Rio Grande National Forest – Draft Assessment 2
Air Quality, Soils, and Water Resources

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This document provides a rapid assessment of air, soil, geologic, and water resources that may be useful in developing plan components and other plan content. This assessment is in three sections: Air Quality, Soils, and Watersheds and Water Resources.[1] There is a minor amount of repetition between sections in the event they are used as stand-alone documents.

[1] This document contains non-italicized excerpts, in-full or paraphrased, from in-house Forest Service sources such as working documents, planning documents, NEPA documents, resource-area specific reports, manuals, handbooks, etc. This information may or may not be cited directly in the text but the source is listed in the information sources sections of the assessment. Information from published literature, such as scientific papers and investigations, is referenced directly in the text, with formal citation in the information sources sections of the assessment.

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Air Quality

Introduction

Air quality is recognized as an important resource to protect on national forests. The public values the clean air and sweeping vistas that national forests provide. Managers become concerned when poor air quality is or may affect forest resources such as forest health, visibility, water quality, aquatic organisms, or heritage resources.

The 2012 Planning Rule requires National Forests and Grasslands to consider air resources when developing plan components. The purpose of this assessment is to evaluate available information about air resources within the Rio Grande National Forest. This assessment describes current conditions and trends regarding these resources. This information is used to anticipate future conditions, and to determine if trends pose risks to system integrity at the forest level. Additionally, this assessment identifies information gaps and any uncertainty with the data. The information contained in this assessment will be used to inform agency officials whether current direction needs adjustment to protect air resources and the systems that rely on them.

The following items are addressed in this assessment, as specified by Forest Service Handbook, Chapter 10 Section 12.21.

- Airsheds relevant to the plan area
- Location and extent of known sensitive air quality areas, such as Class I areas, non-attainment areas, and air quality maintenance areas
- Emission inventories, conditions, and trends relevant to the plan area
- Critical load exceedances, including extent and severity
- Federal, State, and Tribal governmental agency implementation plans for regional haze, non-attainment, or maintenance areas (including assessing whether Forest Service emission estimates have been included in the appropriate agency implementation plans)
- Known large, broad-scale, and major geologic hazards that may affect air quality
- Air quality considerations important to consider in providing multiple uses and ecosystem services
- Conditions and trends assuming existing plan direction remains in place

Concepts in Air Quality Management

By identifying national forest components that are impacted by air pollution, and by measuring the effect of air pollution on these sensitive elements, the degree to which air pollution is affecting the forest can be measured. This information can be, and has been, used by air regulators, land managers and concerned citizens to promote improvements in air quality that will benefit national forest areas and the people who visit them. Several important concepts in air quality management are described below.

Impacts of Air Pollution

Air pollution affects the natural quality of National Forest lands, particularly wilderness areas, and is one reason that it is a concern to managers. High ozone concentrations can injure sensitive vegetation. Atmospheric deposition can cause lake body acidification, eutrophication, and hypoxia, soil nutrient

changes, and vegetation impacts. Deposition of toxic metals such as mercury and lead can be harmful to both aquatic and terrestrial ecosystems. Visibility in most national forests is obscured some portion of the year by a haze of fine pollutant particles. Air pollution affecting national forests comes from a myriad of sources, large and small, located nearby and far away. It includes emissions from industry, including power plants, as well as cars and trucks, wood burning stoves and fireplaces, and ground disturbing activities such as mining and road construction. The pollution typically originates outside of national forest boundaries, but is transported through the atmosphere and deposited inside national forest boundaries.

The impact on the ecosystem is related to the amount of pollution emitted, the distance from the ecosystem of concern, and meteorology affecting the transport and dispersion of pollutants. The ecological effects of air pollution may also vary by location, time, and sensitivity of individual species. As such, certain species that are known to be sensitive to air pollution can be monitored as an indicator of adverse effects on the ecosystem. For example, changes in lichen communities may be the first signs of adverse impacts on vegetation. If changes are not observed in indicator species, it is unlikely that adverse impacts will be realized in less sensitive species. However, if changes in sensitive species are observed, then additional signs of adverse impact are often investigated.

The response of an ecosystem to air pollution is not only dependent upon the amount of contaminants to which it is exposed, but also dependent upon the ability of the ecosystem to buffer itself against the effects of air pollution. For example, the geo-chemistry of high alpine lakes determines the lake's ability to neutralize acidic precipitation. Land form, predominate wind direction, and aspect also play significant roles in particulate deposition and accumulation. Additionally, some pollutants accumulate in the food chain in which the effects are only evident in certain species. Hence, understanding and monitoring for air quality values in a national forest requires a comprehensive view, combined with local knowledge.

Wilderness Air Quality Values

Wilderness air quality values are the general categories of features or properties of wilderness that are affected in some way by air pollution. Identified values are: visibility, odor, flora, fauna, soil, water, geologic features and cultural resources. This includes Air Quality Related Values (AQRVs) in Class I areas, as well as similar features and properties in Class II areas, titled Wilderness Air Quality Values (WAQVs). All wilderness areas 5,000 acres or greater in size in existence in 1977 are considered Class I areas. All areas designated after 1977 are Class II areas. The difference between the two is that Class I areas are protected through the Clean Air Act and air quality related values (AQRVs) that have been established for each region. The Forest Service is responsible to protect air quality values in wilderness the same regardless of whether they are Class I or Class II areas; it is the agency's ability to affect change, and the process that is used in Class I areas, that is different. For both Class I and II areas, Forests report the results of air quality monitoring and the effects from sources outside wilderness to the state regulatory agency. For Class I areas the Forest Service, working with State regulators, can also model the potential effects of new pollution sources on Class I areas and provide comment to the planning and permitting processes.

Similar properties that reflect air quality impacts are atmospheric deposition, snow pack chemistry, and meteorology. Air chemistry and atmospheric deposition monitoring are necessary to establish the linkages between air pollution and any changes to the physical, chemical, or biological condition of the sensitive receptors.

Sensitive Receptors and Indicators

Sensitive receptors are specific types of features or properties within a wilderness that can be negatively impacted by air pollutants, e.g., high-altitude lakes, lichens, scenic vistas. In other words, sensitive

receptors are the specific components of an ecosystem through which change in an AQRV or WAQV is quantified. Sensitive receptors are selected for 1) known or suspected sensitivity to pollutants, 2) availability for manageable, cost-effective monitoring, sampling, and analysis methods, and 3) relevance for modeling capabilities. Examples of indicators for sensitive receptors might be a population survey for a particular amphibian, a plankton count and water quality analysis in a sensitive lake, or an assessment of the vista from a particular viewpoint.

The relationship between air pollution and effects on individual components of the wilderness is influenced by a component's ability to resist displacement from its natural condition, ability to recover from an individual human-caused event, and the number of times the wilderness component can return back to the natural condition after repeated human-caused change incidents.

Critical and Target Loads

Fossil fuel burning emits sulfur dioxide (SO_2) and nitrogen oxides (NO_x) into the atmosphere. Certain types of agricultural activities emit ammonia (NH_3) to the atmosphere. Such emissions can lead to atmospheric deposition of sulfuric acids, nitric acids, and ammonium to national forest ecosystems. In sensitive ecosystems, acid compounds can acidify soil and surface waters, affecting nutrient cycling and ecosystem services. In more resilient ecosystems nitrogen deposition can lead to chemical and biological changes through nitrogen saturation, which can then affect ecosystem services. To address whether atmospheric deposition is having negative effects critical loads are calculated. If monitoring and modeling indicate critical loads are being exceeded then target loads are established.

Critical loads are quantitative estimates of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment are not expected to occur according to present knowledge. Values are scientifically determined based on expected ecosystem response to a given deposition level. When values are exceeded the environmental effects can extend over great distances. Target loads are acceptable pollution loads or levels agreed upon by policy makers and land managers. Acceptable target loads are based on economic costs of emissions reductions, timeframes, and other matters.

Legal Framework and Forest Service Policy

The Forest Service has a role in implementing air quality programs. This role is identified in and a result of numerous legislative acts, regulations, and standards.

National Forest Management Act

The National Forest Management Act directed each national forest to prepare a land and resource management plan. The Act recognizes national forests are ecosystems and their management requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems.

Rio Grande National Forest Land and Resource Management Plan

The air resource is a recognized component of the Rio Grande National Forest Land and Resource Management Plan (Forest Service 1996). The Final Environmental Impact Statement (FEIS) for the Forest Plan recognized, at that time, air quality across the Forest rates among the best in the country and the air pollution that does exist on the Forest comes mostly from unpaved roads and smoke from prescribed and wildfires.

Desired conditions, objectives, and standards and guidelines in the Forest Plan are described in a subsequent section of this assessment. Annual Forest Plan monitoring reports provide annual summaries

of air quality on the Forest and indicate air quality is being adequately protected and no changes in the Forest Plan are needed.

Wilderness Act

The Wilderness Act of 1964 contains language directing the management of wilderness to secure for the American people, and future generations, the benefits of an enduring resource of wilderness unimpaired for future use and enjoyment. The Act further states that Congress intended to manage these wilderness areas so that the earth and its community of life are untrammeled by man. A wilderness must retain its primeval character and influence and be affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable. The direction provided in this Act makes it clear that Congress intended that the natural conditions in wilderness be preserved and that it be influenced primarily by the forces of nature rather than by human activity.

There are four wilderness areas on the Rio Grande National Forest. The Weminuche and La Garita are Class I wilderness. The South San Juan and Sangre de Cristo are Class II.

Clean Air Act

The regulation of air pollution sources has clearly been delegated by the Clean Air Act (CAA) to the Environmental Protection Agency (EPA), and as applicable, the States. In Colorado, air pollution is regulated by the Air Pollution Control Division (APCD) of the Department of Public Health and Environment (CDPHE). Specific air quality and pollution regulatory information for APCD is located at http://www.colorado.gov/cs/Satellite/CDPHE-AP/CBON/1251582562056. Even though regulatory oversight of the CAA resides with EPA and the State of Colorado, the Forest Service has the responsibility under the CAA to protect particular values of national forest lands from the adverse impacts of activities inside and outside the forest boundary.

The Clean Air Act, as amended, significantly broadened the authority and responsibility of the Forest Service. Originally passed in 1963, major amendments followed in 1967, 1970, 1977, and 1990. The purpose of the CAA is to protect and enhance the quality of the Nation's air resources so as to promote public health and welfare. The CAA requires cooperation among all Federal departments and agencies having functions relating to the prevention and control of air pollution.

Though the CAA provides the legal and regulatory framework for protecting National Forest lands, it is the responsibility of federal land managers to determine exactly how the lands are to be managed. The act requires that the Forest Service comply with all applicable Federal, State, or local air control rules, regulations, and directives, and requires compliance with applicable substantive and procedural requirements imposed by a Federal, State, interstate, or local administrative authority or court. Furthermore, the Forest Service must consult with each State having delegated authority on all matters concerning the prevention of significant deterioration of air quality, visibility, air quality maintenance plan requirements, and nonattainment requirements.

The Clean Air Act declared as one of its purposes to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, or historic value. The CAA gives direction to federal land managers and federal officials charged with direct responsibility for management of such lands the affirmative responsibility to protect the air quality related values, including visibility, of any such lands within a Class I area, and the responsibility to consult with EPA in the statutory process required for the approval of a Prevention of Significant Deterioration (PSD) permit application for a major source.

National Ambient Air Quality Standards (NAAQS)

In 1971, under the authority of Section 109 of the Clean Air Act, the EPA adopted health-based standards that limit the concentration of certain air pollutants, known as criteria pollutants, throughout all locations across the United States. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution, and sulfur dioxide. The limits (http://www.epa.gov/air/criteria.html) are known as the National Ambient Air Quality Standards (NAAQS). The primary standards are designed to protect public health, including sensitive populations such as the elderly, children, or people with asthma. Secondary standards are designed to mitigate harmful effects to animals, vegetation, and buildings, and limit decreases in visibility. Individual States have the responsibility for air quality management and for meeting air quality standards.

Forest Service Conformity with National Ambient Air Quality Standards

Under the Clean Air Act, an area that violates NAAQS for any of the six criteria pollutants listed above is designated as a non-attainment area. Maintenance areas are any non-attainment area that has been re-designated to attainment status and may be more sensitive to maintaining the designation. If a State has a non-attainment area, it must develop a State Implementation Plan (SIP) which describes how the State will achieve and maintain Federal and State standards. The conformity rule of the CAA states no department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve any activity which does not conform to an implementation plan.

This rule ensures that federally funded or supported actions taken by Federal agencies and departments, including the Forest Service, meet national standards for air quality in Federal non-attainment and maintenance areas, and requires the Forest Service to demonstrate that its actions, or actions of those who occupy and use National Forest lands under Forest Service authorization, will not impede the State Implementation Plans to attain or maintain the ambient air quality standard. A few examples of activities on National Forests and Grasslands that may require a review for conformity include fuel treatments, including prescribed fire and harvest activities, road, trail, or building construction, and land use and special use permit decisions such as ski or winter sports area, mining, oil and gas development and landfills.

Prevention of Significant Deterioration Program

The Prevention of Significant Deterioration (PSD) sections of the Clean Air Act include a permit program for certain new sources of air pollution. The purpose of the PSD process includes the protection and enhancement of air quality in national wilderness areas and other locations of scenic, recreational, historic, or natural value. Before the construction of certain new air pollution sources is approved, the applicants must receive a PSD permit from the appropriate air regulatory agency. The Forest Service manager, during the permitting process, must make three decisions:

1. What are the sensitive air pollution receptors within the wilderness that need protection?
2. What are the Limits of Acceptable Change (LAC's) for these receptors?
3. Will the proposed facility cause or contribute to pollutant concentrations or atmospheric deposition within the wilderness that will cause the LAC's to be exceeded?

The first two decisions are land management issues based upon the management goals for the wilderness in question. The third is a technical question analyzed by models combining proposed emissions, background levels of pollutants, and the sensitivity of visibility and forest resources to the pollutants.

Close coordination between the Forest Service and the appropriate air regulatory agency is essential in the PSD process. The Forest Service makes a determination of whether a proposed project will adversely impact Forest lands. The air regulatory agency then makes a decision to grant or deny the permit.

Best Available Control Technology Review for New or Modified Pollutant Sources

The Forest Service reviews air permit applications for new and modified industrial facilities to ensure that air emissions do not adversely impact the air quality related values, such as visibility, of federally-protected wilderness areas. The agency provides these comments to the permitting authority, typically the state.

One key part of the air permit application, required by various regulations, is a review of the air pollution control technology proposed on each of the new or modified emission units at the facility. The air quality regulations envision that it would be most cost effective to require pollution control upgrades at the time new sources are built or modified, thereby allowing plant owners to plan for these costs as part of the construction of a new plant or an overall plant upgrade.

In general, the review of air pollution control technology involves an application of engineering to analyze what types of control technologies are possible for each regulated pollutant from each emission unit at the facility. Then, the best performing option is selected unless it is deemed to be too expensive or causes other adverse environmental impacts. This process of ensuring that the best available control technology is applied to industrial sources reduces air emissions to the lowest possible amount and minimizes air pollution impacts to the National Forests.

Regional Haze Program

The Regional Haze Rule of 1999 requires states and interested tribes to address sources of pollution contributing to regional haze in the 156 mandatory Class I areas across the country. To do this, states have or are in the process of developing State Implementation Plans (SIPs) to demonstrate to the public, the federal land managers and EPA how they plan to address regional haze to reach the goal of natural background conditions by the year 2064. The Forest Service, as the federal land manager of 88 mandatory Class I areas, has been working closely with the states, interested tribes, EPA, and the Regional Planning Organizations in the development of the technical products and policy documents that are being used by each state as they develop their plans.

Agency Policy

Forest Service Manual 2580 – Air Resource Management contains agency direction for managing air resources. Objectives are to protect air quality related values within Class I areas, control and minimize air pollutant impact from land management activities, and cooperate with air regulatory authorities to prevent significant adverse effects of air pollutants and atmospheric deposition on forest and rangeland resources. Agency policy calls for integrating air resource management into all resource planning and management activities and using cost effective methods of achieving resource management objectives.

Information Sources and Data Gaps

Information Sources

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Numerous websites as shown throughout the document; links to each site are contained in the narrative. Some of the figures are downloaded from these sites.

Data Gaps

While not necessarily needed for Forest Plan revision, the 1994 Air Resources Monitoring Plan for the Rio Grande National Forest is outdated and should be revised. The revision should be conducted in conjunction with surrounding national forests since the four wilderness areas on the Rio Grande National Forest cross boundaries with the San Juan, GMUG, and Pike/San Isabel National Forests. The monitoring plan revision should include a review and appropriate updating of air quality related values, statistical analysis of visibility and deposition trend, consideration of refined critical loads, target loads, and adjustments to the existing air program accordingly.

Existing Forest Plan Direction for Air Quality

The Rio Grande National Forest Plan contains desired conditions, objectives, and standards and guidelines. For air resources they are:

Desired Conditions

Air quality remains excellent. It is better than state and federal standards. Visibility distances are among the best in the country. Forest activities do not affect long-term changes or contribute to off-Forest problems.

Objective

Protect the environment from air pollution, at least to the degree required by law.

Standards and Guidelines

Standard

Conduct all land management activities in such a manner as to comply with all applicable federal, state, and local air quality standards and regulations, including:

- Federal: The Clean Air Act, as amended, 1991, (P.L. 95-95)
- State of Colorado: The Colorado Air Quality Control Act, Colorado Statutes 25-7-101 through 25-7-505

Guideline

None

Scale of Analysis

The characterization of air resources in this assessment is generally oriented towards air mass conditions above the Rio Grande National Forest but those conditions are affected by activities within the geographic region (airshed) and beyond (regional and global). In other words, air and various air-borne emissions are not constrained by surface area boundaries.

