge. Deposition at or above the CL is expected to have harmful effects on the environment. Therefore, a CL exceedance greater than, or equal to zero indicates the likelihood of harm.

Calculate the following metrics for all receptors showing CL exceedances on the forest and assemble in a table similar to the one shown below (if values for an individual data layer are all negative, you have no CL exceedances and do not need to determine exceedance metrics *for that layer*). For information on interpreting multiple CL exceedances simultaneously, please reference the "Interpreting Multiple CL Exceedances Protocol" document.

Exceedance Metrics	**Critical Loads**			
	Acidity: Surface Waters	Acidity: Forested Ecosystems	Nutrient N: lichens	Nutrient N: others
Extent	Number of Streams/ Lakes exceeding CL and Number of Streams/ Lakes sampled	% of land exceeding CL	% of land exceeding CL	% of land exceeding CL
Severity – Range of exceedance amount	Minimum & Maximum Exceedance Values (meq/ha/yr)	Minimum & Maximum Exceedance Values (eq/ha/yr)	Minimum & Maximum Exceedance Values (kg/ha/yr)	Minimum & Maximum Exceedance Values (kg/ha/yr)
Severity - 95% exceedance value	95% of sites exceed by X meq/ha/yr (only relevant when number of data points > 25)	95% of grid cells exceed CL by X eq/ha/yr	95% of grid cells exceed CL by X kg/ha/yr	95% of grid cells exceed CL by X kg/ha/yr
Reliability	High	Low	High	Variable

Before using the following instructions to calculate critical load exceedance metrics, clip your exceedance value data layers using the directions provided in the GIS Instructions for Mapping and Clipping CL Exceedance Layers Protocol. If you do not clip the data layer, the results will apply to the entire US rather than just your area of interest.

**When analyzing the empirical CLs of nutrient nitrogen for lichens, the overall exceedance layer for mapping purposes does not contain actual values: you need to analyze the "min" or "max" layers. If you do not know which layer to analyze, we recommend analyzing both, or relying on the "Lichen Min Exceedance Values.lyr" which is the more conservative layer, and therefore more protective of the resources in question.

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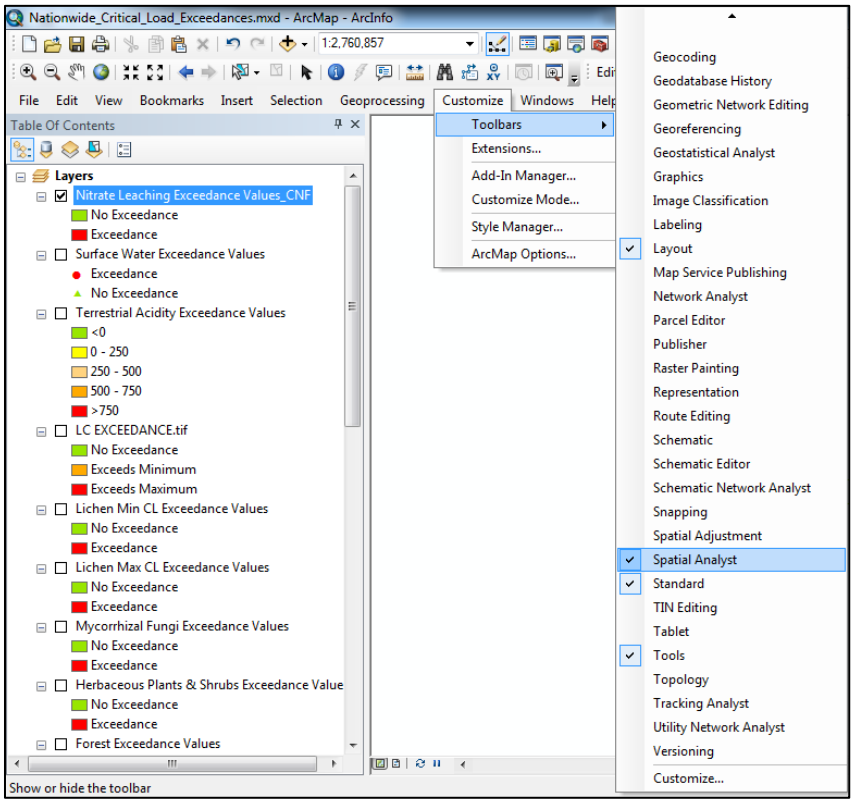
Extent Exceedance Metric

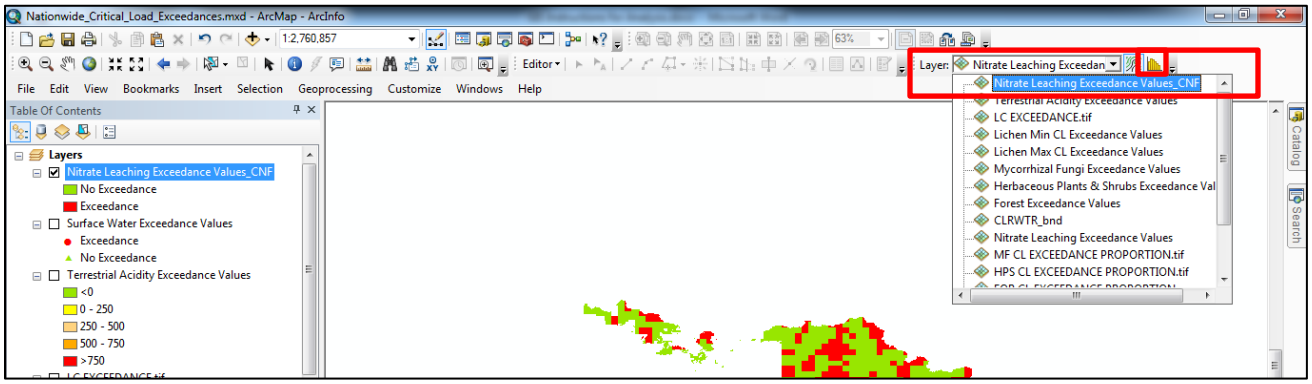
Extent: This metric describes how widespread the exceedance is.

