Forest Service Air Program
Critical Loads Implementation Strategy for Land Management Planning
(July 2014)

Introduction

A critical load (CL) is the level of atmospheric deposition below which no detrimental ecological effects occur over the long term, based on current scientific knowledge.

The Critical Loads section of the Air Quality Portal for Land Management Planning hosts information for the following critical load exceedance data sets: 1) nationwide CLs of acidity for surface waters, 2) nationwide terrestrial CLs of acidity for forested ecosystems, and 3) nationwide empirical CLs of nutrient nitrogen for several ecosystem receptors and responses (fungi, lichens, herbaceous vegetation, forests, nitrate leaching). Information for Alaska and Puerto Rico are not available for the terrestrial CLs of acidity for forested ecosystems. The critical loads included in this strategy are thresholds for sulfur and nitrogen deposition. The Forest Service hopes to eventually incorporate critical levels for mercury and ozone deposition into this assessment process.

The portal also hosts information on atmospheric deposition. Nitrogen and sulfur deposition occur as wet deposition (rain and snow), dry deposition (gases and particles), and occult deposition (cloud and fog). Deposition information is measured and modeled from a variety of sources. The CL exceedances provided on the portal are based on the most recent three-year average estimates produced by the NADP Total Deposition Science Committee (TDEP) v2014.01 because these estimates incorporate both measured and modeled information. We are continuously working to refine nitrogen and sulfur deposition estimates, and will therefore accept exceedance calculations using more current regional deposition data sets, if available and appropriate. All deposition datasets must reflect total deposition (wet and dry) for CL exceedance calculation, because CLs are set as thresholds for total deposition, not wet or dry deposition on their own.

The CLs and deposition data are used together to determine areas of CL exceedance. Examining CL exceedance is a "risk assessment" to evaluate the risk of sulfur and/or nitrogen deposition causing harm to the resource/ecosystem of concern. Exceedance is calculated as:

Exceedance = Deposition – Critical Load

If deposition equals or exceeds the critical load, the pollutant is likely causing harm to the ecosystem, or will cause harm in the future. If pollutant exposure is less than the CL, adverse ecological effects are not anticipated, and recovery is expected over time if an ecosystem has been damaged by past exposure. A CL exceedance is a measure of pollutant exposure above the CL. This means the pollutant exposure is higher than, or "exceeds," the CL and the ecosystem continues to be exposed to damaging levels of pollutants. In other words, deposition must be below the CL in order to protect the ecosystem. Exceedance calculations based on the 2010-2012 TDEP deposition data are provided on the portal for the three nationwide CL assessments described above.

The following strategy outlines the process, or steps, for incorporating the concept of critical load exceedance into the air quality assessments for Forest Plan Revisions. If a forest manages any wilderness with Class I area designation, critical loads may be established for air quality related value (AQRV) protection through this process and these may differ from CLs on the remainder of the forest. Refer to the Air Quality Portal for Land Management Planning for the supporting documentation and details necessary to complete the assessment.

Remember: Planning Rule Directives also require the assessment of additional air quality resources not discussed in this strategy (e.g., ozone and visibility). We hope to eventually provide guidance for these assessments on the portal.

Proceed to Step 1 of the Critical Load Implementation Strategy: Initial critical load exceedance screening.

STEP 1: Initial critical load exceedance screening.

In this step, exceedance calculations will be used as a screening tool to identify the extent of CL analyses that forests will need to include in forest plans.

The Critical Loads section of the Air Quality Portal for Land Management Planning hosts a "National Forest Exceedance Table" that documents critical load exceedances for each national forest. Locate your forest in the table to see whether any of the seven nationwide CLs are exceeded, and follow the instructions in the boxes below.

NOTE: TDEP is known to underestimate nitrogen deposition in certain situations (high elevations and complex terrain, as well as areas with high cloud and fog deposition, and areas in the arid south and west). If your forest is concerned about the underestimation of atmospheric deposition you may want to complete the critical loads assessment, even if you do not have a CL exceedance on the forest. The assessment will show how close deposition is to calculated critical loads (magnitude of non-exceedance) and recent trends in deposition, which can help the forest interpret the likelihood of exceedance if accurate deposition was available. This information could be used to support monitoring recommendations.

No exceedance of any CL

If there are missing values in the National Forest Exceedance Table for your forest, developing a monitoring strategy for collecting information to calculate these missing CLs would ensure that the potential impacts are not being overlooked.

If there is NO potential for CL exceedance on a forest, this finding should be documented and no further assessment is required. The Portal hosts a description of the National Forest Exceedance Table and documents the protocols used to create this table. This information can be incorporated into the Air Specialist Report for forest plan revision. Annual reports from the National Atmospheric Deposition Program (NADP) should be monitored for deposition trends. If deposition is increasing, CL exceedance should be reevaluated during the next forest plan revision.

One or more CLs exceeded

If a forest shows the potential for CL exceedance, proceed to Step 2.

STEP 2: Define your concern.