Airsheds

An airshed is a geographical area where local topography and meteorology limit the dispersion of pollutants away from the area. They are typically identified as a geographic boundary for air quality assessments. Airsheds can be affected by air pollution emission sources, which are categorized as stationary (point) and area/mobile. Stationary emissions are sources authorized by permit and emit pollution through an identifiable stack. Area/mobile sources are emissions from a number of locations too

small, numerous, or difficult to be inventoried individually. They generally extend over a large area and can include vehicle emissions, natural gas wells, and certain commercial operations such as dry cleaners. Fire and windblown dust are often considered area sources as well.

The Rio Grande National Forest is in the Canon City airshed (Forest Service 1993), a large geographical area in south-central Colorado. The Continental Divide runs along the western side of this airshed. The two highest peaks in the lower 48 states, Mount Elbert at 14,433 feet and Mount Massive at 14,421 feet, are located in this airshed. These two peaks are directly north of the Rio Grande National Forest.

The Continental Divide exhibits considerable control over air currents and circulation in the Canon City airshed. From a macro-scale airflow perspective, the prevailing upper-level winds are from the southwest and west (Mast et al 2005). Following the passage of cold fronts, gradient winds shift to a northwest to northerly direction. This condition normally persists for a few days and then changes back to a more southwesterly and westerly flow. Occasionally, gradient wind direction shifts to a more southerly flow. This is particularly common during July and August when summer "monsoon" conditions become established. Most of the precipitation during the summer months is the result of the southerly flow of sub-tropical moisture.

From a more micro-scale airflow perspective there is one sub-airshed within the Canon City macro-scale airshed of importance to the Rio Grande National Forest. Hereafter, this sub-airshed is described as the San Luis Valley sub-airshed. This sub-airshed is bounded by the Continental Divide within the San Juan Mountains to the west, Poncha Pass to the north, the Sangre de Cristo Mountains to the east, and, generally speaking, the San Luis Hills and Taos Plateau to the south. The highest peak along the Continental Divide is Rio Grande Pyramid at 13,821 feet. The highest peak in the Sangre de Cristo Mountains is Blanco Peak at 14,345 feet. Poncha Pass is at 9,010 feet. This sub-airshed is approximately 100 miles long and 60 miles wide. This sub-airshed is approximately equal to Colorado’s San Luis Valley Monitoring Area, a multi-county area delineated by the Air Pollution Control Division based on topography and similar airshed characteristics (Colorado 2014a). However, the western portion of the Forest is in the Central Mountains Region Monitoring Area.

From a micro-scale airflow perspective, winds vary seasonally (Binkley et al date unknown). Winter and spring winds are primarily from the southwest. Summer winds are primarily from the southwest and east. Fall winds are from all directions except north.

There are two Class I areas on the Forest within this sub-airshed: the Weminuche and La Garita Wilderness Areas. There are two Class II wilderness areas within this sub-airshed: South San Juan and Sangre de Cristo Wilderness Areas. All non-wilderness areas with the Rio Grande National Forest are also considered Class II areas. Additionally, Great Sand Dunes National Park, a Class I area directly adjacent to the Rio Grande National Forest at the southern end of the Sangre de Cristo Mountains, is within this sub-airshed.

All Colorado communities are currently in attainment of all National Ambient Air Quality Standards (NAAQS), with the exception of the Front Range ozone control area, i.e., Denver-Boulder-Greeley-Ft. Collins-Loveland, which is in non-attainment for the 8-hour ozone standard. In the past there were several communities across the State in non-attainment for violation of one or more of the federal clean air standards (CDPHE 2014a and 2014b). Implementation plans have since been developed for these communities. These plans show how these communities have attained and will maintain compliance with the standards. The closest downwind community to the Rio Grande National Forest under one of the maintenance plans is Pagosa Springs for particulate matter (PM_{10}). Details can be found at https://www.colorado.gov/pacific/cdphe/state-implementation-plans-sips. The Forest Service works closely with the State of Colorado to ensure compliance with NAAQS.

Air Quality

There is an abundance of current and historical data related to air quality in or near the Rio Grande National Forest. Knowledge of the data and any relevant trends provides an understanding of the air quality parameters that influence air quality on the forest that could affect resources impacted by air pollution. Included are general descriptions of baseline emissions inventories, ambient air quality measurements, visibility, and deposition measurements that define current air quality conditions of the plan area.

Existing and Potential Sources and Inventories

Air quality effects on national forests are generally traceable back to the original source of emissions. Therefore, air emission information provides an overview of the magnitude of air pollution and is important in understanding air quality on the forest. Also, trends in precursor emissions would be expected to track with trends on the forest, e.g., visibility, acid deposition. For example, improving visibility conditions in Class I areas would generally be associated with corresponding decreases in emissions for visibility precursor pollutants.

Emissions information is generally tracked for pollutants that have health-based air quality standards such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), volatile organic compounds (VOCs), and particulate matter (PM). VOC emissions do not have a health-based standard, but are involved in the atmospheric chemical reactions that lead to ozone (O_3), which does. Ozone pollution is of added concern because it can stress sensitive ecological systems. PM emissions are generally broken into two categories based on the size of the emissions. Fine PM represents the particulate matter sized at or below 2.5 microns in diameter. Course PM represents the particulate matter sized at or below 10 microns but above 2.5 microns, in diameter. Smaller sized particles have greater health-related impacts because the smaller particles are more easily inhaled into the lungs.

Stationary Sources

Stationary sources of pollution include facilities such as those used for energy production, mining and milling operations, gravel and cement plants, and ski areas. Areas directly affected by these facilities are typically confined to a radius of tens of kilometers downwind of the facility. The dimensions of the downwind zones of influence are variable, and are primarily controlled by the strength of the effluent at its source, local meteorology, and regional topography. Large stationary sources, typically facilities that produce more than 100 tons/year, can impact national forest areas in excess of 300 km downwind by contributing to pollutant haze layers.

The Colorado Department of Public Health and Environment, Air Pollution Control Division website at http://www.colorado.gov/airquality/ss_map_wm.aspx was queried for stationary sources of air pollution within a 100 kilometer (62 mile) radius (the upper distance limit of the query) of Monte Vista, Colorado, which serves as a good centroid for the Rio Grande National Forest and its associated sub-airshed. Priority pollutants carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter < 10 microns (PM_{10}) and particular matter < 2.5 microns ($PM_{2.5}$), as well as non-priority pollutant volatile organic compounds (VOC), were queried (Figure 1 through Figure 6).

The major stationary sources of CO, $NO_{x,}$ and SO_2 are in the central part of the San Luis Valley. The major stationary sources of PM10, PM2.5, and VOC are in the central, north-central, south-central, and south-eastern parts of the Valley. Facility names and emission quantities are available at the CDPHE website.

In addition to the State of Colorado inventory, the Environmental Protection Agency 2011 National Emissions Inventory at http://www.epa.gov/ttn/chief/net/2011inventory.html was queried for emissions in the dominant upwind directions pertinent to the Rio Grande National Forest. This query allowed for assessment of stationary source emissions that extend beyond the 62 mile limit of the State of Colorado query. Upwind areas that contain facilities that could potentially affect air quality in the Forest include a large area south of Durango, Colorado and east of Farmington, New Mexico, and a concentrated area around Spanish Peaks west of Trinidad, Colorado. Facilities in these areas are associated primarily with energy use and development. Other potential sources include areas around and south/southeast of Phoenix, Arizona and the Los Angeles metropolitan area in California.

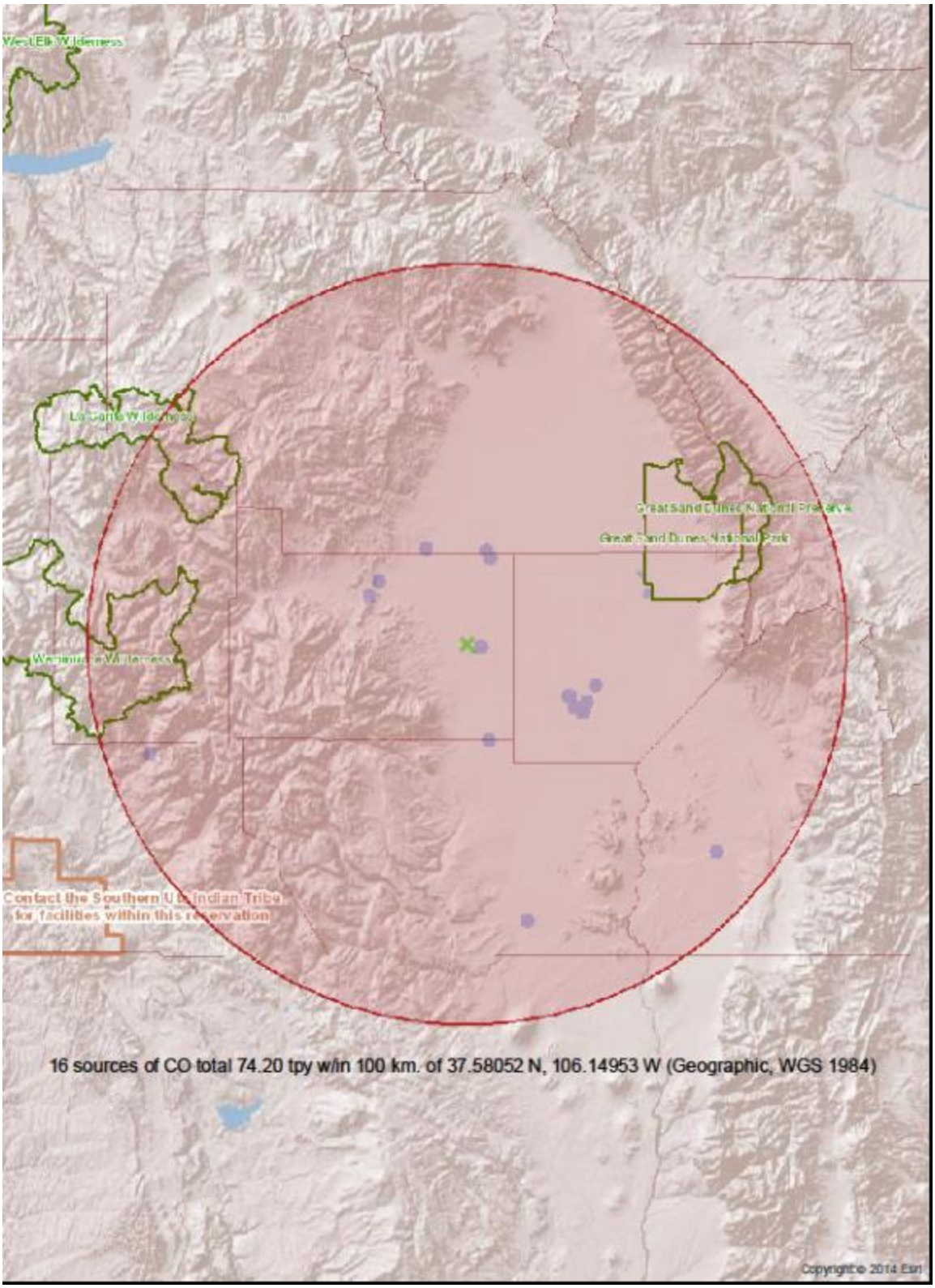

Figure 1. Sources of carbon monoxide (CO) within 100 kilometers (62 miles) of Monte Vista, Colorado.

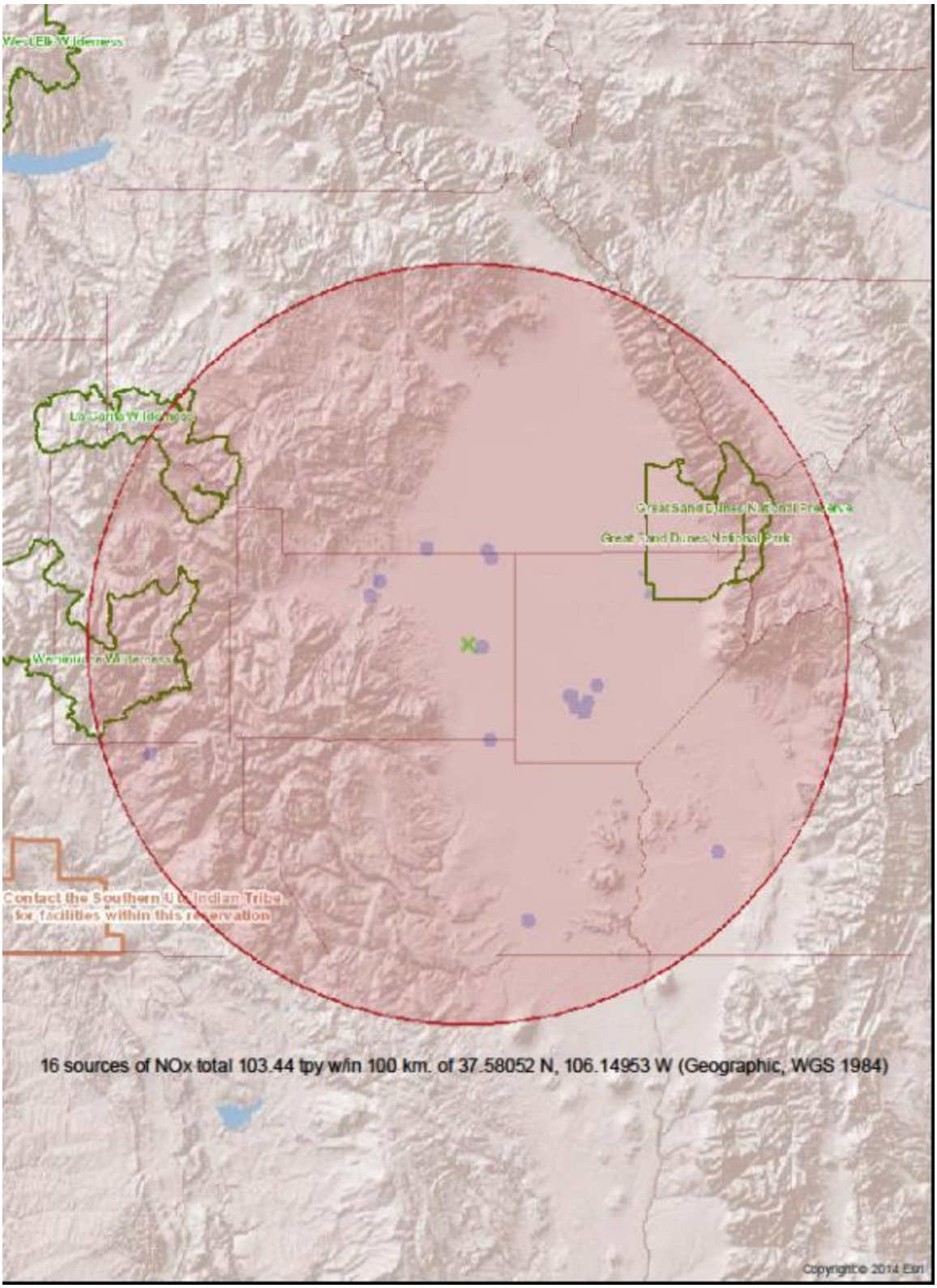

Figure 2. Sources of nitrous oxides (NO_x) within 100 kilometers (62 miles) of Monte Vista, Colorado.

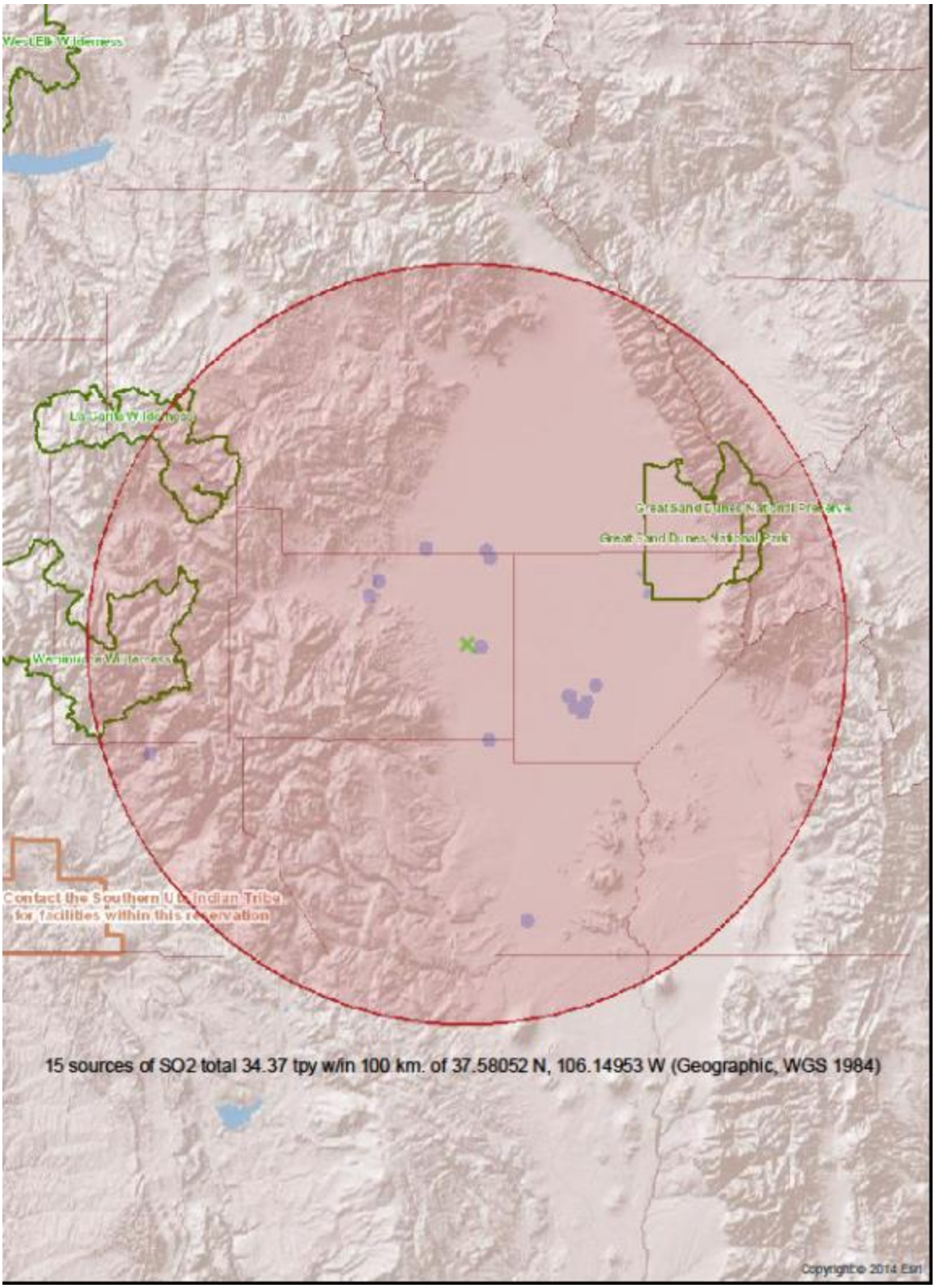

Figure 3. Sources of sulfur dioxide (SO_2) within 100 kilometers (62 miles) of Monte Vista, Colorado.