For continuous gridded data (CLs of acidity for forested ecosystems and empirical N CLs for mycorrhizal fungi, lichens, herbaceous plants & shrubs, forests, and nitrate leaching), calculate the percent of grid cells on the Forest showing exceedance of the CL (CL exceedance value ≥ 0, or CL exceedance class ≥ 1) following the instructions below. Calculate this separately for each CL receptor of interest. Instructions to calculate extent for CLs of acidity for surface waters begin on page 4.

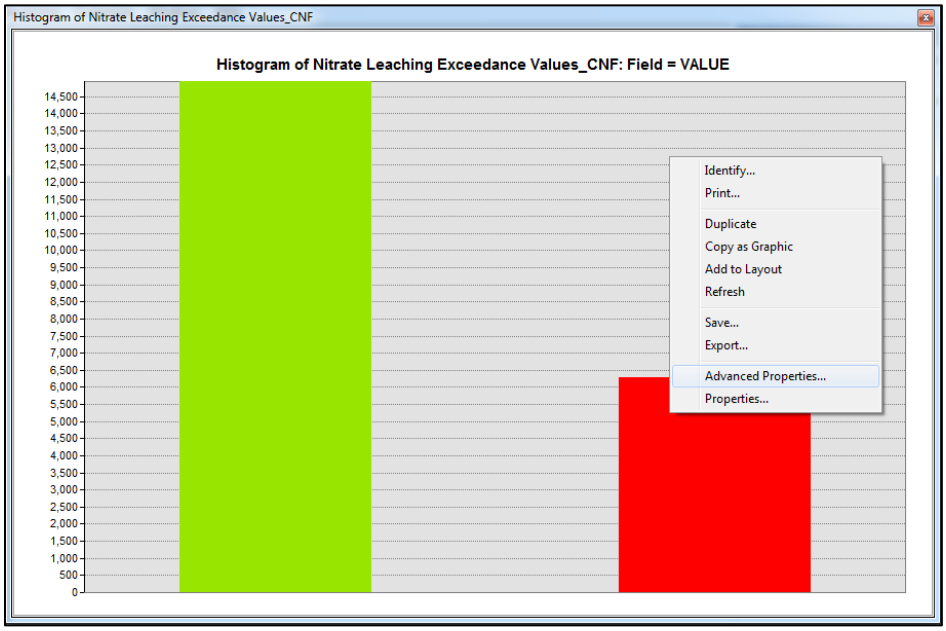
1. Select "Customize," "Toolbars," and make sure there is a checkmark next to the "Spatial Analyst" toolbar to activate the toolbar.



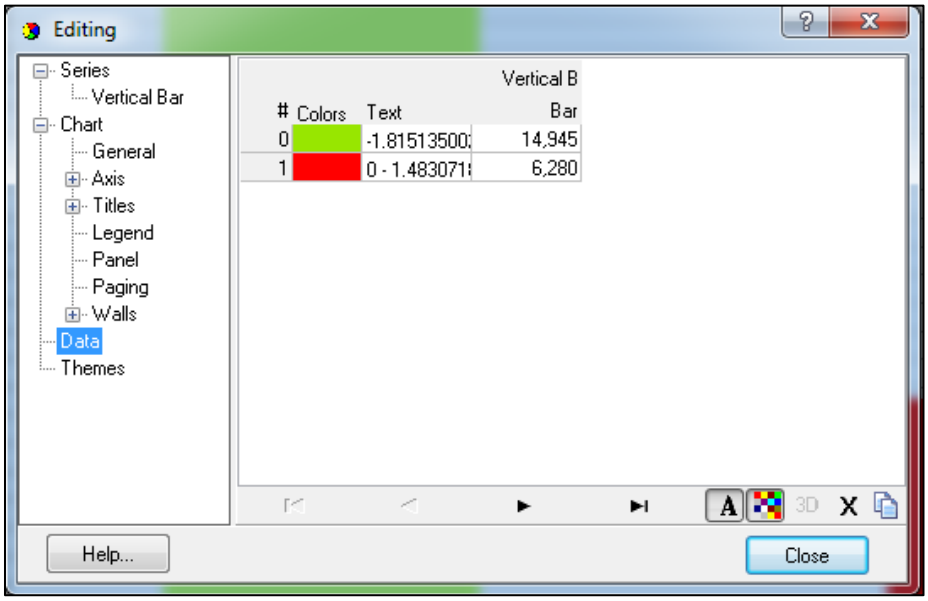
2. From the Spatial Analyst Toolbar, select the data layer you would like to analyze from the dropdown menu. Then select the histogram icon  .



3. The histogram displays the number of pixels within each predetermined category, using the colors set in the layer symbology. In the example below, the categories are "No Exceedance" (green) and "Exceedance" (red). To determine the exact values for each category, right click inside of the histogram and select "Advanced Properties…"

