Testimony by Jill S. Baron

Ecologist
U.S. Geological Survey

Mr. Chairman and distinguished Members of the Committee, thank you for this opportunity to present, on behalf of the U.S. Geological Survey, this statement regarding sources, transport, and fate of atmospheric deposition in the Western United States.

I am an ecologist with the U.S. Geological Survey (USGS). In 1981, I began research into the susceptibility of Rocky Mountain National Park lakes to acidic atmospheric deposition. I, and my colleagues, now have over 20 years in understanding alpine and sub-alpine ecological processes and the influence of atmospheric deposition on these natural environments. The USGS has been quite active in studying the ecological and biogeochemical influences of airborne pollutants throughout the United States, and has produced cutting-edge science from our long-term watershed research and monitoring efforts. I am confident of the results I will present to you today regarding atmospheric deposition and ecological effects for the specific areas we have studied. The response to atmospheric nitrogen deposition in Southern California has been pronounced, and it is well documented by scientists working there. In Colorado, we see significant changes from nitrogen deposition that tell us our ecosystems are just beginning to respond, and our results are also well-documented in the scientific literature. However, the West is very large, and our studies and monitoring are limited in geographic scope. There is also a great amount we do not yet know about combined interactions between many environmental stresses and the plants, animals, and microbes that make up our ecosystems.

Definition of the Issue

The history of atmospheric deposition to the Western United States beyond the 100th Meridian (hereafter referred to as West) differs from that in the Eastern half of the country. Because the West has been settled more recently than the East, it has not experienced emissions of sulfur and nitrogen oxides for as long. Although population in the West is increasing rapidly, human density is still far below much of the rest of the country. This has resulted in a lower density of power plants and industrial facilities that have been a large source of air pollutants elsewhere. Compared to the East, the West is fortunate to have energy sources that generally do not emit high amounts of sulfur dioxide, one of the major precursors to acid rain. Low sulfur coal, hydropower, nuclear, and solar and wind energy have helped the West suffer less the effects of atmospheric deposition to ecosystems and historical structures common to the East. The major sources of sulfur oxide emissions in the Intermountain West were refineries and smelters for metals such as copper, and many of these smelters have closed over the past 20 years. As they have closed, both emissions and atmospheric deposition of sulfur compounds have decreased significantly (Epstein and Oppenheimer 1986). A final important difference between West and East is that the complex topography and localized arid climates of the West combine to create places where most atmospheric deposition occurs as dry particles and aerosols, such as in Southern California and in the deserts of the Southwest.

Emissions and atmospheric deposition of nitrogen oxides and ammonium, however, are increasing rapidly and significantly in the West, creating their own set of environmental concerns (Lynch et al.1995, Campbell, unpub. data). While we consistently find acid rain, especially in the summer, in Rocky Mountain National Park, it has not yet had a measurable effect on lake chemistry in the Park (NADP/NTN 2000, Baron et al. 2000, Campbell et al. 1995).

The major anthropogenic source of nitrogen oxides is combustion of fuels at high temperatures. Combustion sources include automobiles; trucks, trains, and heavy farm and construction machinery, the utility and industrial sectors, and increasingly, energy development from coal-bed methane, natural gas. Additional nitrogen comes from agricultural emissions, both from fertilized croplands and from large manure piles of confined animal feeding operations. These are regionally important, and in some areas, such as the Colorado Front Range, account for more than 20 percent of the nitrogen emissions (Baron and Mosier, in prep).

Where are the Regions of Elevated Wet Nitrogen Deposition?

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) provides our best coverage of precipitation chemistry in the United States, and its records began in 1978. As measured at NADP/NTN sites, wet deposition of nitrogen in the West is lower on an annual average than other more industrialized parts of the world, such as Europe and the Northeast United States (NADP/NTN 2000). Nevertheless, there are hotspots of elevated wet nitrogen deposition in Southern California and along the Colorado Front Range when compared with the rest of the West (Fenn et al. 1998). These are regions of high population and agricultural activity, and sufficient precipitation to receive the deposition in rain and snow. Wet deposition measurements in Southern California reflect only 10 percent of the total atmospheric nitrogen deposition (Bytnerowicz et al. 1998). Because of its Mediterranean climate, most deposition occurs as dry deposits in Southern California, and is not measured by the NADP/NTN network. Wet deposition to the high mountain areas of the Colorado Front Range are perhaps an order of magnitude lower than those from California, but they are high enough to have caused chemical and ecological change, as described below (Baron et al. 2000, Fenn et al. 1998, NADP/NTN 2000). Other parts of the West, such as near Tucson, Phoenix, and Las Vegas, may also have high nitrogen deposition, but it falls as dry deposition due to the arid climate.

Chemical and Ecological Responses to Elevated Nitrogen Deposition

Nitrogen is an essential fertilizer, and atmospheric nitrogen deposition is a boon to croplands and commercial forests around the world. In natural forests and parks, however, it can affect both plant communities and aquatic environments. Some species are better able to use nitrogen for enhanced growth, allowing them to out-compete their neighbors. This can lead to changes in plant and animal community structure. In many parts of the world with long histories of nitrogen additions, grasses now dominate meadows and fields that once had much greater species diversity (Vitousek et al. 1998). This is well-documented in England and the Netherlands, in experimental plots in the Great Plains, and increasingly, in native coastal sage scrub vegetation of Southern California (Padgett and Allen 1999). Experiments have shown that nitrogen additions have the same effect on alpine tundra (Bowman et al. 1993,1998,2000), enhancing grass production at the expense of the wildflowers.