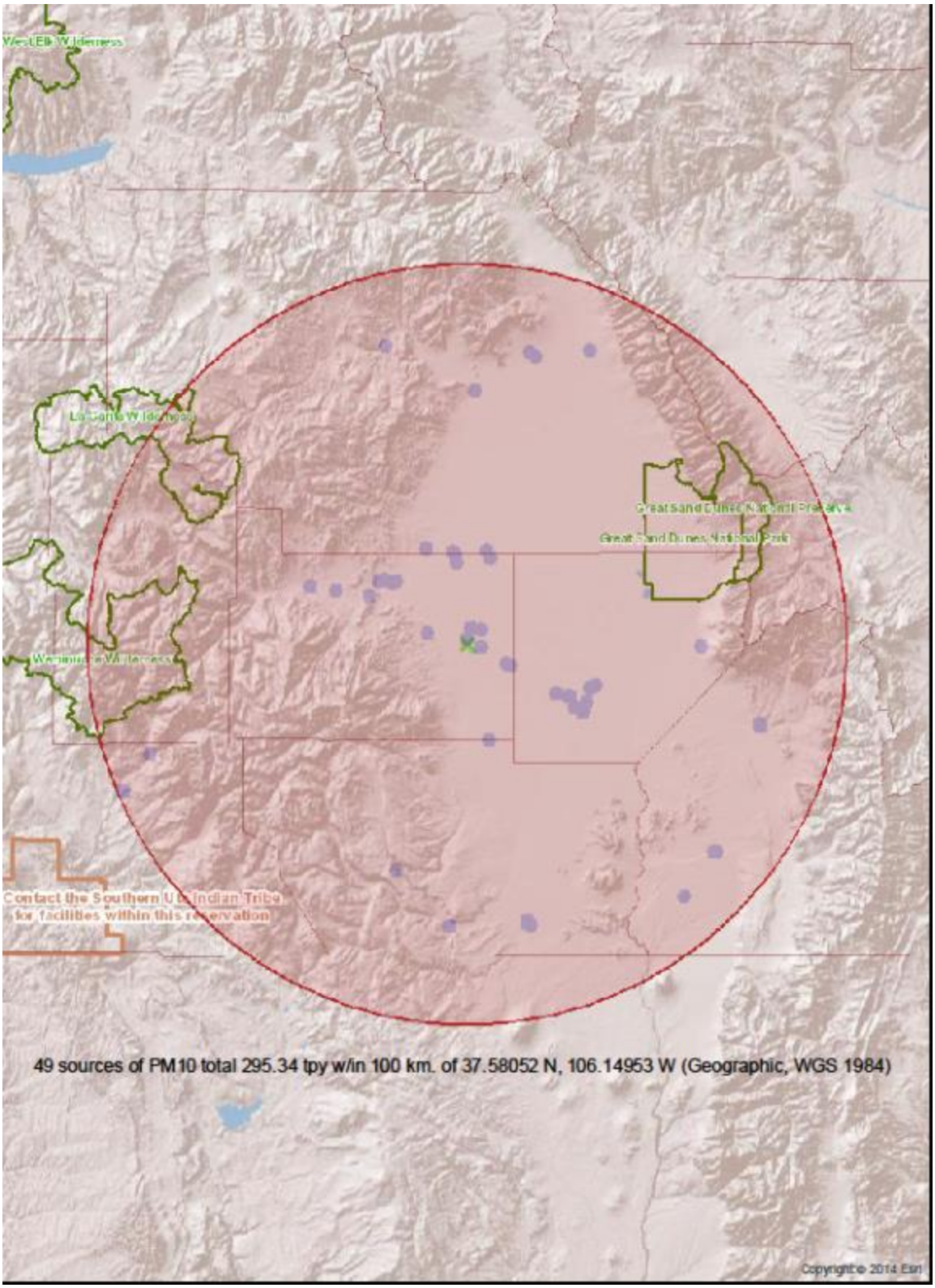

Figure 4. Sources of course particulate matter (PM10) within 100 kilometers (62 miles) of Monte Vista, Colorado.

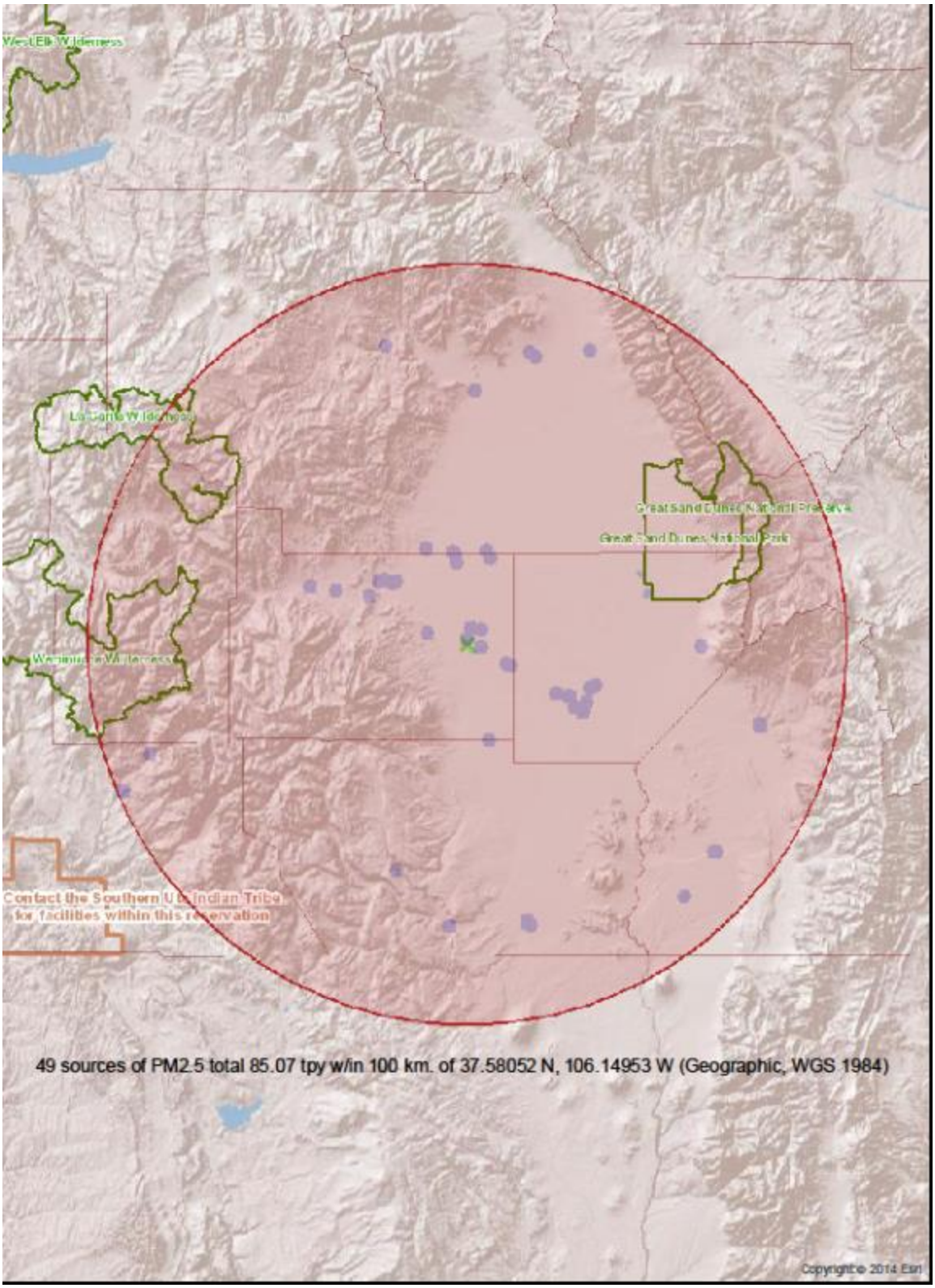

Figure 5. Sources of fine particulate matter (PM2.5) within 100 kilometers (62 miles) of Monte Vista, Colorado.

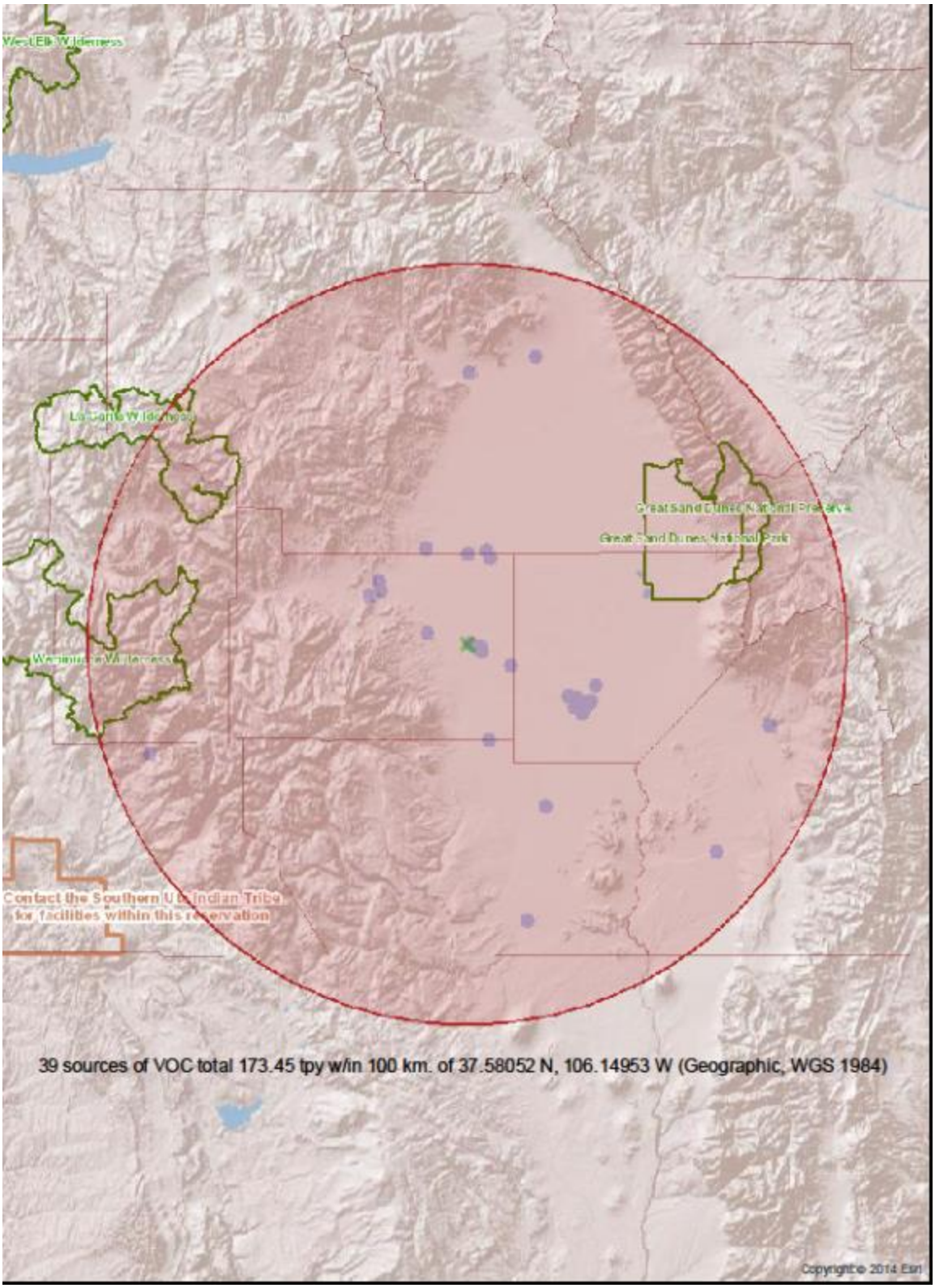

Figure 6. Sources of volatile organic compounds (VOC) within 100 kilometers (62 miles) of Monte Vista, Colorado.

Area and Mobile Sources

Area and mobile sources of pollution include, among other things, automobiles, agricultural activities, planes, trains, residential wood burning, lawn mowers, and barbeques. Smoke from wild and prescribed fires, as well as wind-blown dust, are also considered area sources. While stationary sources were the initial focus of the Clean Air Act, pollutants from regional-scale area sources are more likely to affect national forest areas. Global emissions of carbon dioxide and other greenhouse gases are increasing in concentration, and very likely causing dramatic changes in climate. The effects from a changing climate may result in the greatest anthropogenic changes to national forest areas.

The Colorado Department of Public Health and Environment, Air Pollution Control Division website at http://www.colorado.gov/airquality/inv_maps.aspx was queried for area/mobile sources of pollution in the vicinity of the two wilderness areas (Table 1). The queries are done by county. The Rio Grande National Forest lies within ten Colorado counties: Alamosa, Conejos, Costilla, Mineral, Rio Grande, Saguache, Hinsdale, Custer, San Juan, and Archuleta.

Primary sources for CO include wood burning, vehicles and non-road engines; for NOx vehicles, non-road engines, oil/gas, and railroads; for SO2 wood burning, combustion, vehicles, oil/gas, and non-road engines; for PM wood burning, road dust, agriculture tilling, and construction; and for VOC pesticides, wood burning, non-road engines, and vehicles.

Wildfire and Prescribed-fire Smoke, and Dust

Wildfire smoke, particularly from large fires, is a vivid air quality impact to the Forest on a seasonal basis. Prescribed fire is the predominant emission-producing management activity practiced by the Forest Service. Emissions from fire (wildland and prescribed) are an important episodic contributor to visibility-impairing aerosols, including organic carbon, elemental carbon, and particulate matter. Wildfire impacts are increasingly difficult to manage due to excessive fuel loads, history of fire exclusion, increased urban interface, and climate change (drought and increasing temperatures). Prescribed fire and fuel treatment projects include mastication, thinning, broadcast burns (area burns designed to reduce fuels in a contiguous area over a landscape) and pile burns (discrete piles of slash from timber harvest and/or thinning from fuel treatment projects). These treatment techniques are designed to reduce the size, frequency, and intensity of wildland fires and improve fire control, increase predictability of fire effects, and allow for smoke emissions management.

Dust generated by winds blowing across the San Luis Valley is also an apparent air quality impact to the Forest, particularly the part of the Forest in the Sangre de Cristo Mountains. Dust generated in the southwestern U.S. and at a global scale also impacts the Forest, most apparent as a dark covering of the snowpack as it melts in the spring.

Potential Future Sources

A potential future source of emissions that could impact the Forest is energy development in southwest Colorado and northwest New Mexico. The adjacent San Juan National Forest tracks this potential source for possible effects on the Weminuche Wilderness Area. This tracking will be useful to the Rio Grande National Forest in the future.

Table 1. Area and mobile sources of pollutants near the Rio Grande National Forest. All values are in tons/year (T/Y).

County	CO	NOx	SOx	PM10	VOC
Saguache	2646	339	4	1879	3125
Mineral	2615	222	1	201	975
Conejos	2917	354	5	975	734
Rio Grande	4721	539	6	1175	4305
Hinsdale	2325	67	2	640	944
San Juan	2580	76	4	169	1103
Alamosa	3832	555	36	1218	3047
Archuleta	4661	459	5	1130	830
Custer	2120	145	2	718	460
Costilla	2016	237	3	1606	845
Total	30433	2993	68	9711	16368

Air Resource Monitoring

Visibility

IMPROVE

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program was established in 1985 to assist in the management of visibility in Class I areas. Four objectives were identified:

- Establish current visibility and aerosol conditions in mandatory Class I areas
- Identify chemical species and emission sources responsible for existing man-made visibility impairment
- Document long-term trends for assessing progress towards the national visibility goal
- Provide regional haze monitoring as part of the enactment of the Regional Haze Rule

There are three IMPROVE monitors representative of the Rio Grande National Forest: Site GRSA1 located in Great Sand Dunes National Park and sites WEMI1 and SHMI1 located on the San Juan National Forest. GRSA1 and WEMI1 were installed in 1988. SHMN1 was installed in 2004. Increased levels of aerosols are common and likely related to wind driven dust events and wildfire smoke (Figure 7). These spikes affect visibility, particularly at Great Sand Dunes National Park. The visibility effects at the Park are likely being observed in portions of the Sangre de Cristo Wilderness as well.

Haze index data indicate visibility on the clearest days is on an upward trend, i.e., visibility improvement, at both Great Sands Dunes and Weminuche, with no apparent trend on the haziest days (Figure 8 through Figure 10). The period of record at Shamrock is too short to assess trend.

Extinction trends on the best visibility days at Great Sand Dunes and Weminuche indicate apparent upward, i.e., visibility improvement, trend with organic mass, course mass, and ammonium sulfate (Figure 11 through Figure 13). Elemental carbon is on an apparent upward trend on the best visibility days at Weminuche, while there is no apparent trend on the best visibility days with elemental carbon at Great Sand Dunes. There is no apparent trend on the best visibility days with ammonium nitrate, soil, or sea salt at either of these two locations. The period of record at Shamrock is too short to assess trend.