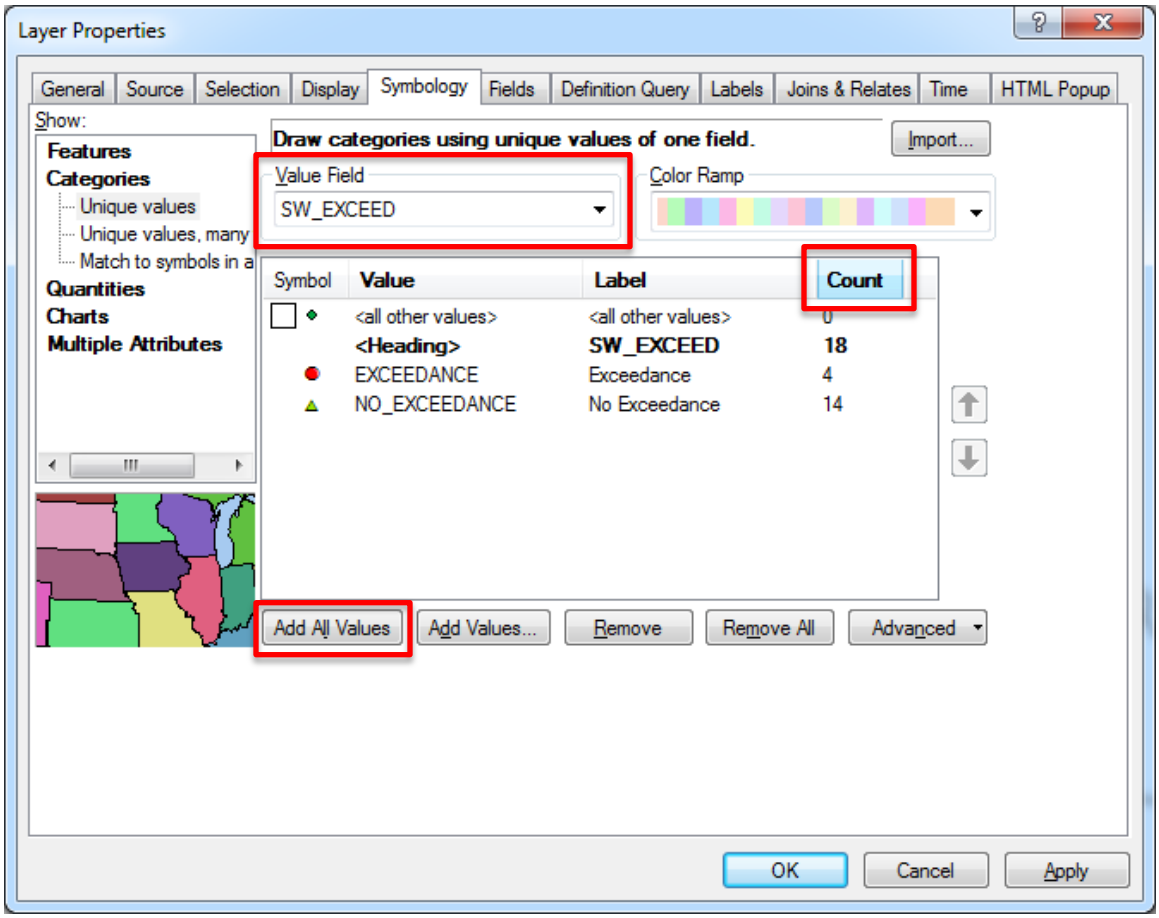


4. When the "Editing" box opens, select "Data" to get a breakdown of the distribution of values within each exceedance class. The values under column "Vertical B Bar" represent the number of pixels within each category. To determine the percent of land exceeding the CL: <u>divide the number of pixels within the exceedance category by the sum of the total number of pixe</u>ls. In the example below, the percent of land in exceedance of the CL is [6,280 / (6,280+14,945)] = 29.6%. For layers where there are multiple exceedance categories ("Terrestrial Acidity Exceedance Values"), sum the number of pixels in all exceedance categories (do not include number of pixels in "No Exceedance") and divide by the total number of pixels in all categories. If all pixels are in the same class (all exceedance values >0 or all values <0), then 100% or 0% of the area is in exceedance, respectively.



For point data (only CLs of acidity for surface waters) determine the number of streams and/or lakes showing exceedance of the CL (CL exceedance value ≥ zero, or CL exceedance class ≥ 1), as well as the number of streams and/or lakes that were sampled following the instructions below. The national database contains CL exceedance information only for sites where surface water chemistry is measured; these locations may not be representative of conditions across the entire forest. To best assess the extent of aquatic acidification, it is important to have surface water samples from the most sensitive areas of the forest. You may want to postpone developing TLs until the calculated CLs of acidity for surface waters are more representative of your forest as a whole, or at least the areas expected to be most sensitive to acidification effects. See the Monitoring Strategy for recommendations on developing a surface water monitoring plan that captures these sensitive areas.

1. Double click on the name of the surface water layer clipped to your boundary of interest in the "Table of Contents" to open the "Layer Properties" box. On the "Symbology" tab, select "SW_EXCEED" from the "Value Field" dropdown box and select "Add All Values." If you don't already see the number of exceedances displayed, select the "Count" button to populate the values for each category. The count next to the "Exceedance" category represents the number of streams/lakes in exceedance within the area of interest, while the count next to the "SW_EXCEED" heading represents the total number of streams/lakes sampled (also determined by adding all Exceedance and No Exceedance counts). In the example below, there are 4 streams/lakes exceeding the CL out of 18 streams/lakes sampled.