The negative effects of atmospheric deposition occur on sites that are sensitive to acidification or nitrogen saturation/eutrophication AND have excessive amounts of deposition. Decide whether to focus on acidification or nitrogen saturation/eutrophication, or both, in the following analysis.

Include all CLs that showed exceedance in Step 1.

Consider the ecosystem characteristics that indicate sensitivity to deposition, referring to the "Acidity" and "Nutrient Nitrogen" boxes, below. Interdisciplinary discussion with ecologists, geologists, hydrologists, soil scientists, fisheries biologists, air specialists, etc. can help identify whether one, both, or neither of these CL categories might be of concern to the forest. Results of these discussions can reduce the list of CLs you address in your analysis. (Later you will see how maps of CL exceedance can be used to identify areas at greater risk of harm from deposition.)

If investigation indicates a focus on empirical CLs of nutrient nitrogen, review the "User's Guide for setting empirical critical loads for nutrient nitrogen" for an explanation of how to refine the broad CL ranges provided for each forest and incorporate the concept of data reliability.

Proceed to Step 3 to identify the types of data available for the assessment.

Does your forest have any of the characteristics of ecosystem sensitivity?

Acidity

- Is there elevated deposition of sulfur or nitrogen in the area?
- Does the lithology/geology of the area have a low buffering capacity for acidity?
- Does the area have shallow soils?
- Does the area have very old weathered soils?
- Is the area found at high elevation?
- Do you have water chemistry data that indicates low buffering capacity (i.e. ANC, pH values)

Nutrient Nitrogen

- Is there elevated deposition of nitrogen in the system?
- Did the area historically have low nitrogen deposition?
- Have there been observed shifts in species composition of sensitive species in the area?
- Are there elevated stream water nitrate concentrations?

STEP 3: Examine available data.

Before beginning your assessment of critical load exceedances, take stock of all available data. Most forests will use the nationwide CL exceedance information provided on the Air Quality Portal because this is the best information available. Some forests will have access to refined CLs and/or deposition data; this data should be used when available to reduce uncertainty inherent in nationwide efforts. If you are not aware of ongoing regional efforts to refine CLs or deposition information, please consult the list of published data sources, available on the portal. Once you have compiled all available data, follow the instructions in the boxes below.

Published regional/local data is available

If published regional/local CLs or regionally refined deposition estimates are available and preferable for use in this air quality assessment, proceed to Step 4 and Step 5 to create the exceedance maps you will use in Step 6.

Published regional/local data is not available

If regional/local CLs or deposition data are not available and you will be basing your analysis on the provided national data, proceed to Step 6.

STEP 4: Review the critical loads available for the forest.

The Critical Loads section of the Air Quality Portal for Land Management Planning hosts the following critical loads data sets: 1) nationwide CLs of acidity for surface waters, 2) nationwide CLs of acidity for forested ecosystems, and 3) nationwide empirical CLs of nutrient nitrogen for several ecosystem receptors and responses. Only published critical loads are used in this process. If more site-specific CLs are available for your forest, determine whether they provide better information for the assessment than the associated national CL effort. The Portal hosts a description of the different approaches for calculating CLs, including advantages and disadvantages associated with the different methods.

Important Concept: The degree of uncertainty associated with the different critical loads calculations will vary with environmental variability (i.e., the high degree of variability in soils) and the method of critical load calculation (i.e., the use of site-specific data versus extrapolated/modeled data). Step 6 incorporates uncertainty and reliability into future recommendations.

After you have assembled all available published CLs for your forest, proceed to Step 5 where you will identify the best deposition data to use in your analysis, and calculate exceedances.

STEP 5: Identify the appropriate deposition information to compare with critical loads and calculate exceedances.

To understand the threat of negative effects of deposition to your forest you must compare the CLs from Step 4 with current levels of total deposition (wet +dry). Deposition information is measured and modeled from a variety of sources. Absent specific rationale to the contrary, we recommend using the 3-year average TDEP deposition data provided on the portal to maintain nationwide consistency. Regionally-refined deposition models that have documented QA/QC methods can be substituted where appropriate. In addition, you can analyze recent trends in deposition to assess the accuracy of the deposition data used to calculate CL exceedances.

After the appropriate deposition has been selected, exceedance is calculated using the following equation:

Exceedence = Deposition – Critical Load.

Instructions for calculating CL exceedances are available on the portal.

You now have critical loads and critical load exceedance values specific to your forest or region.

Proceed to Step 6 for guidance on examining and interpreting exceedance information.

STEP 6: Use CL exceedance to conduct a closer examination of atmospheric pollution impacts.