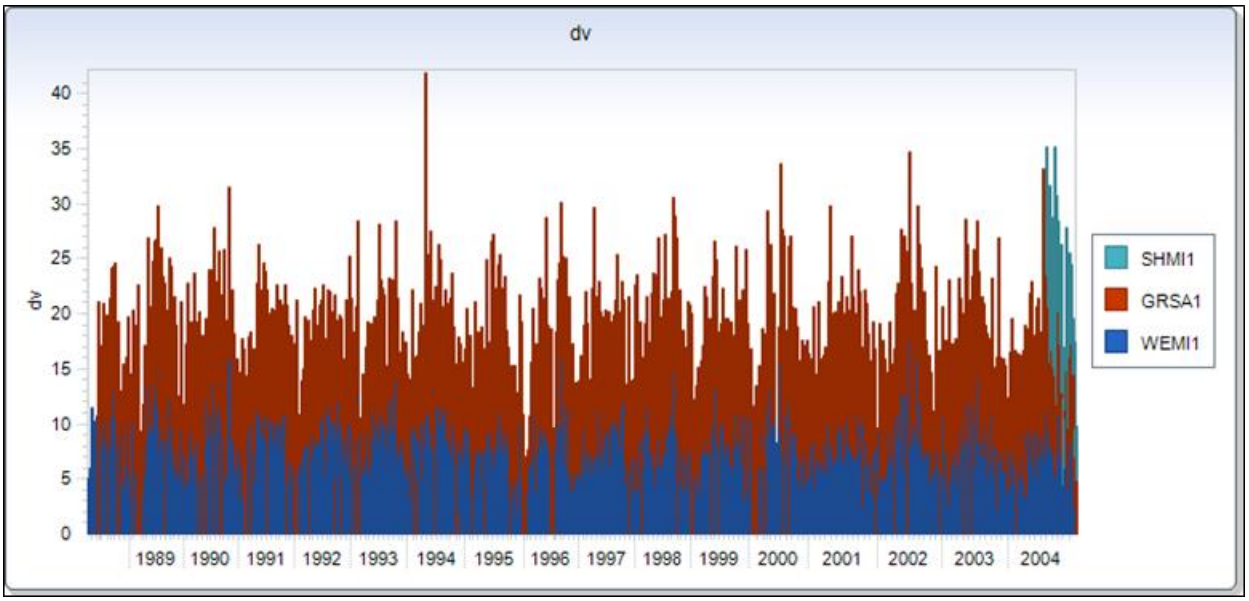

Figure 7. Visibility (deciviews) at Shamrock Mine (SHM1), Great Sand Dunes National Park (GRSA1), and Weminuche (WEMI1). Data is available through 2013 but a glitch in the website plot function prevents display of these data.

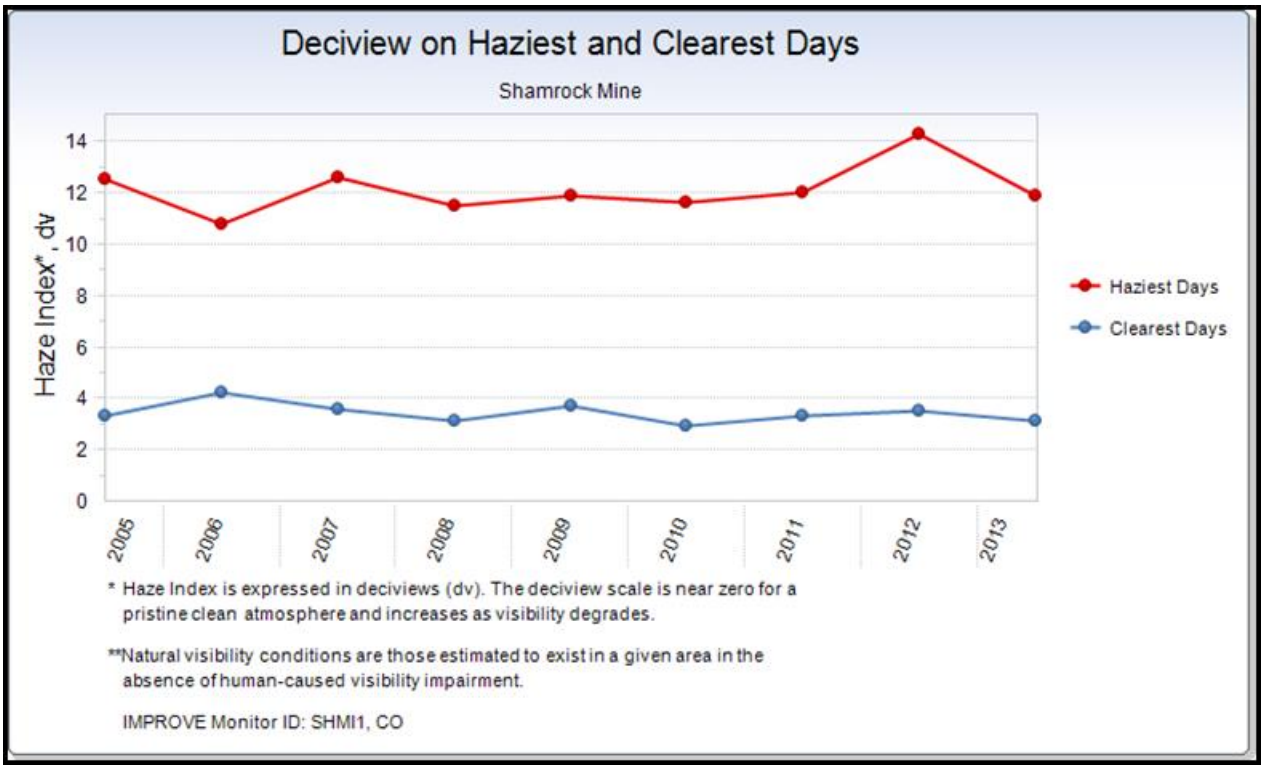

Figure 8. Haze index (deciviews) at Shamrock Mine (SHM1)

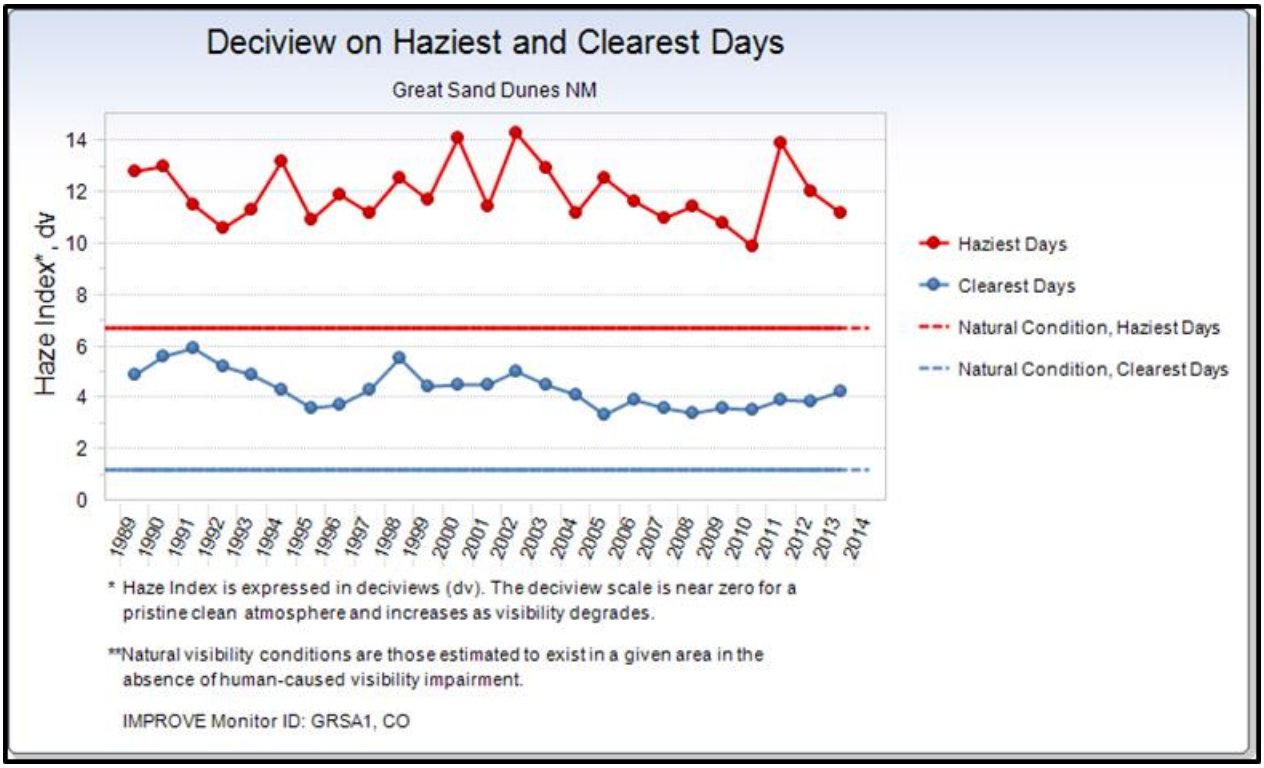

Figure 9. Haze index (deciviews) at Great Sand Dunes National Park (GRSA1)

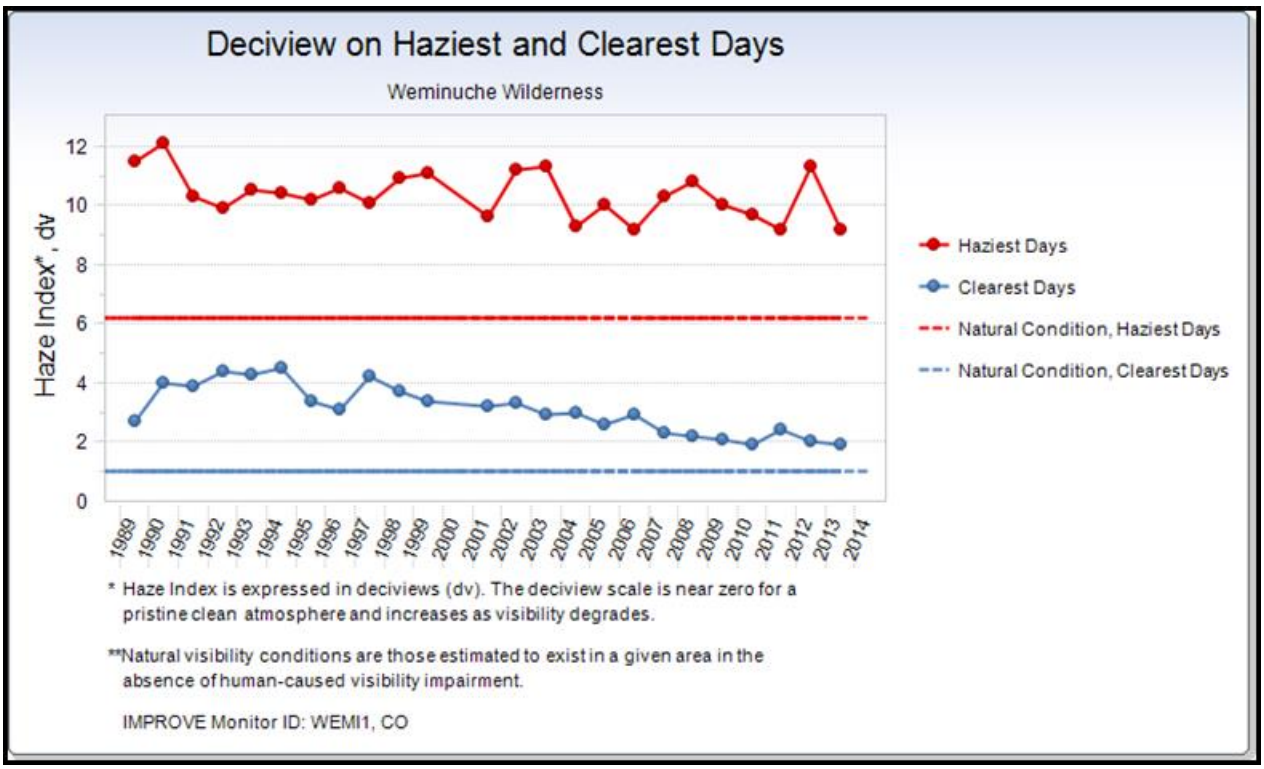

Figure 10. Haze index (deciviews) at Weminuche (WEMI1)

Extinction trends on the worst visibility days at Great Sand Dunes and Weminuche indicate apparent upward, i.e., visibility improvement, trend with ammonium sulfate, but downward, i.e., visibility

reduction, trend with organic mass (Figure 14through Figure 16). There is no apparent trend on the worst visibility days with the other aerosol constituents at either of these two locations. The period of record at Shamrock is too short to assess trend.

Colorado Scenic and Important Views

The Colorado Air Pollution Control Division (CAPCD) maintains a database of "scenic and important views" in Class II areas. This database is used by the Division to determine if there are any sensitive Class II views that might trigger their visibility "additional impact analysis" requirements under the PSD rules. Knowledge of these sites is not necessarily useful to Forest Plan Revision, but knowing they exist is important to Forest Plan implementation as the Forest works with the State on PSD permits. At that time, CAPCD can be contacted for the most current list of sites in their database.

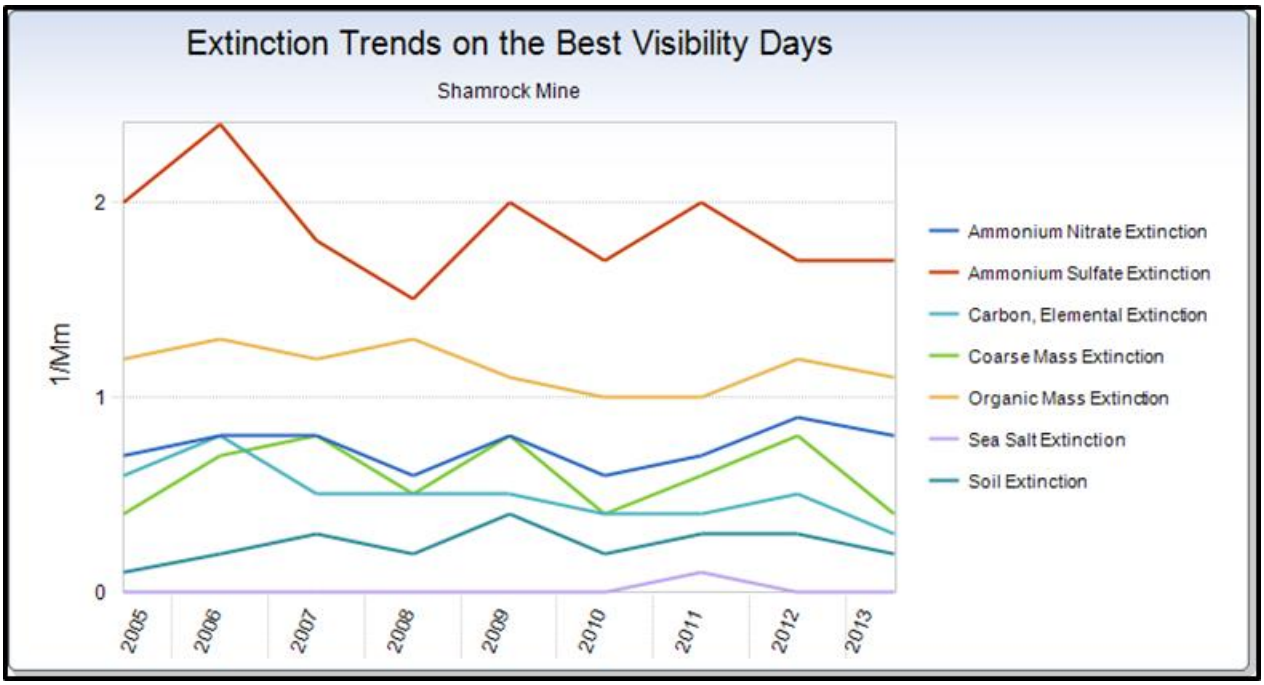

Figure 11. Extinction trends on the best visibility days at Shamrock Mine (SHMN1).

Wilderness Lake Monitoring

Lake sampling in or around the Rio Grande National Forest has been conducted by various entities over the last three decades, i.e., since the mid-1980s. This sampling was and still is designed to characterize wilderness lake chemistry and sensitivity to acidic deposition. Some of these data is synoptic while some identify current conditions and trends of acid deposition in wilderness lakes. Data may be reported as acid neutralizing capacity (ANC) or alkalinity. Lakes are generally considered sensitive to atmospheric induced acid deposition change if ANC is less than 50 µeq/L and highly sensitive if ANC is less than 25 µeq/L. Lakes are considered highly sensitive if alkalinity is less than 10 mg/l, moderately sensitive if alkalinity is between 10 and 20 mg/l, and non-sensitive if alkalinity is over 20 mg/l.