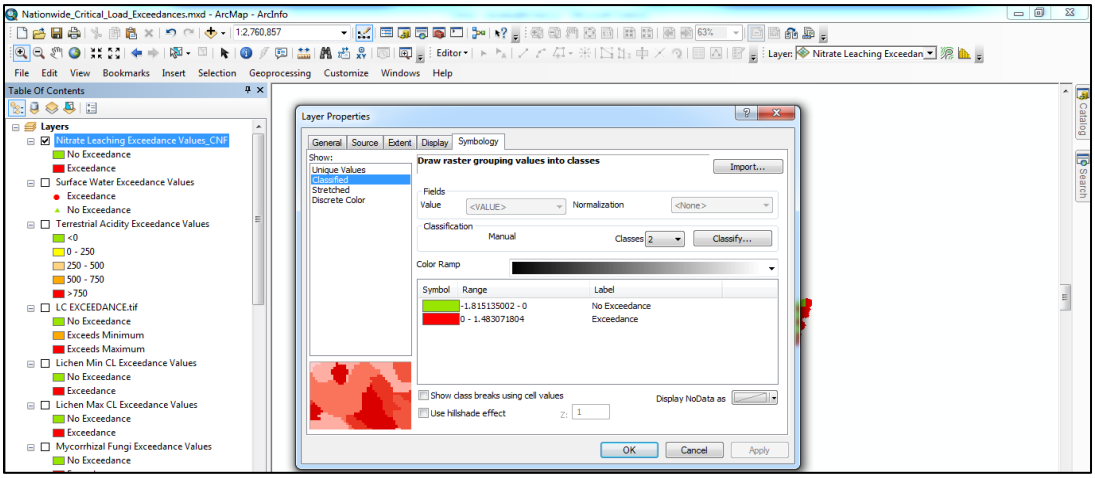


Severity – Range Exceedance Metric

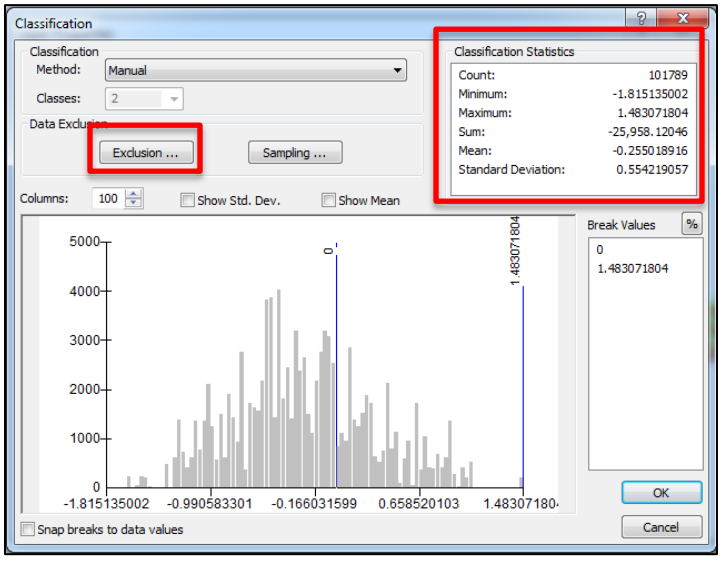
Severity: This metric focuses on the magnitude of the exceedance. The range is described by the minimum and maximum exceedance values.

For continuous gridded data (CLs of acidity for forested ecosystems and empirical N CLs for mycorrhizal fungi, lichens, herbaceous plants & shrubs, forests, and nitrate leaching), determine the largest exceedance value as well as the smallest exceedance value >0.

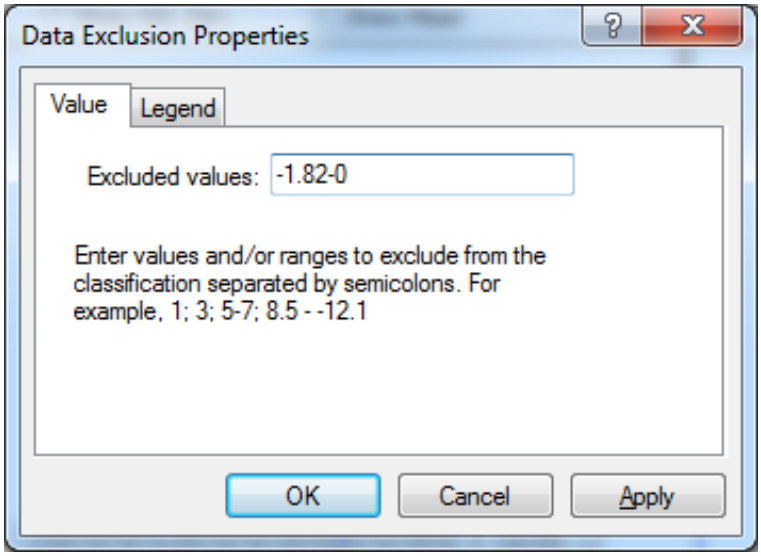
1. Double click on the layer name in the "Table of Contents" to open the Layer Properties box. Select the Symbology tab and "Classified."