In this step you will examine CL exceedance patterns across the forest to better understand the extent and severity of potential impacts to resources, as well as the reliability of the CLs exceedance information. CL exceedance data for each of the nationwide CL efforts are hosted on the portal. If you have used site-specific data to create refined exceedance information, we recommended using that data to examine the extent, severity, and reliability of CL exceedance. For each type of CL identified in Steps 1 through 5, examine the extent, severity, and reliability of the exceedances. "Extent" refers to the percent of landscape in exceedance, while "severity" refers to the amount/quantity of exceedance. For example, one forest may exhibit exceedance in only 1% of land area while another forest exhibits exceedance in 75% of land area (extent); deposition in one forest may be only slightly above the CL while deposition in another forest may exceed the CL by a large amount (severity). Reliability is an expression of the certainty of the CL and exceedance estimates. Understanding the extent, severity, and reliability of exceedance on your forest can help you interpret patterns and make appropriate management recommendations.

Spatial representation of CL exceedance information is provided on the portal for the three nationwide CLs efforts. The portal also hosts important Forest Service boundaries including national forest, Class I Area, wilderness area, 6th level HUC, and landscape-scale analysis units, so that exceedance information can be examined by unit for management purposes. Special attention should be given to national forest and Class I boundaries.

Detailed instructions on assessing these CL exceedance metrics are available on the portal. A tabular description and example of this analysis is shown below.

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/m^2/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/m^2/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*

**The variable reliability rating for the empirical CLs of nutrient nitrogen (non-lichens) will be important when interpreting exceedance information and making management recommendations in Step 7.*

Complete this analysis and proceed to Step 7 for guidance on interpreting exceedance information.

STEP 7: Interpret the CL exceedance information.

Interpretation of CL exceedance must consider the type of CL (empirical vs. modeled), the site specificity of the data used in calculating the CL, and the quality of the deposition estimates. Management recommendations will vary with the reliability or certainty of the CL exceedance estimates.

For example, the CLs of acidity for surface waters provided on the portal are based on water chemistry measurements from specific sample sites and have a high level of reliability. Coupled with modeled-deposition information, CL exceedances for surface water have one of the higher levels of certainty which allows land managers to develop target loads. Target loads represent a policy or management decision about the amount of deposition that is an acceptable level of resource protection, and will be discussed further in the Target Load Strategy). On the other hand, the terrestrial CLs of acidity for forested ecosystems are created from geospatially extrapolated information that is acceptable for understanding risk across the landscape, but does not have the adequate site specificity necessary to make management recommendations. Exceedance of the CLs of acidity for forested ecosystems should therefore only be used for creating a monitoring plan to gather site-specific data.

You should now have a list of CLs that represent forest resources of concern, as well as information on the relationship between deposition and the CL (the CL exceedance). Your exceedance information may have changed as you refined your analyses (through investigation of exceedance metrics, empirical N CL guidance, or the use of local/regional CLs and deposition information). Review all CL exceedance information and decide whether the extent and severity of the CL exceedances indicate a potential for harm to the forest:

- *If the CL exceedance information suggests that the area is at low risk of any detrimental effects from S and/or N, conduct a deposition trend analysis to determine whether deposition has increased or decreased in recent years.*
  - *If the recent deposition trend is decreasing, continue to monitor NADP reports for deposition trends in the future. If deposition starts to increase, address possible needs for field measurements (e.g., water chemistry) in the next planning cycle and review the "Monitoring Strategy" in the Critical Loads section of the Air Quality Portal.*
  - *If the recent deposition trend is increasing, your exceedance metrics are likely underestimating the risk of detrimental effects. In this situation it is recommended that you proceed as though there is a higher risk of detrimental effects and implement instructions in the boxes below.*
- *If the CL exceedance information suggests a risk that the area is experiencing detrimental effects from S and N, implement instructions in the boxes below according to the type of CL used.*
- *If multiple CLs are in exceedance and indicate a risk of detrimental effects, review the "Interpreting Multiple CL Exceedances Protocol" and implement instructions in the boxes below.*

Surface Water CLs AND Reliable Empirical Nutrient N CLs (including lichen results from Mediterranean CA, PNW, Sierras) AND Appropriate Regional CL Efforts

Nationwide surface water CLs and reliable empirical nutrient N CLs (as determined in Step 2) have lower associated uncertainty because they were calculated with site-specific/locally relevant data. In addition, you may have access to regional CL results based on site-specific data.

***Deposition ≥ CL** : CL is exceeded, ecosystem is currently impacted, or likely to be in the future.*
Action: IDENTIFY a TARGET LOAD to protect or restore key components of the ecosystem per FS Directives. Go to the "Target Load Strategy."

Critical Loads of Acidity for Forested Ecosystems AND Other Empirical Nutrient N CLs

These CLs were developed to assess regional differences in exceedance, not for land management decision-making. They should be used to guide further monitoring and/or research experiments in areas of predicted exceedance.

***Deposition ≥ CL** : CL exceedance is possible.*
Action: Create a plan for collecting site-specific water chemistry, soil chemistry, and/or lichens as appropriate to refine analysis and confirm exceedance predictions. For other empirical nutrient N CLs you may want to work with FS research scientists to develop an N experiment or gradient study that will improve reliability of the CLs. Go to the "Monitoring Strategy."