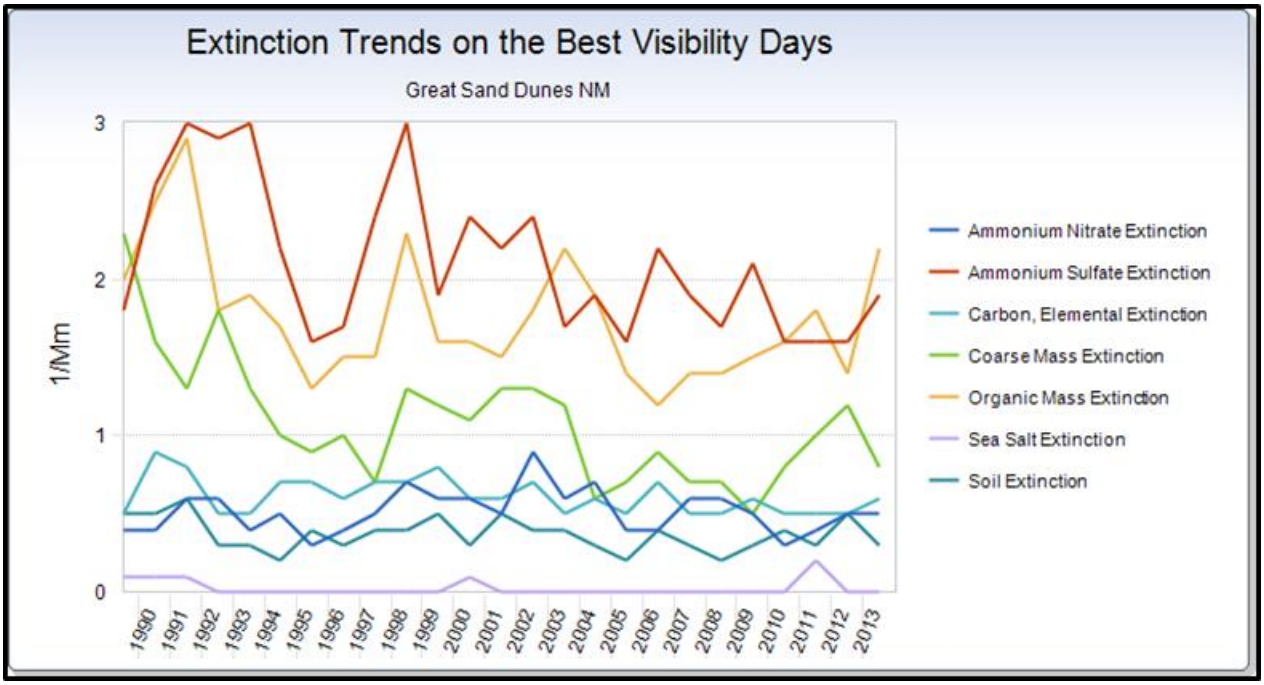

Figure 12. Extinction trends on the best visibility days at Great Sand Dunes National Park (GRSA1).

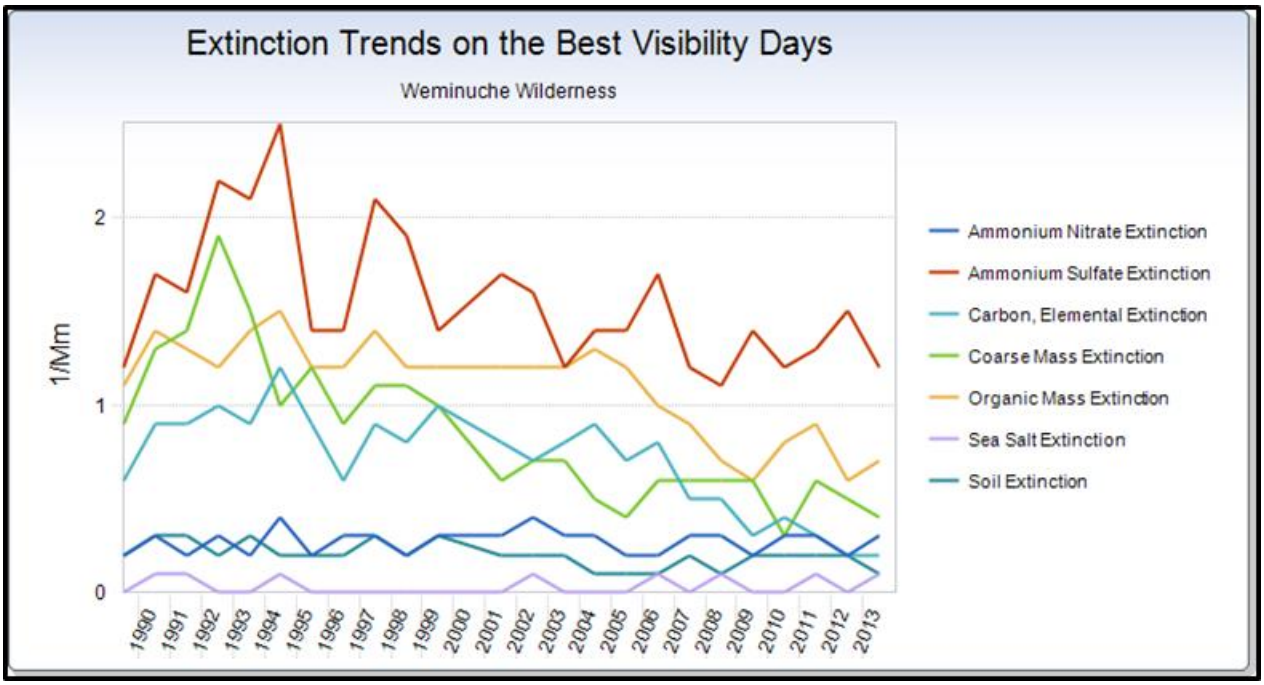

Figure 13. Extinction trends on the best visibility days at Weminuche (WEMI1).

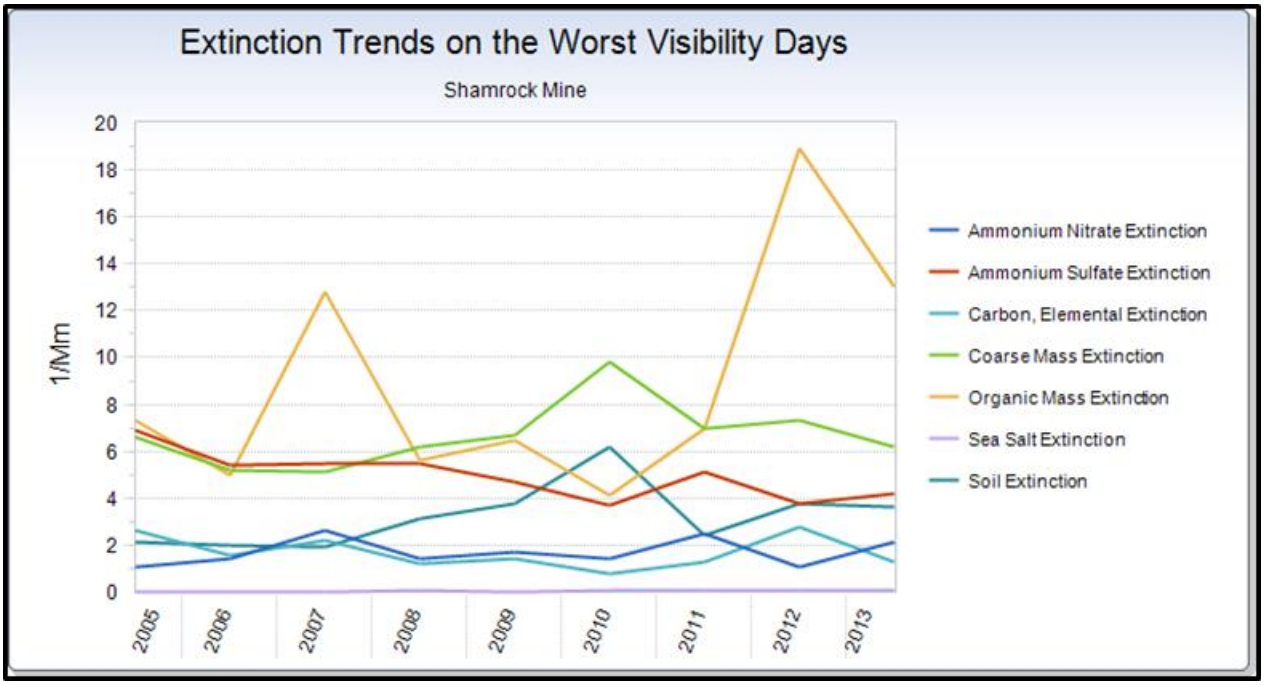

Figure 14. Extinction trends on the worst visibility days at Shamrock Mine (SHMN1).

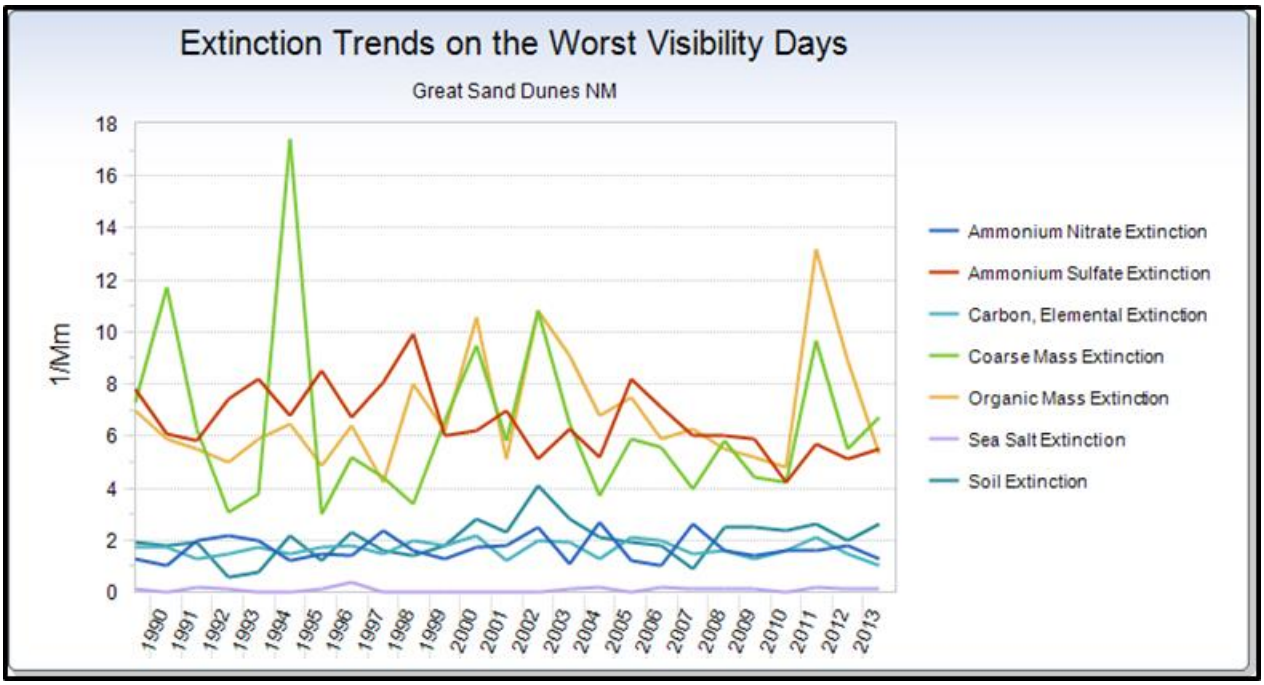

Figure 15. Extinction trends on the worst visibility days at Great Sand Dunes National Park (GRSA1).

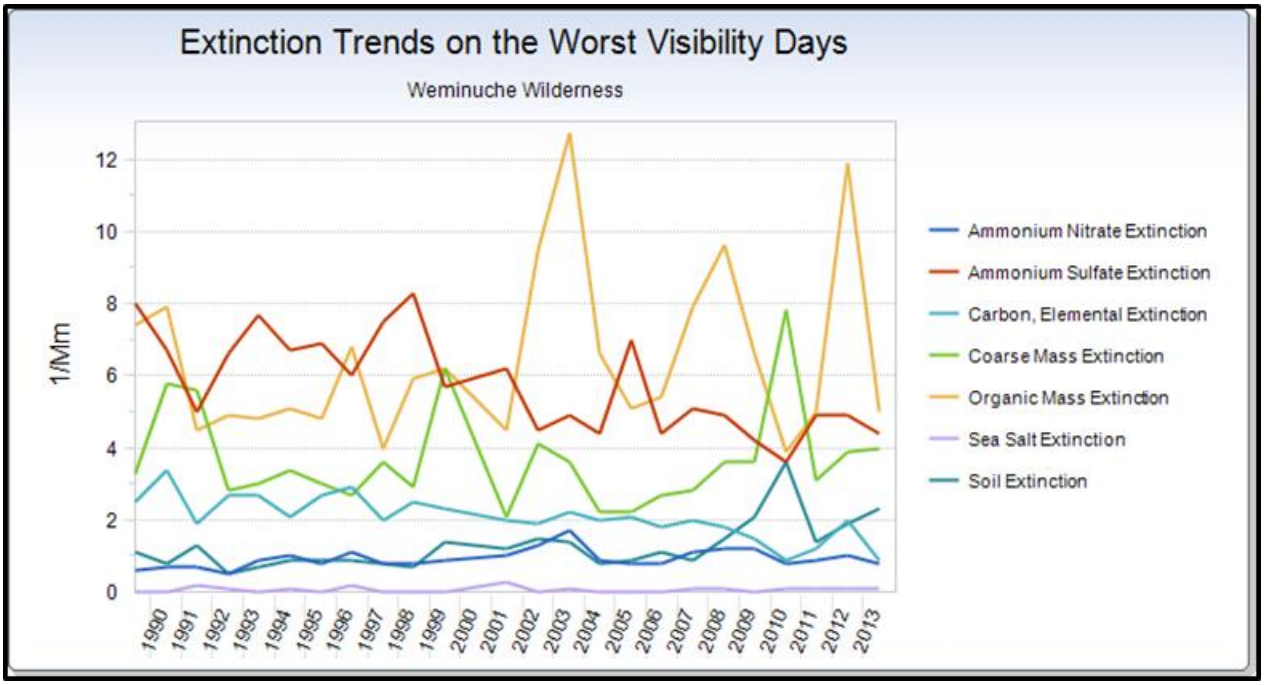

Figure 16. Extinction trends on the worst visibility days at Weminuche (WEMI1).

EPA Western Lakes Survey

In 1985, the Environmental Protection Agency (EPA) conducted a nationwide study of acid deposition. The Western Lakes Survey (WLS) was a one-time stratified sampling effort designed to provide large scale regional information about lake chemistry throughout the United States (Eilers et al 1987 and Landers et al 1987). Three lakes on the Rio Grande National Forest were sampled: Pioneer Lake, Willow Crk Lks (SE), and Lost Lakes (North). The first two lakes are in the Sangre de Cristo Mountains. The third lake is in the San Juan Mountains. These historical data did not give detailed information about the processes occurring over time in any one lake but did provide some indication of the buffering abilities of the sampled lakes. Acid neutralizing capacity (ANC in ueq/l) for the three lakes was 441, 422, and 556, respectively, suggesting considerable buffering capacity.

Rio Grande National Forest Lake Monitoring

Selected wilderness high lake monitoring has occurred on the Rio Grande National Forest since 1992. Synoptic surveys of 32 lakes in the Weminuche, 16 lakes in the South San Juan, and 6 lakes in the La Garita wilderness areas were conducted in 1992. In 1993, annual monitoring began on 8 lakes in the Weminuche, 2 lakes in the South San Juan, and 2 lakes in the La Garita. In 1994, three of the Weminuche lakes were dropped from the monitoring effort.

In 1995 synoptic surveys were conducted on numerous lakes in the Sangre de Cristo wilderness. Crater Lake and Upper Little Sand Creek Lake were then selected for long-term monitoring, which began in 1996. Upper Little Sand Creek Lake is now part of Great Sand Dunes National Park.

ANCs for the above mentioned lakes indicate waterbodies in the Weminuche and South San Juan wilderness areas are sensitive to atmospheric deposition, while waterbodies in the La Garita and Sangre de Cristo wilderness areas are not.

San Juan, GMUG, and PSI Lake Monitoring

The surrounding San Juan, GMUG, and Pike/San Isabel National Forests also monitor high elevation lakes in the Weminuche, South San Juan, La Garita, and Sangre de Cristo wilderness areas. The Rocky Mountain Regional Office, in cooperation with these Forests and the Rio Grande National Forest, is in the process of analyzing the entire high elevation lakes water chemistry dataset for trend. This analysis may or may not be available for the Plan revision effort. If it becomes available the Forest should utilize it as part of the plan revision effort, as well as for general air program management.

Snowpack Chemistry Monitoring

The U. S. Geological Survey (USGS) conducts annual snow chemistry surveys along the Rocky Mountain range from New Mexico through Montana. Annual snow packs accumulate atmospheric deposition such as nitrates and sulfates throughout the winter and offer opportunity to collect composite samples of the majority of annual precipitation. The survey network was initiated to determine annual concentrations and deposition of selected nutrients and other constituents collected in snowpack samples, assess trends, and support investigations of the effects of atmospheric deposition at local and regional levels. Detailed information about this monitoring program can be found at http://co.water.usgs.gov/projects/RM_snowpack/.

There are eight monitoring sites in close proximity to the Rio Grande National Forest potentially useful for atmospheric deposition monitoring: Hopewell, Molas Lake, Monarch Pass, Music Pass, Red Mountain Pass, Slumguillion Pass, Taos Ski Valley, and Wolf Creek Pass. A map showing the locations of these sites is available at the above mentioned website.

Site Data and Comparisons

Data are collected for seventeen metrics at each of these three sites. Each site is sampled once per year in late March to early April, which corresponds to the time when annual snow packs are near their maxima. For this assessment, ammonium (NH_4), nitrate (NO_3), sulfate (SO_4) and mercury (Hg) concentrations were visually evaluated for trend. The period of record varies by site and constituent. Deposition data for these four constituents were not evaluated as a part of this assessment due to concerns with snow water equivalent data (some data are measured while some are estimated) needed to convert concentrations to deposition.

Apparent concentration trend varies by site and metric (Figure 17 to Figure 20and Table 2). Generally speaking, there is no apparent trend with NO_3. SO_4 is on an apparent downward trend. NH_4 and Hg apparent trend varies from none to upward depending upon the site. The Forest should conduct statistical analysis on these data similar to the analysis done for the Mount Massive and Buffalo Peaks Wilderness Areas on the Pike and San Isabel National Forest (Forest Service 2014).