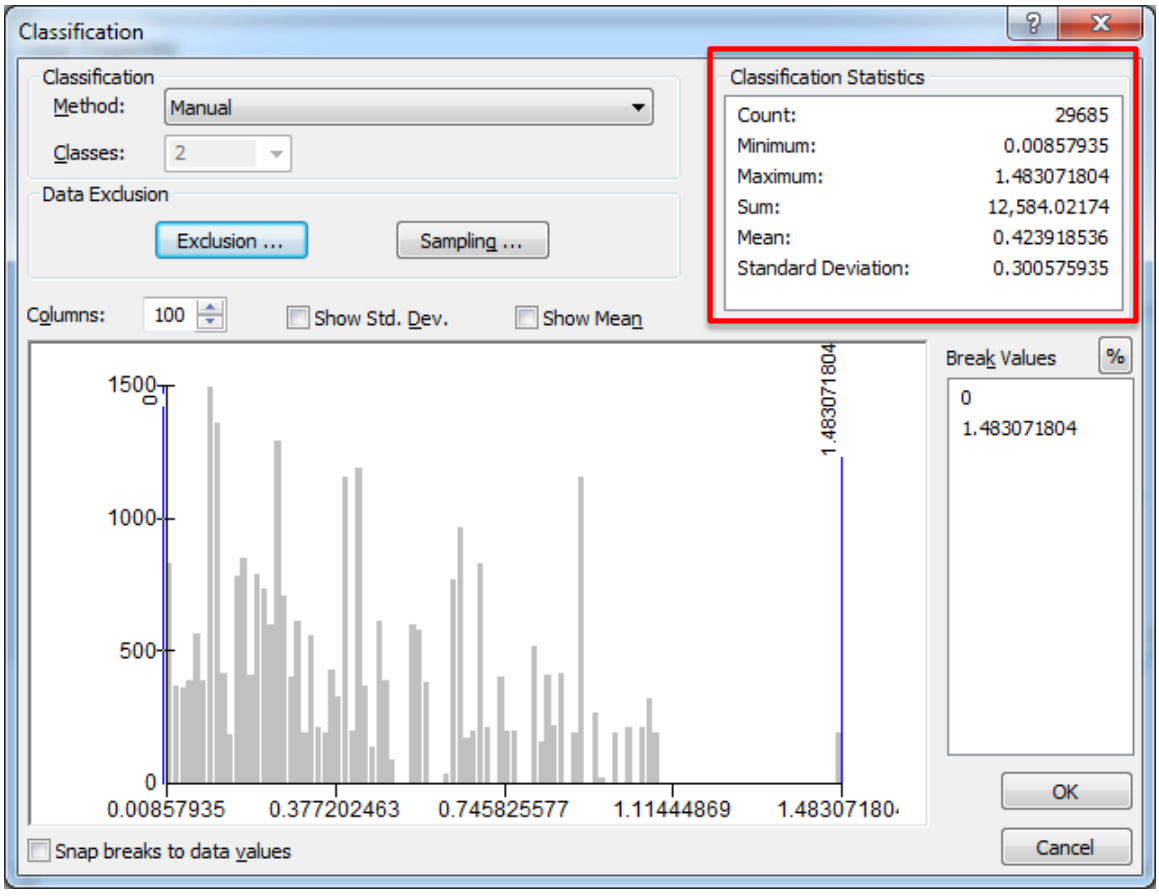
2. If you clipped your file as directed in the GIS Instructions, the "Classification Statistics" in the upper right hand corner of the Classification box will provide you with relevant statistics for the critical load exceedance values in your area of interest. The "maximum" value is the maximum exceedance value for the severity range. If all of the values within your area of interest exceed the CL, the Classification Statistics "minimum" value will be positive and will therefore be the minimum exceedance value for the severity range. If the Classification Statistics "minimum" value is negative (as in the example below), click on the "Exclusion…" button.



3. In the "Data Exclusion Properties" box, manually enter a range in "Excluded values." For the lower end of the range enter the negative minimum value from the Classification Statistics box on the previous page. For the upper end of the range, always enter 0. Select OK.

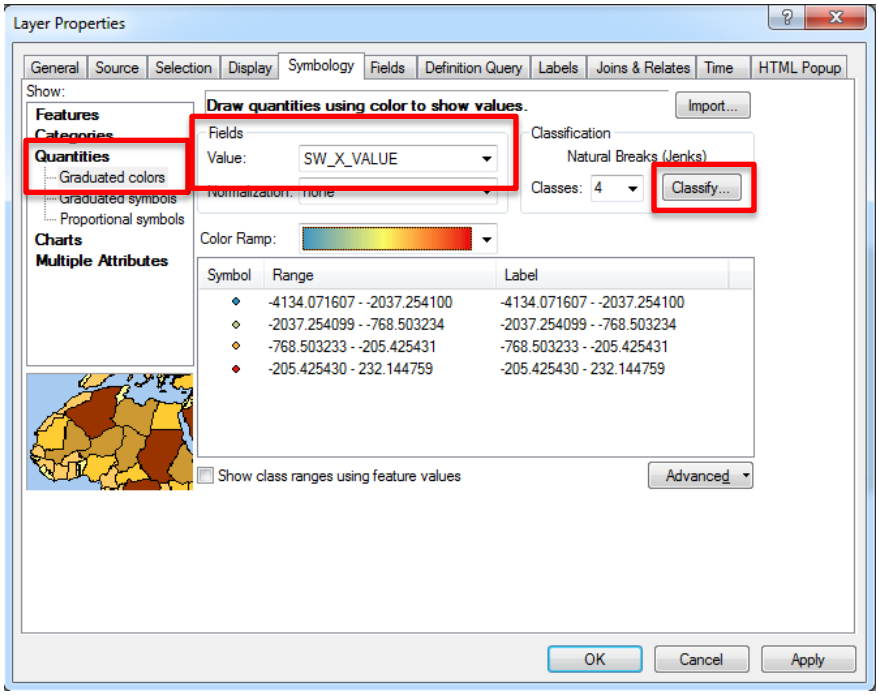


4. The Classification Statistics have now been recalculated to exclude all "No Exceedance" values. The new Classification Statistics "minimum" value is the minimum exceedance value for the severity range, and the Classification Statistics "maximum" value is still the maximum exceedance value for the severity range.

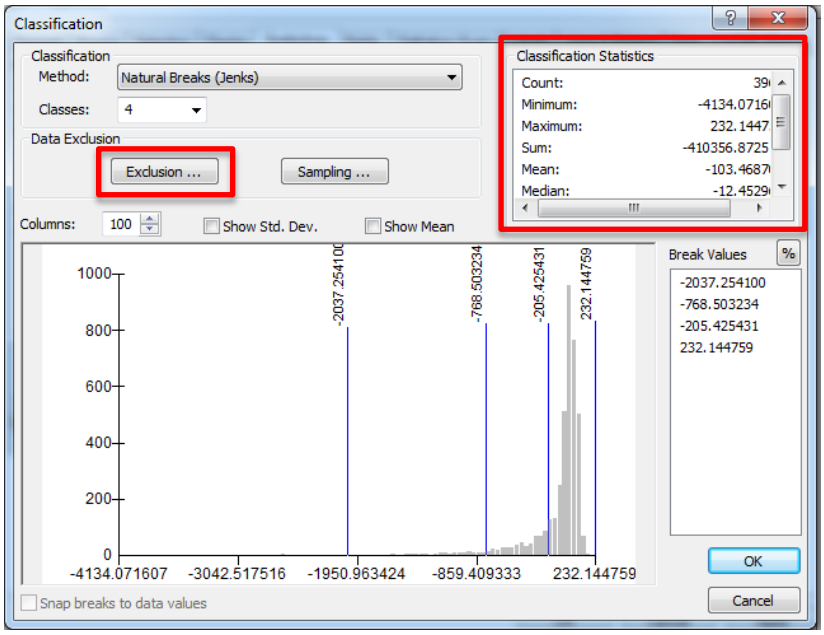


For point data (only CLs of acidity for surface waters), determine the largest exceedance value as well as the smallest exceedance value >0.

