Development of total nitrogen deposition budgets for U.S. critical loads assessments

John T. Walker[1]*, Robin Dennis[2], Donna Schwede[2], Gary Lear[3], Jesse Bash[2], Kristen M. Foley[2], Brett Schichtel[4], Jeff Collett[5], Mike Barna[4], William Malm[6], Kristi Morris[7], Christopher Lehmann[8], Tom Butler[9], Tara Greaver[10]

Atmospheric deposition is a pathway of the nitrogen (N) cascade by which reactive N emitted from anthropogenic and biogenic sources is returned to the earth's surface by wet and dry air-surface exchange processes. For many terrestrial and aquatic ecosystems, atmospheric deposition represents the primary exogenous N source and therefore plays an important role in system productivity and biogeochemical cycling. The atmospheric reactive N pool consists of oxidized and reduced compounds, both organic and inorganic, which are incorporated into precipitation (wet deposition) and deposit directly to the surface as particles and gases (dry deposition). While N is a key nutrient, long-term ecosystem inputs in excess of biosphere demand may lead to changes in vegetation and microbial species composition, decreased resistance of vegetation to pests and climate variability, soil acidification, eutrophication, and other stressors. The concept of a "critical nitrogen load", below which harmful effects are not expected to occur, has been developed as a policy tool for protecting ecosystems from excessive N deposition. Widely used in Europe since the 1980s, federal agencies in the U.S. are now employing critical loads (CL) approaches to protect key ecosystems and research in support of this effort is advancing.

Estimates of total N deposition are often required for calculation of the CL itself. Additionally, speciation of the N deposition budget is necessary to quantify the relative contribution of individual compounds to the total N load and thereby accurately quantify the fraction of the budget that is subject to regulatory control. Speciated N deposition budgets are therefore required to develop the most effective and cost efficient strategies for meeting target deposition loads identified through CL assessments. While much progress has been made in developing measurement and modeling approaches for quantifying atmospheric N deposition, most CL assessments in the U.S. currently rely on budgets that are to some extent incomplete (e.g., do not include some compounds such as organics) or contain deposition estimates for some important compounds that are highly uncertain. The purpose of this study is to examine the state of the science with respect to development of total N deposition budgets for the U.S. We begin by summarizing current approaches for constructing deposition budgets, including chemical transport models, measurement networks, and recent intensive field studies. Site specific case studies are presented in which speciated budgets developed from each approach, and combinations thereof, are compared. Key uncertainties of the budgets are discussed, including the implications for ecosystem protection and policy effectiveness. Finally, recommendations for near- and long-term monitoring and process oriented research needed to improve current methods for developing total deposition budgets are put forth.

[1]U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory, Durham, NC 27711. [2]U.S. EPA, Office of Research and Development, National Exposure Research Laboratory, Durham, NC 27711. [3]U.S. EPA, Office of Air and Radiation, Clean Air Markets Division, Washington, DC 20460. [4]National Park Service, Colorado State University, Fort Collins, CO 80523. [5]Colorado State University, Department of Atmospheric Science, Fort Collins, CO 80523. [6]Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 80523

[7]National Park Service, Air Resources Division, Denver, CO 80225. [8] National Atmospheric Deposition Program, Illinois State Water Survey, University of Illinois at Urbana-Champaign, Champaign, IL 61820. [9]Cary Institute of Ecosystem Studies, Millbrook, NY 12545. [10]U.S. EPA, Office of Research and Development, National Center for Environmental Assessments, Durham, NC 27711

***** Corresponding author, Email: walker.johnt@epa.gov, Telephone: (919) 541-2288