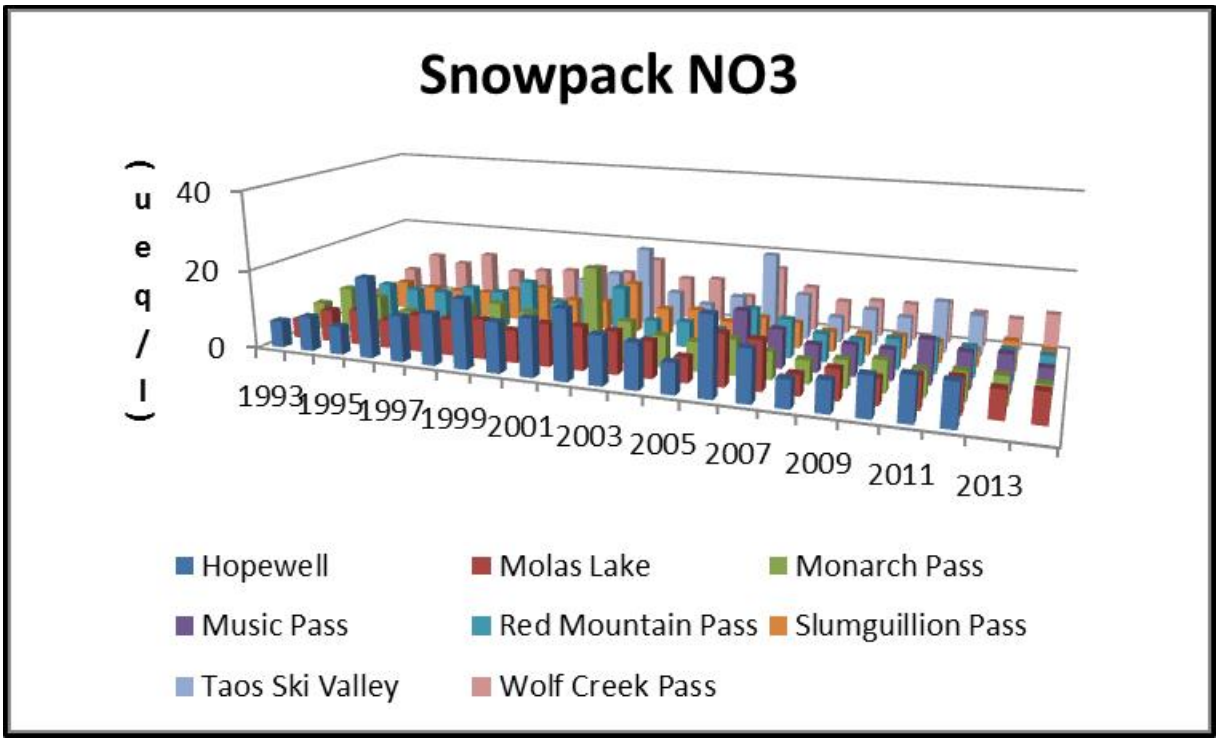

Figure 17. Annual snowpack nitrate concentration at eight locations in and around the Rio Grande National Forest.

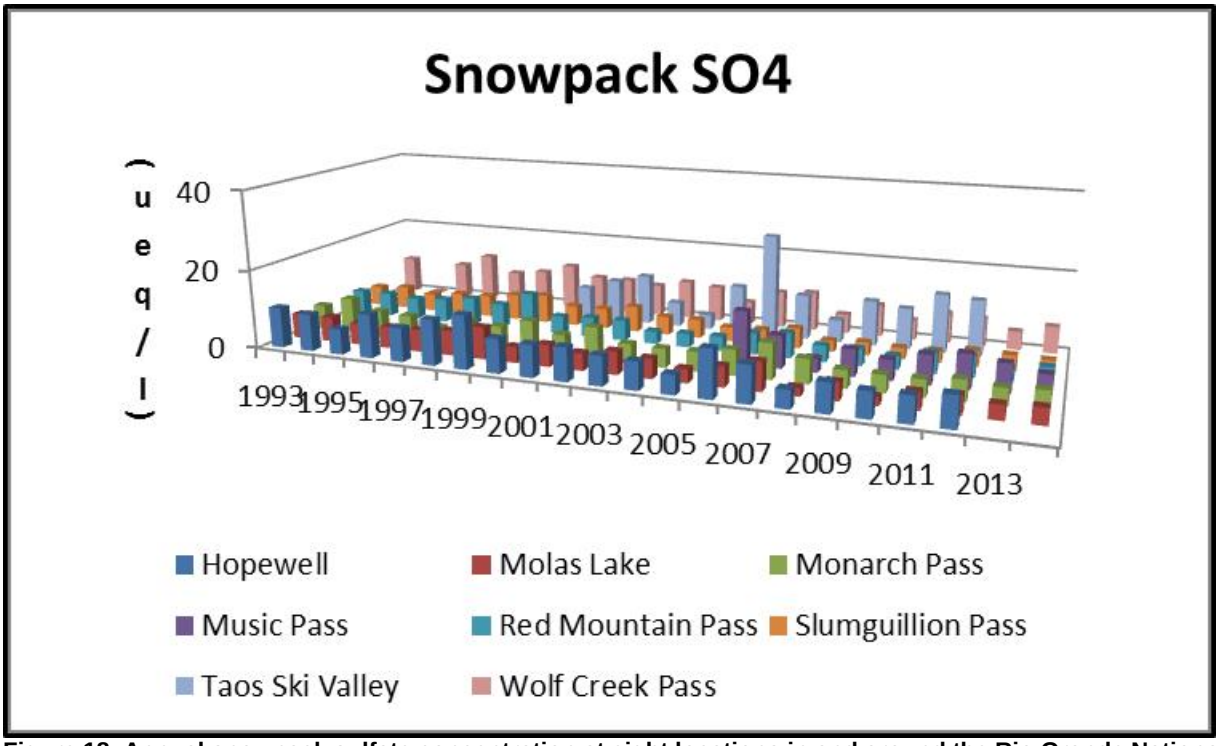

Figure 18. Annual snowpack sulfate concentration at eight locations in and around the Rio Grande National Forest.

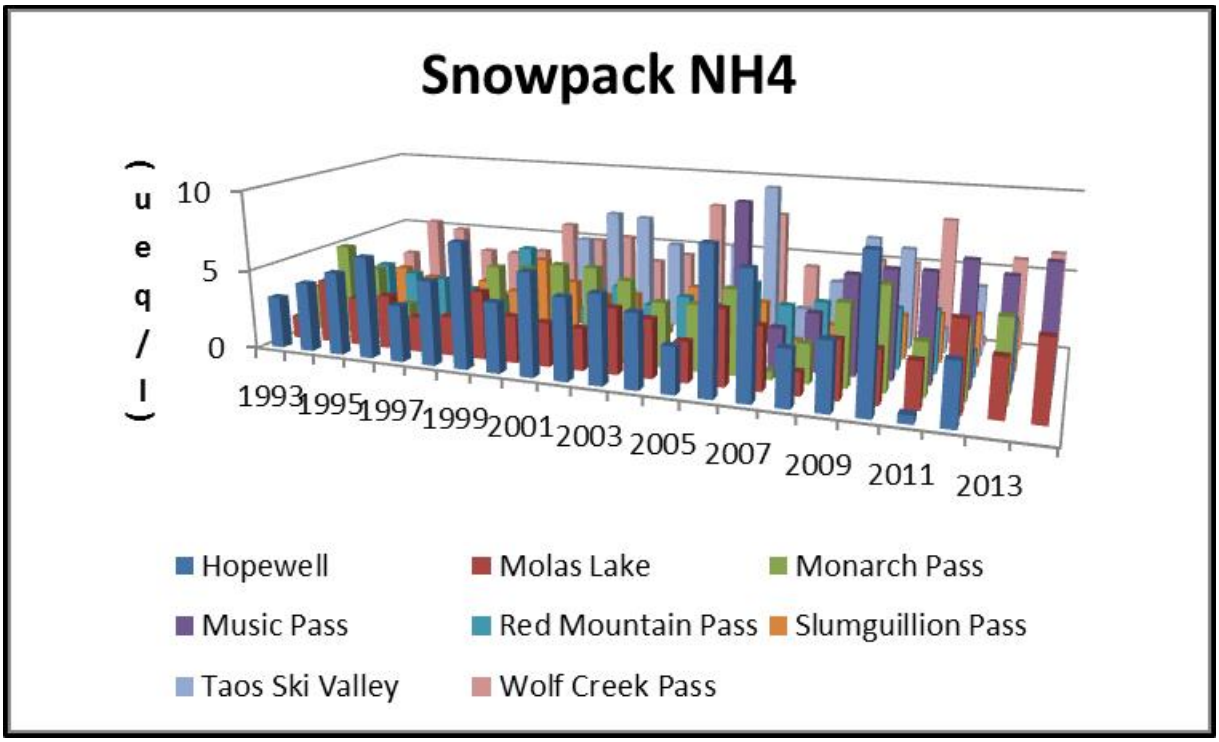

Figure 19. Annual snowpack ammonium concentration at eight locations in and around the Rio Grande National Forest.

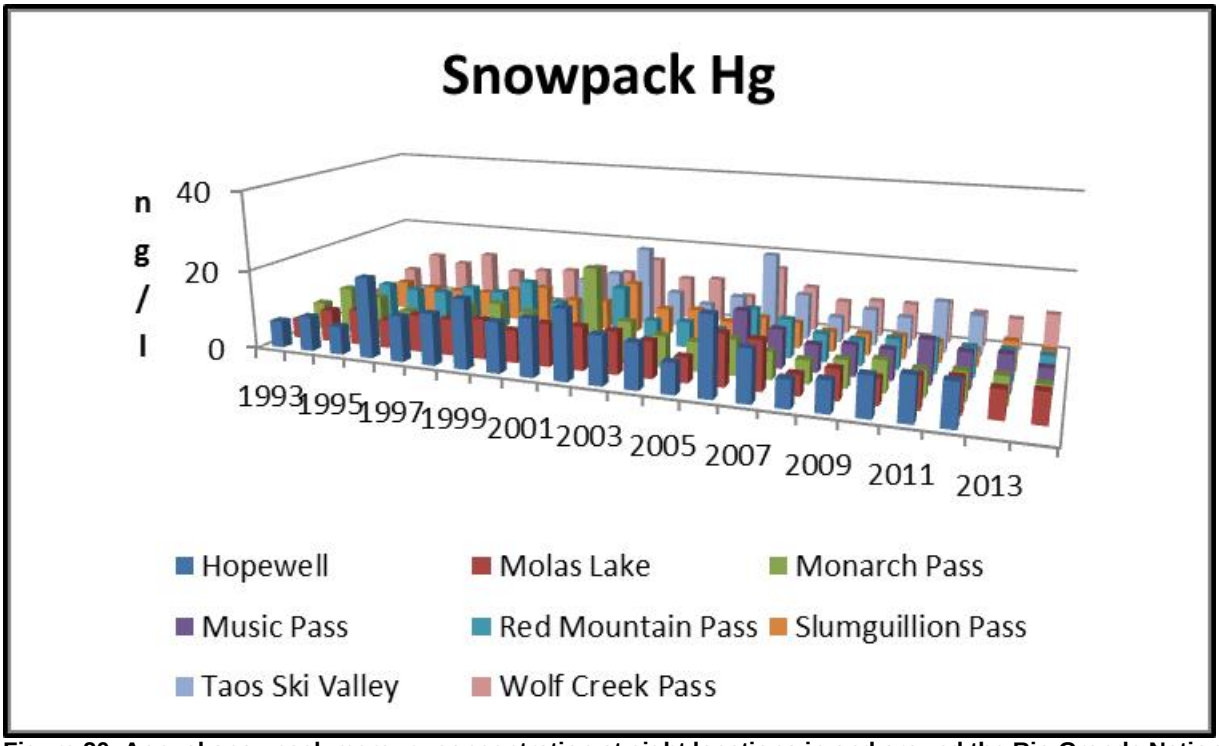

Figure 20. Annual snowpack mercury concentration at eight locations in and around the Rio Grande National Forest.

Table 2. Apparent (visual) trend of nitrate, sulfate, ammonium, and mercury at eight locations in and around the Rio Grande National Forest.

Apparent Concentration Trend								
Site	Hopewell	Molas Lake	Monarch Pass	Music Pass	Red Mountain	Slumguillion Pass	Taos Ski Valley	Wolf Creek Pass
NO_3 (ueq/l)	None	None	None	None	None	None	None	None
SO_4 (ueq/l)	Down	Down	Down	None	Down	Down	Down	Down
NH_4 (ueq/l)	Up	Up	None	Up	None	None	Down	Up
Hg (ng/l)	Up	None	None	None	Up	Up	Up	Up

Atmospheric Deposition Monitoring

National Atmospheric Deposition Program

The National Atmospheric Deposition Program (NADP) is a cooperative monitoring effort between many different groups and agencies. NADP began as a precipitation chemistry network to provide data on the amounts, trends, and geographic distributions of acids, nutrients, and base cations in precipitation. Overtime, the program expanded and now has five components: NADP National Trends Network (NTN), Atmospheric Integrated Research Monitoring Network (AIRMoN), Mercury Deposition Network (MDN), Atmospheric Mercury Network (AMNet), and Ammonia Monitoring Network (AMoN). Data for the NADP program are available at http://nadp.sws.uiuc.edu/.

NTN is the original NADP program. The nearest NTN sites are Alamosa (CO00) established in 1980, Wolf Creek Pass (CO91) established in 1992, and Molas Pass (CO96) established in 1986. AIRMoN is similar to NTN in that the same chemicals are measured but sampling is daily rather than weekly. Currently all AIRMoN sites are in the eastern United States. MDN assesses total mercury and at certain sites methyl mercury. The nearest MDN site is Molas Pass (CO96), established in 2009. AMNet measures atmospheric mercury fractions which contribute to dry and total mercury deposition. The nearest AMNet site is Salt Lake City, UT. AMoN provides a long-term record of ammonia gas concentrations. The nearest AMoN sites are Gothic (CO10) near Crested Butte, Colorado and Navajo Lake (NM98) in north-central New Mexico. Gothic was established in 2012. Navajo was established in 2008. The MDN and AMoN data sets are insufficient for trend analysis as a part of this assessment. Data from these sites may prove useful to managers on the Forest at some point in the future.

NTN concentration and deposition data for NO_3, SO_4, and NH_4 are useful for apparent (visual) trend analysis (Figure 21 through Figure 38 and Table 3 and Table 4). Sulfate concentration and deposition are on an apparent downward trend at all sites. Nitrate concentration and deposition apparent trend varies from downward to none to upward depending upon the site. Ammonia is on an apparent upward trend at all sites. These apparent trends are consistent with trends occurring throughout the western United States. The Forest should conduct statistical analysis on these data similar to the analysis done for the Mount Massive and Buffalo Peaks Wilderness Areas on the Pike and San Isabel National Forest (Forest Service 2014).

Clean Air Status and Trend Network

The Clean Air Status and Trend Network (CASTNet) is a national air quality monitoring network designed to provide data for assessing trends in air quality, atmospheric deposition, and ecological effects due to changes in air pollutant emissions. The program provides long-term monitoring of air quality in rural areas to determine trends in regional atmospheric nitrogen, sulfur, and ozone concentrations and deposition fluxes of sulfur and nitrogen pollutants in order to evaluate the effectiveness of national and

regional air pollution control programs. Detailed information on the program can be found at http://epa.gov/castnet/javaweb/index.html.

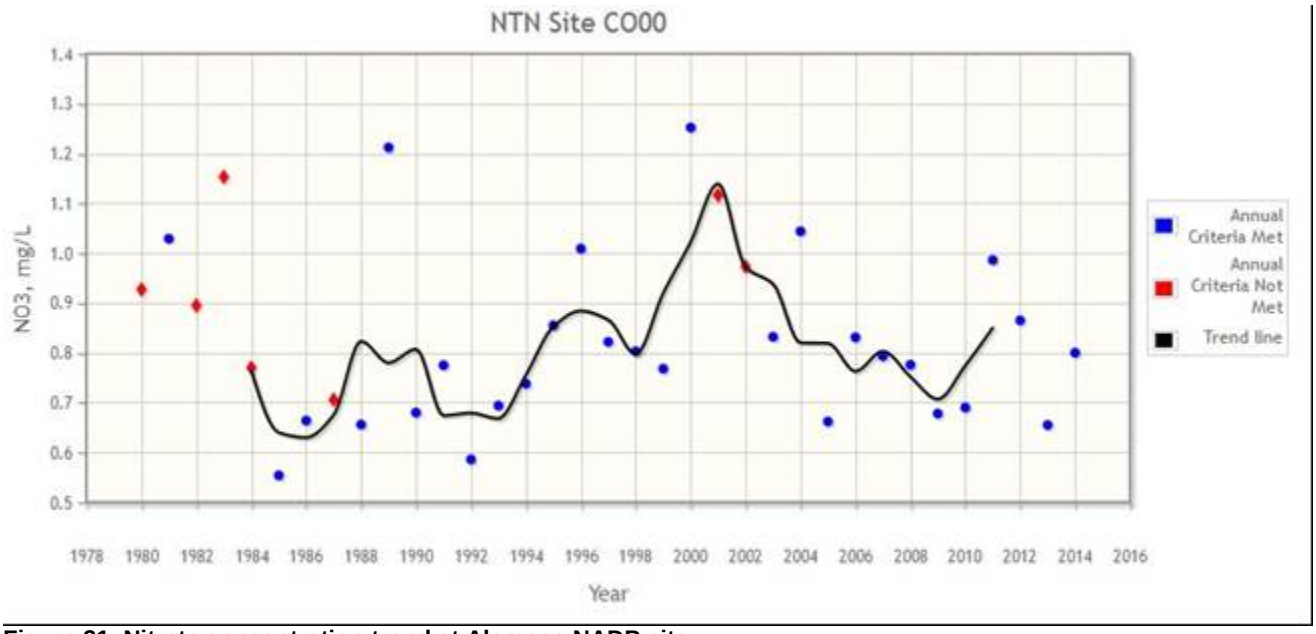

Figure 21. Nitrate concentration trend at Alamosa NADP site.