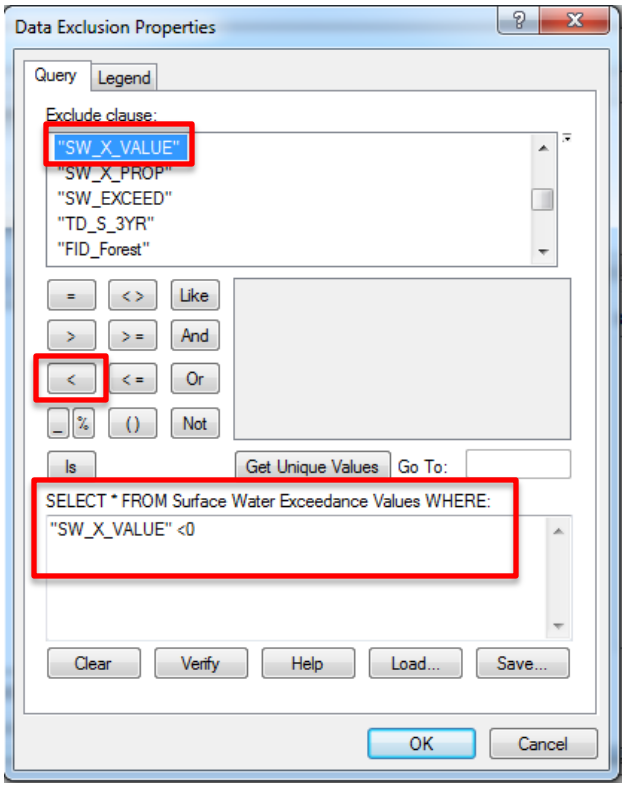
1. Double click on the layer name in the "Table of Contents" to open the Layer Properties box, "Symbology" tab. Select "Quantities/Graduated colors." Then select "SW_X_VALUE" from the Value dropdown box and select "Classify." The number of classes does not matter at this point.



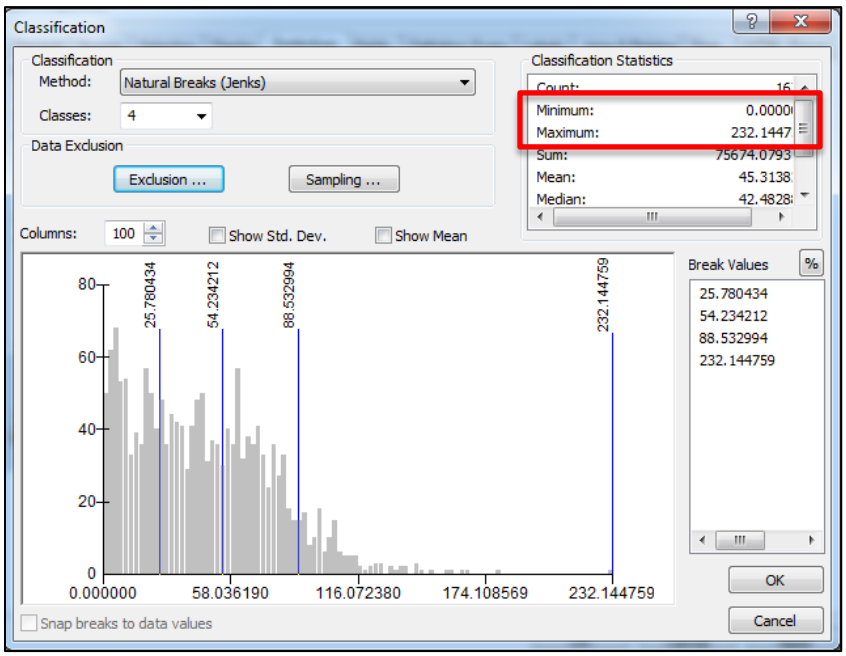
2. If all of the values within your area of interest exceed the CL, the Classification Statistics "minimum" value will be positive and will therefore be the minimum exceedance value for the severity range; the "maximum" value is the maximum exceedance value for the severity range. If the Classification Statistics "minimum" value is negative (as in the example below), click on the "Exclusion…" button.



3. In order to exclude all "No Exceedance" values, double click on "SW_X_VALUE" (which will make it appear in the "SELECT*FROM Surface Water Exceedance Values WHERE:" box), click on the "<" sign, enter "0", and select "OK."



4. The Classification Statistics have now been recalculated to exclude all "No Exceedance" values. The new Classification Statistics "minimum" value is the minimum exceedance value for the severity range, and the Classification Statistics "maximum" value is the maximum exceedance value for the severity range. In the example below the minimum exceedance value is 0.0000 and the maximum exceedance value is 232.14.