Trees grow and respond to nitrogen additions at a slower pace, and there are few forest species that can out-compete those adapted to harsh western environments. At high elevations of the Rocky Mountains all plants live a hard life, and the cold, short growing season, and limited water help to create a situation called nitrogen saturation, with excess nitrogen flushing into streams and lakes. As nitrogen moves through soils, chemicals essential for forest fertility are stripped into the water, enhancing lake and stream acidification (Driscoll et al. 2001).

Before acidification occurs there will be lake fertilization effects. Many high elevation lakes do not get enough nitrogen for algal growth, so additions from atmospheric deposition cause increased productivity and changes in community composition (Morris and Lewis 1992, Elser et al. 1990). Excess nitrogen deposition influences plant growth and community composition. Leaching of nitrate through watersheds leads to eutrophication of lakes and streams, and ultimately, to acidification.

In summary, the best evidence for effects of nitrogen deposition occur in Southern California and the Colorado Front Range. In Southern California, ozone damage, eutrophication of streams, and loss of soil fungi essential to endangered species are evident. On the Colorado Front Range, terrestrial plant communities and algal lake communities are altered and increased nitrogen cycling is poised to create acidification similar to that in the East.

Examples of the Effects of Nitrogen Deposition in the West

Southern California:

- Wet plus dry deposition in Southern California is very high, around 35 kilograms per hectare per year (comparable to deposition in northern Europe and the eastern United States, Bytnerowicz et al. 1999). It, combined with high concentrations of ozone in the San Bernardino Mountains, has caused ponderosa pine growth to be severely reduced (Fenn et al. 1998, Grulke et al. 1999, Arbaugh et al. 1999).
- Perennial streams in the San Bernardino Mountains have average concentrations greater than 10 milligrams of nitrate-N per liter. This average concentration is greater than U.S. Environmental Protection Agency drinking water standards (Fenn and Poth 1999).
- The coastal sage scrub is a unique environment with a great number of native species, many of them sensitive or listed as threatened or endangered. Researchers have found a direct relationship between the increase of nitrogen deposition and the loss of soil microorganisms such as fungi and bacteria. These microorganisms are essential to the sage scrub community, in that they enhance nutrient uptake by plants, and help decompose dead material (Edgerton-Warburton and Allen 2000). Without them, native species are weaker and open to invasion by non-native grasses. The non-native annual grasses perpetuate themselves by providing the fuel for frequent fires (Callaway and Davis 1993). Increased fire, perhaps helped along by the nitrogen deposition, poses risk to people and property as well as the native ecosystem.

Colorado Front Range:

- Alpine tundra with added nitrogen shows a shift in plant community composition that favors grasses over flowering plants (Bowman et al. 2000, 1998, and 1993).
- In the harsh high elevation environments of the Rockies, nitrogen deposition has significantly increased rates of forest and soil nitrogen cycling—the first stage of expected effects on the road toward nitrogen saturation (Baron et al. 2000, Rueth and Baron, accepted).
- Alpine lakes in areas with elevated nitrogen deposition have significantly higher nitrate concentrations than lakes in low deposition areas-another indication of expected effects from excess nitrogen deposition (Baron et al. 2000, Baron, 1992).
- Lake algal communities have changed significantly in the past 50 years. These microscopic plants are the base of the lake food chain. Algae in some alpine lakes is more abundant, and now dominated by species representative of pollution. These species have been shown to dominate in lakes allover the world that have been fertilized or otherwise disturbed, and their presence indicates a profound change in their environment. The communities now found in these remote and otherwise undisturbed lakes are different than any other throughout lake history (Baron et al. 2000, Wolfe et al. 200 I).

I would like to spend the remainder of my time emphasizing the need to develop better research and monitoring information throughout the West.

Research and Monitoring Needs

Monitoring:

- There are hundreds of square miles in the West without any wet deposition monitoring, so our knowledge of atmospheric deposition is incomplete. High elevation regions, especially, are under-represented, but this is where the greatest amount of wet deposition occurs.
- Dry deposition monitoring is even more sparse, but dominates deposition through much of the West.
- Long-term monitoring of chemical and biological trends in watersheds is greatly needed. There are only a handful of long-term study areas in the West, operated by the U.S. Geological Survey, the National Science Foundation Long- Term Ecological Research program, USDA Forest Service, and some universities. In a region undergoing rapid change in population and energy development, we are very poorly set up to detect the consequences. Managers of public lands depend greatly on objective scientific reports of the condition of their resources. Long-term monitoring is highly effective at detecting trends, and when coupled with research, give early indications of the causes of change.

Research:

- Our confidence in atmospheric transport models is poor in the West, where the complex topography makes modeling extremely difficult. More effort in this area would yield great benefits in understanding source-receptor relationships.
- The mechanisms of dry deposition are still not well understood; more research into transport and deposition mechanisms is needed.
- Our understanding of the complex ecological interactions that occur with nitrogen deposition is incomplete. Communities that evolved with low nitrogen availability are changing in novel ways that we do not understand. More research is needed to tell us about possible effects on disturbance regimes such as fire, changes in nutrient cycling and leaching, increased opportunities for invasions and insect outbreaks, and how much nitrogen causes acidification in Western watersheds. Better understanding of ecosystem functions will help managers of public lands, and regulatory agencies make decisions on critical thresholds of ecological change.

Mr. Chairman, this concludes my remarks. I am happy to respond to questions Members of the Committee may have.