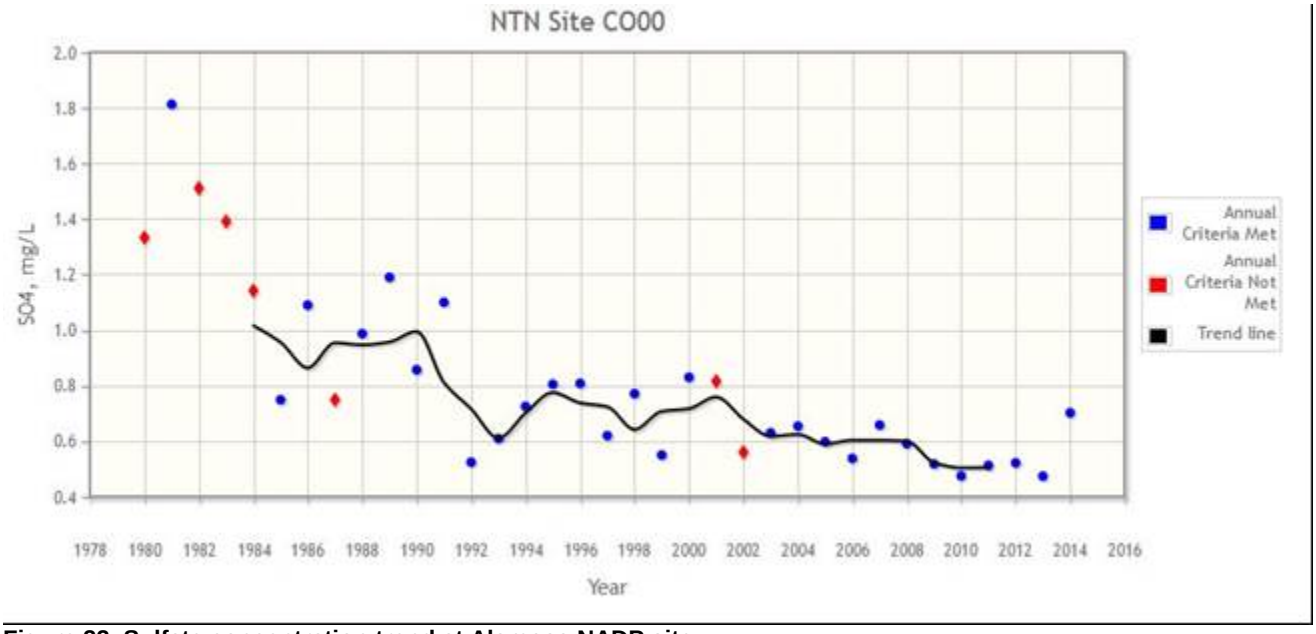

Figure 22. Sulfate concentration trend at Alamosa NADP site.

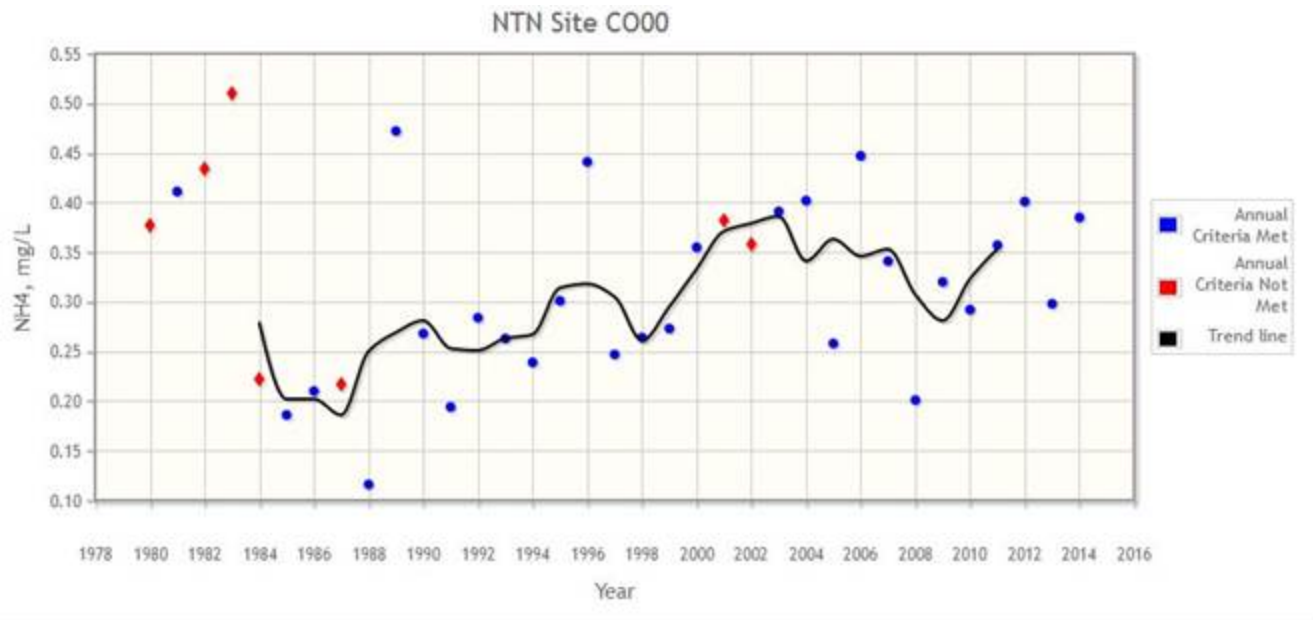

Figure 23. Ammonium concentration trend at Alamosa NADP site.

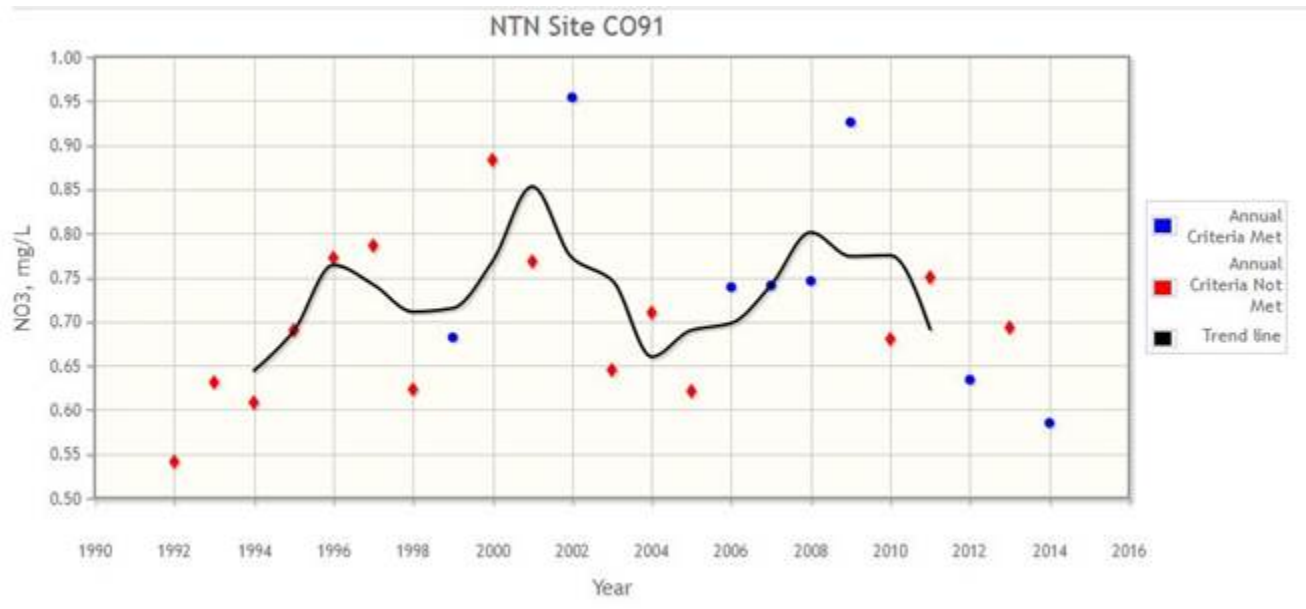

Figure 24. Nitrate concentration trend at Wolf Creek Pass NADP site.

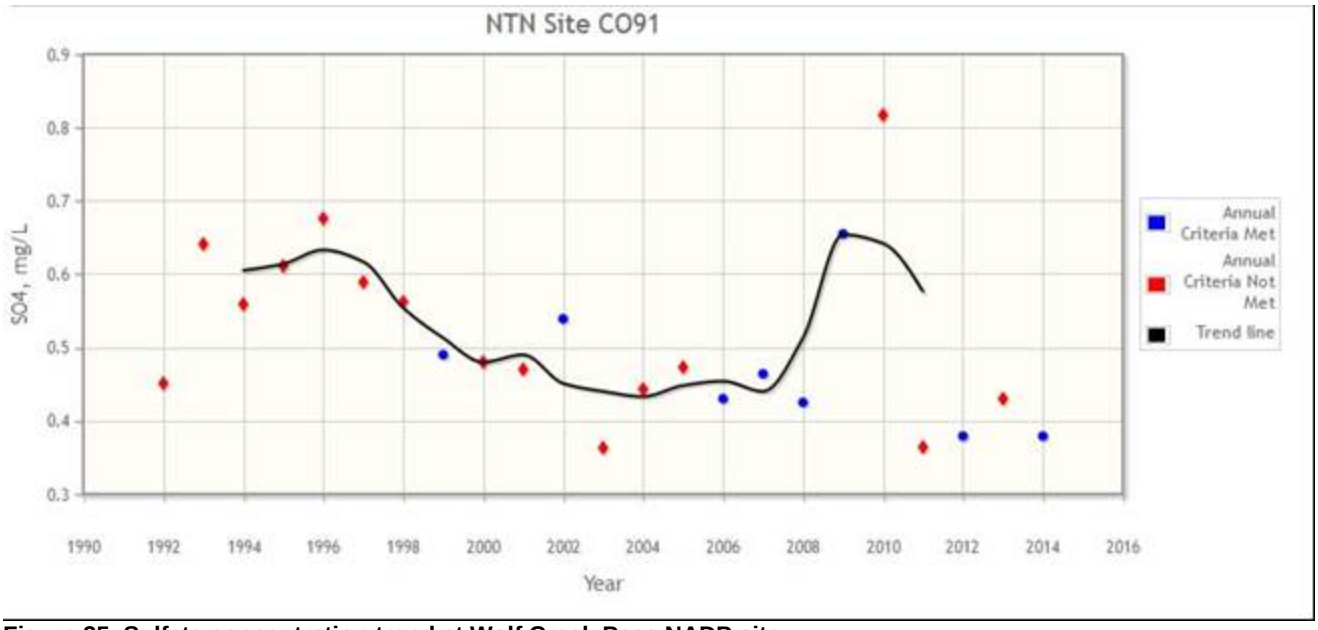

Figure 25. Sulfate concentration trend at Wolf Creek Pass NADP site.

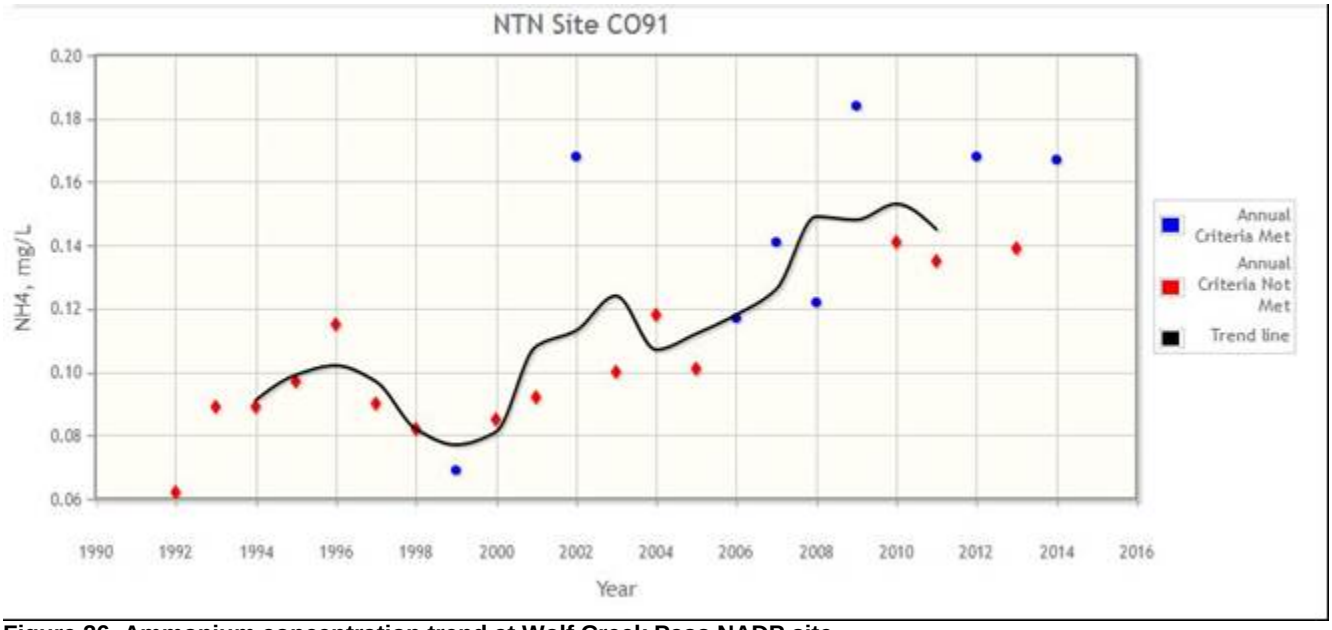

Figure 26. Ammonium concentration trend at Wolf Creek Pass NADP site.

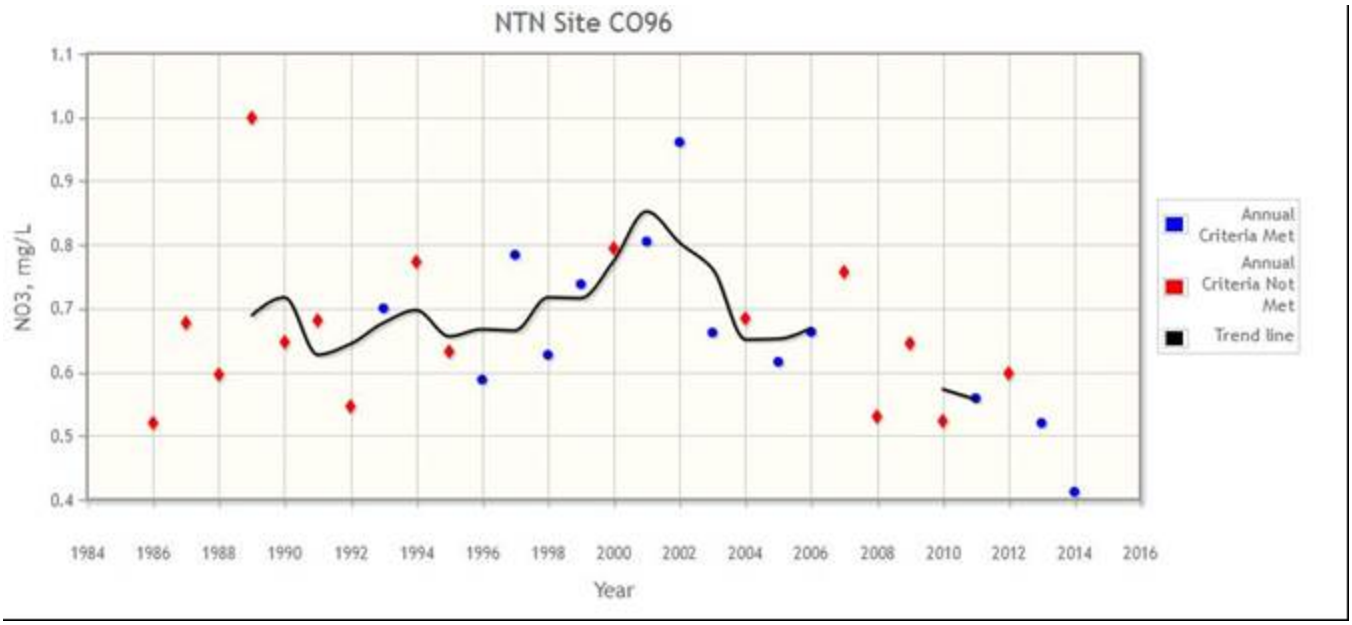

Figure 27. Nitrate concentration trend at Molas Pass NADP site.