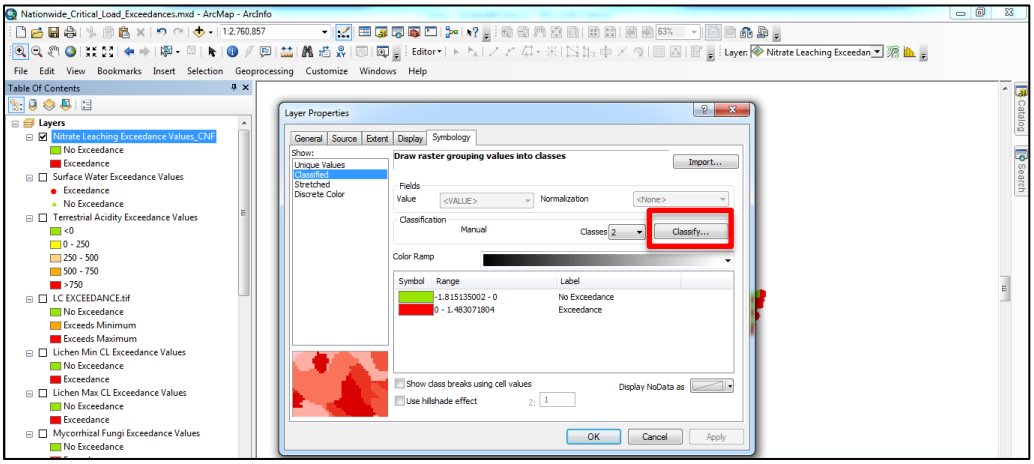


Severity – 95% Exceedance Value Exceedance Metric

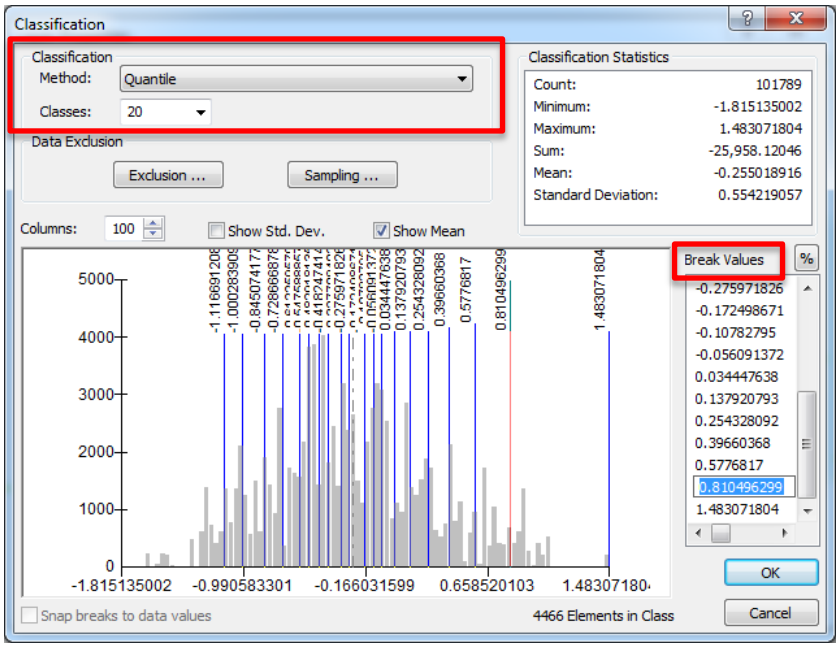
Severity: This metric focuses on the magnitude of the exceedance. The 95th percentile of exceedance values is the CL exceedance value below which 95% of the values are found. This is a useful metric because it describes an upper end of CL exceedance while allowing for the uncertainty around the estimates, as well as the exclusion of outliers.

For continuous gridded data (CLs of acidity for forested ecosystems and empirical N CLs for mycorrhizal fungi, lichens, herbaceous plants & shrubs, forests, and nitrate leaching):

1. Double click on the layer name in the "Table of Contents" to open the Layer Properties box. Select "Classify."

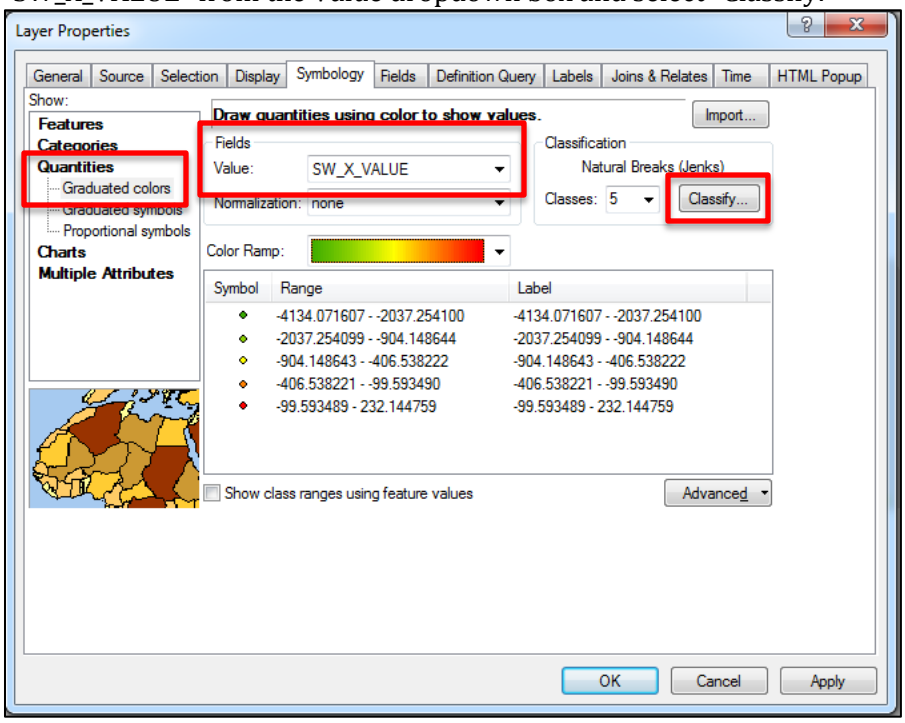


2. Within the Classification box, select the "Quantile" Method and select 20 Classes. This separates the data into 20 classes, each representing 5% of the grid cells. The second largest number in the "Break Values" box represents the 95th percentile (in the example below the 95th percentile is 0.81, meaning that although the exceedance values in this area can be as high as 1.48 kg N, 95% of the exceedance values are actually below 0.81 kg N). This analysis helps eliminate outliers.

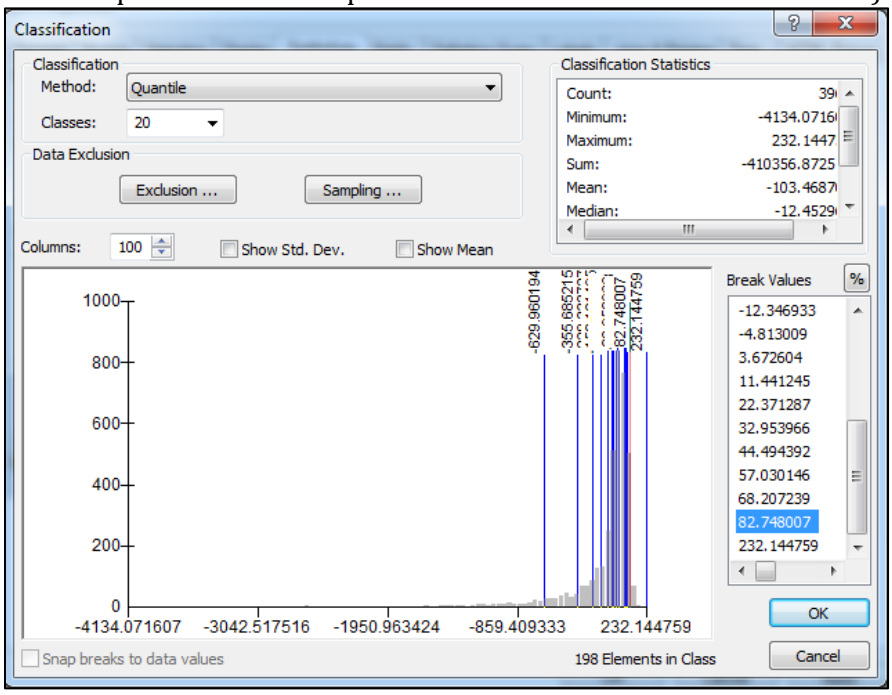


For point data (CLs of acidity for surface waters):
(This metric is only applicable for surface water CLs if there are more than 25 sites)

5. Double click on the layer name in the "Table of Contents" to open the Layer Properties box, "Symbology" tab. Select "Quantities/Graduated colors." Then select "SW_X_VALUE" from the Value dropdown box and select "Classify."



6. Within the Classification box, select the "Quantile" Method and select 20 Classes. This separates the data into 20 classes, each representing 5% of the samples. The second largest number in the "Break Values" box represents the 95th percentile (in the example below the 95th percentile is an exceedance value of 82.75).



Reliability Exceedance Metric

Reliability: This is a qualitative assessment of the uncertainty around the CL estimate or calculation, based on the approach and data used. Reliability will be used in Step 7 of the CL Implementation Strategy to determine whether additional information is needed prior to developing a Target Load. The most reliable CLs will be those that are developed with site-specific data from the Forest or a similar ecosystem.

Reliability for CLs from the CLAD database used in creating the nationwide CL exceedance information. The CLs are listed in order from most to least reliable.
• **Surface Water CLs of Acidity** are considered very reliable because site-specific water chemistry (and sometimes also soil chemistry) was used to calculate the CL using a simple mass balance equation. Critical loads were calculated using average water quality measurements from the most recent 5 years of data. If long-term water monitoring records are available for your Forest, these values should be examined and considered as part of the reliability determination.
• **CLs of Nutrient Nitrogen for lichens** reflect a range of reliabilities based on whether the response threshold used in the CL calculation was determined from lichen community measurements or expert judgment. The CLs are considered very reliable for the Pacific Northwest, Sierras, and Mediterranean California where lichen community data was used to develop the CLs. For other areas of the country, current CL estimates in the database are less reliable because they are based on expert judgment. Although lichen CLs are extrapolated across the landscape, not all community types contain lichens. You do not need to be concerned with exceedences of the CL of nutrient N for lichens in community types that do not include lichens. In addition, many lichen communities in the east may have already been heavily impacted. Monitoring may show compositional shifts from oligotrophic to eutrophic lichens has already occurred; if true, attention might be better spent focused on protecting other resources. *Efforts are underway to model response thresholds using lichen community information for additional Ecoregions around the country, and more reliable CLs of nutrient nitrogen for lichens are expected to be available in 2015.*
• **CLs of Nutrient Nitrogen for receptors other than lichens** vary in reliability. Go to GTR NRS-80 Table 19.1 for receptor reliability ratings by Ecoregion.
• The **CLs of Acidity for Forested Ecosystems** that are available on the Portal are based on work by McNulty et al. (2007). This was the first effort in the US to combine a simple mass balance equation with national-scale databases to estimate critical loads of acidity for forest ecosystems at a 1 km^2 spatial resolution across the conterminous (lower 48) states. It provides a good tool for assessing regional patterns of risk, but does not have sufficient spatial resolution to differentiate exceedance within forest stands. The authors of the study recognized that *more systematic analysis of model-predicted and measured forest soil CL exceedance is needed before this approach can be used as a tool for identifying areas of potential forest health concern*. For this reason we rank these CL exceedances as having a low reliability for this forest planning effort. The CL exceedance information can play a role in developing further monitoring strategies, as discussed in the Monitoring Strategy.