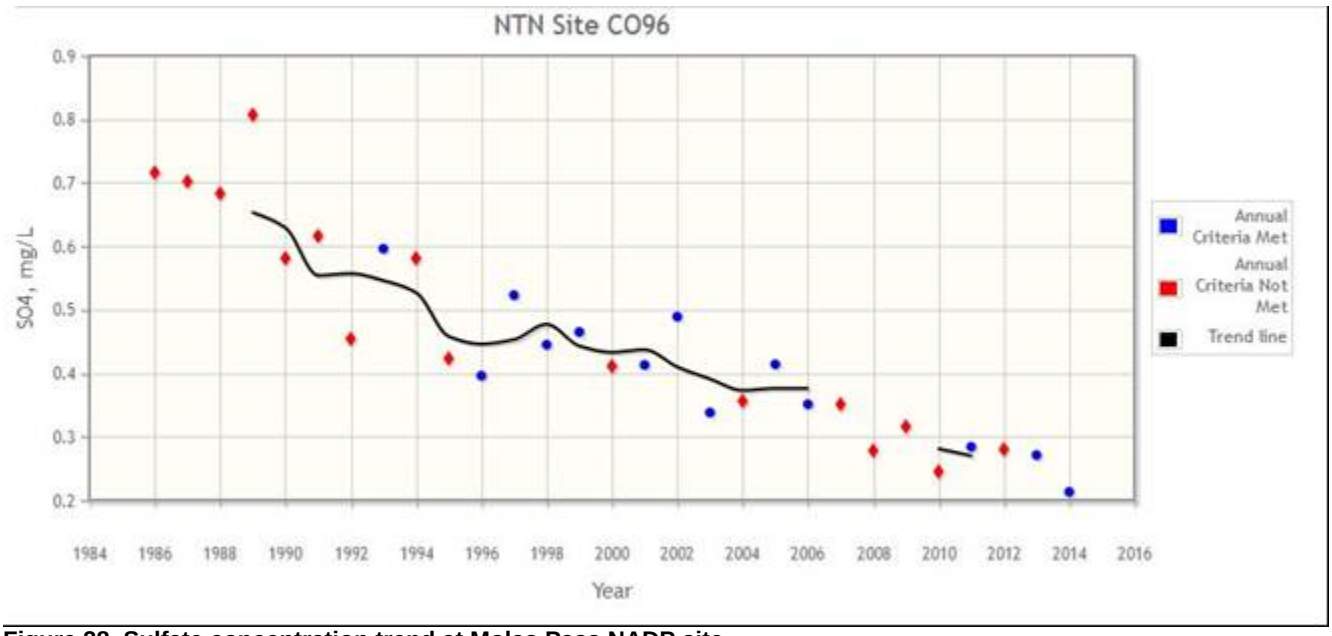

Figure 28. Sulfate concentration trend at Molas Pass NADP site.

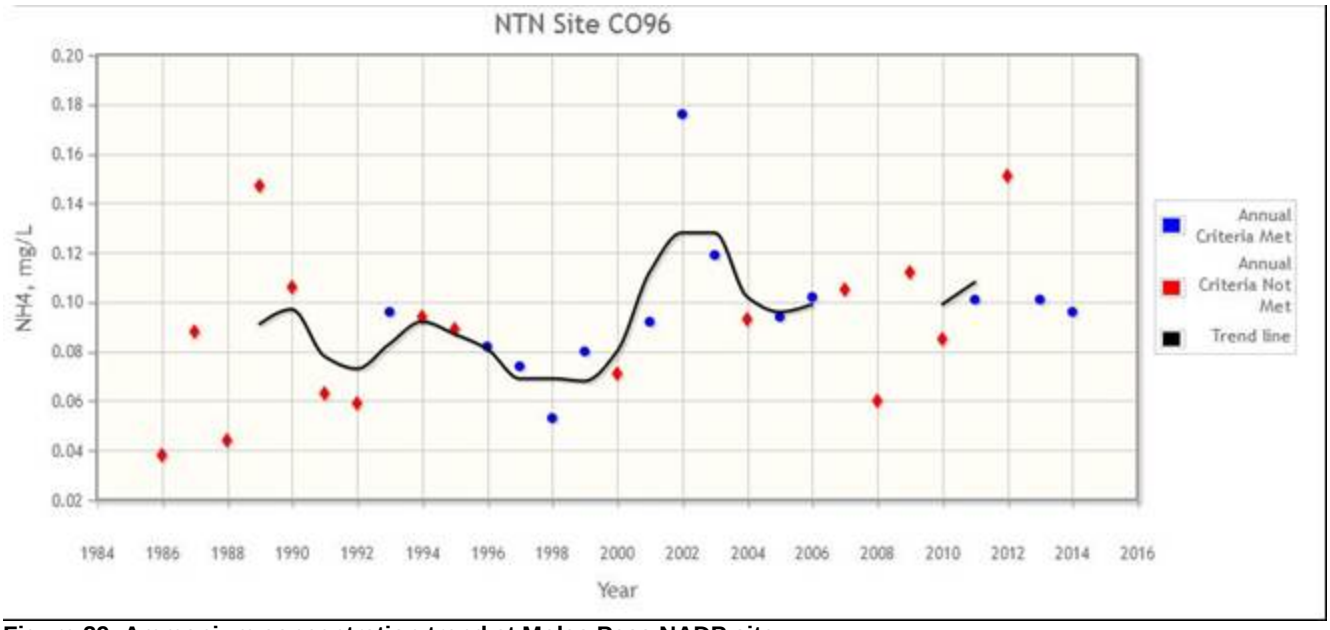

Figure 29. Ammonium concentration trend at Molas Pass NADP site.

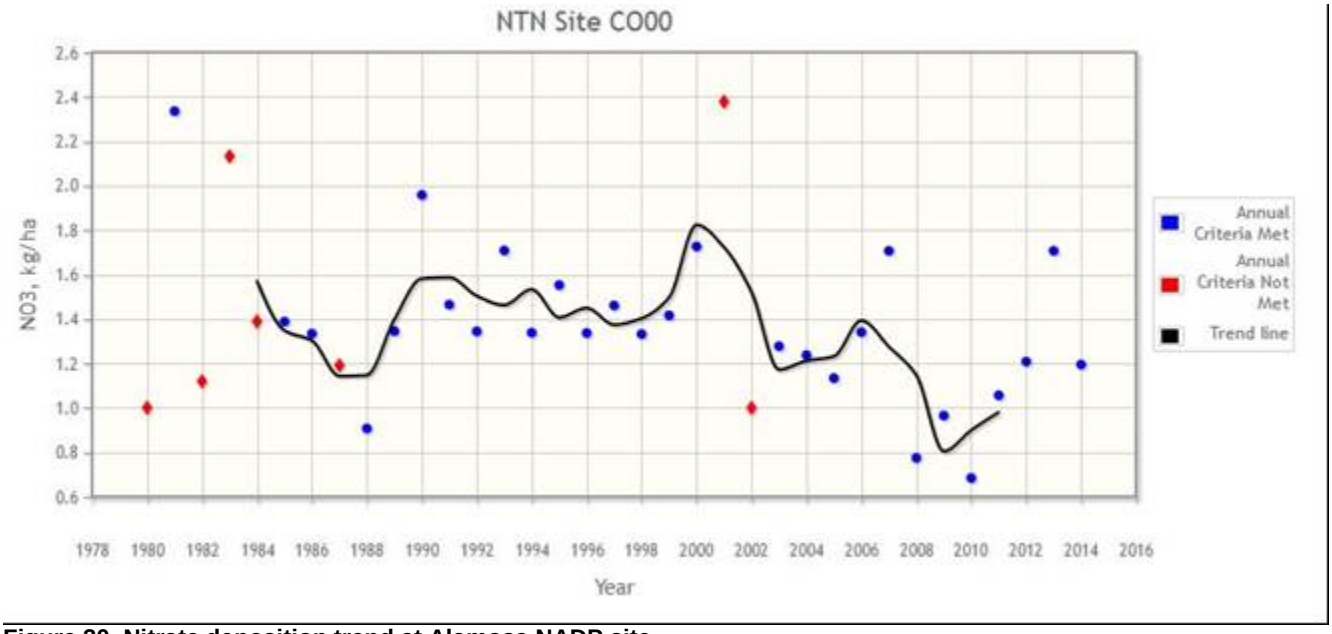

Figure 30. Nitrate deposition trend at Alamosa NADP site.

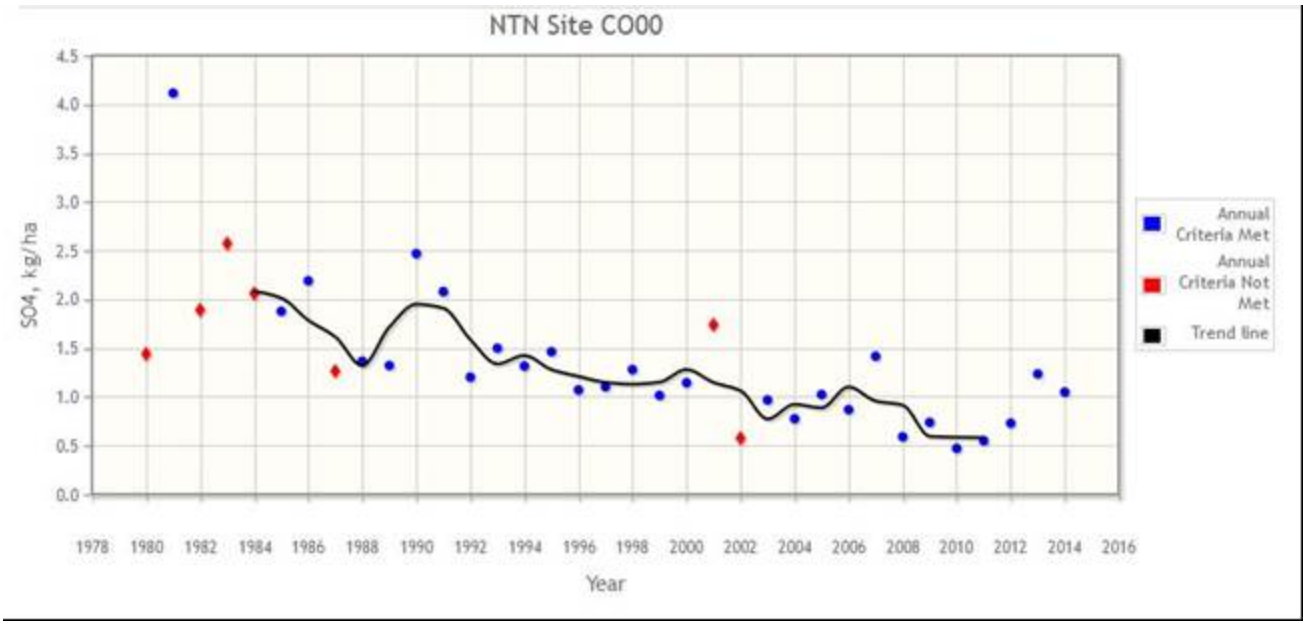

Figure 31. Sulfate deposition trend at Alamosa NADP site.

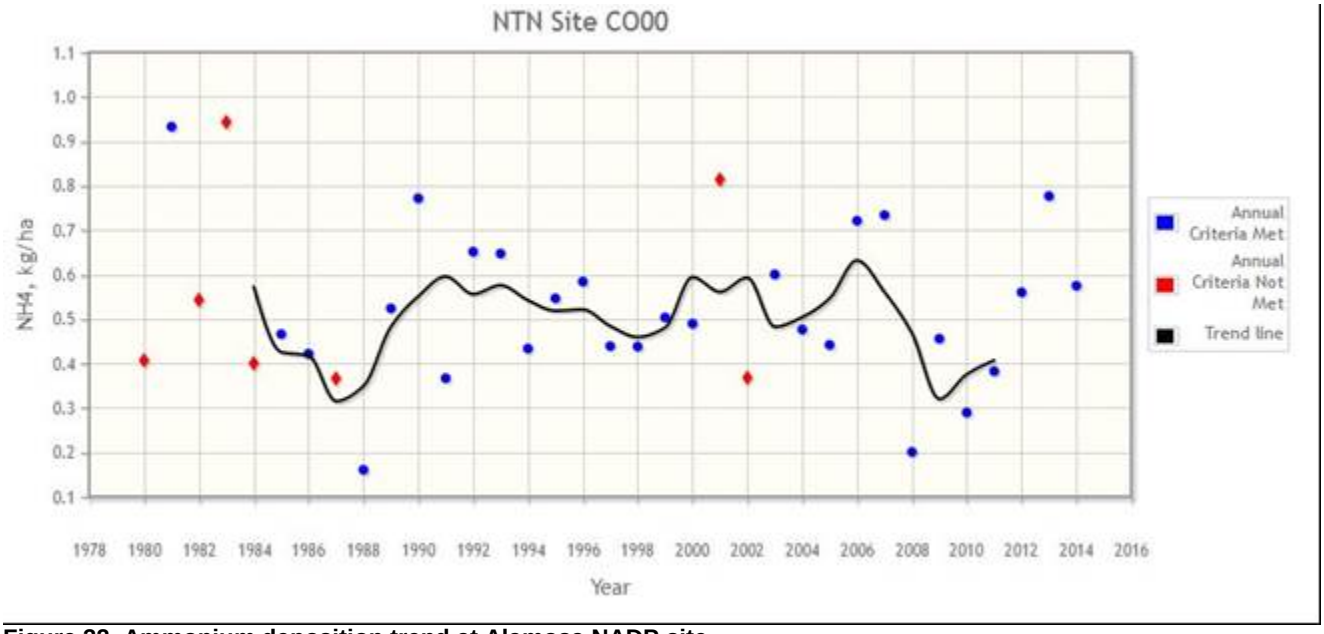

Figure 32. Ammonium deposition trend at Alamosa NADP site.

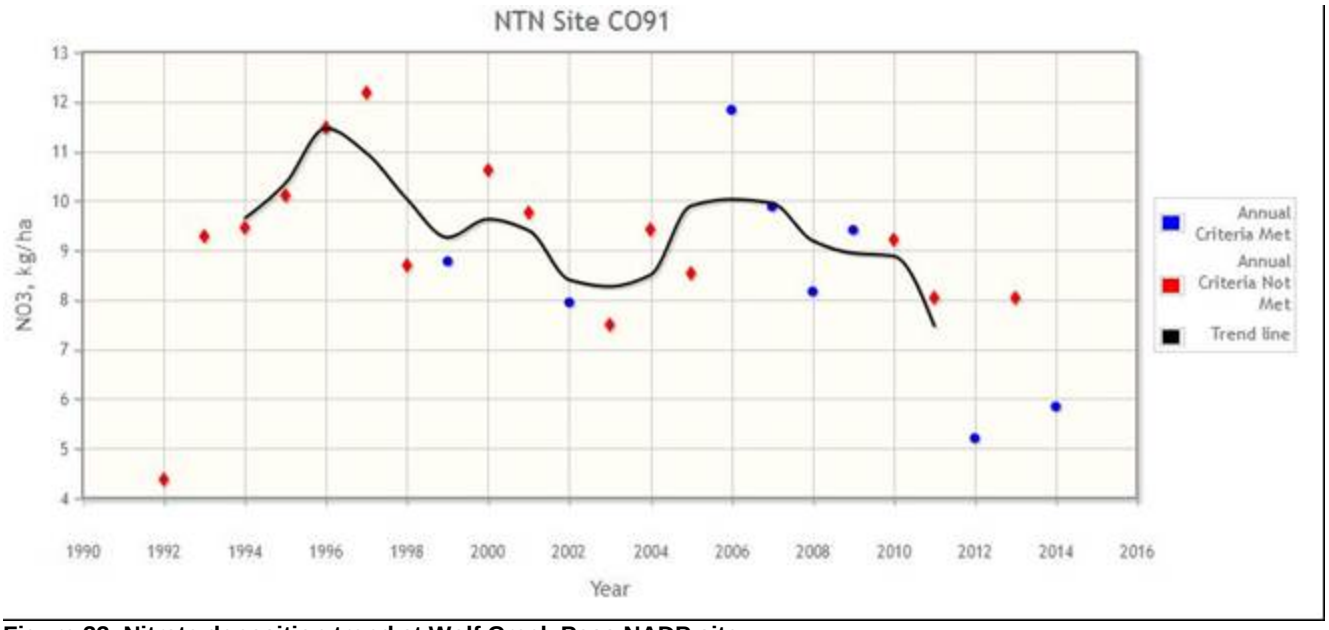

Figure 33. Nitrate deposition trend at Wolf Creek Pass NADP site.

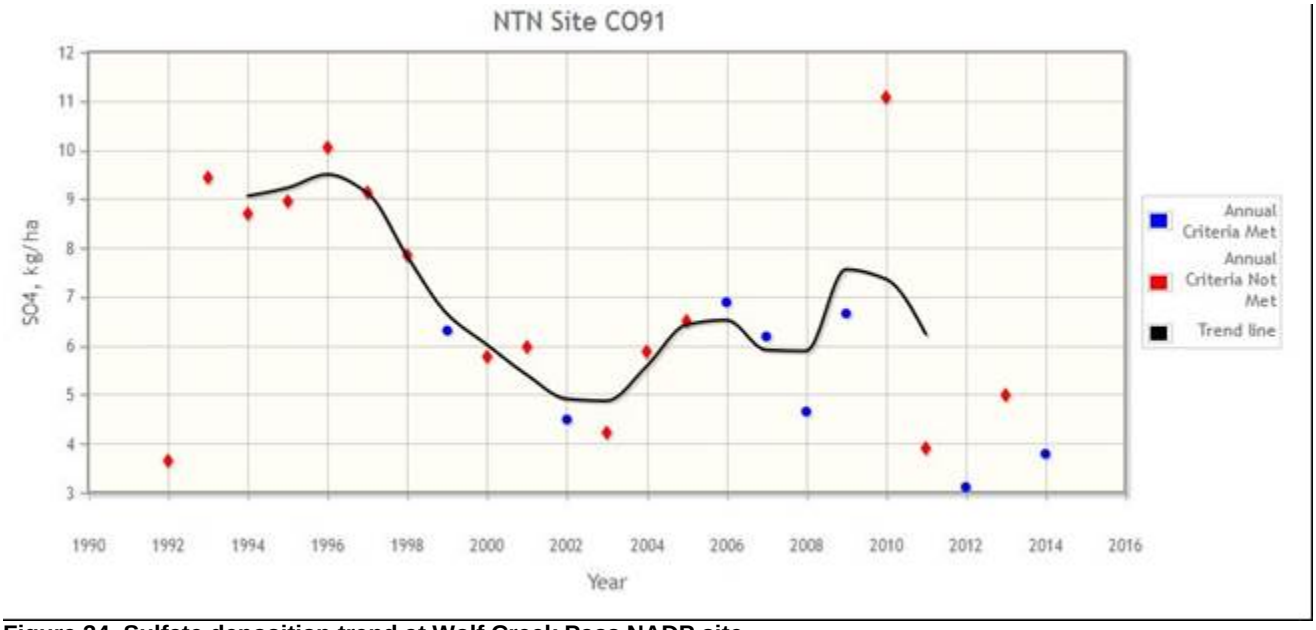

Figure 34. Sulfate deposition trend at Wolf Creek Pass NADP site.

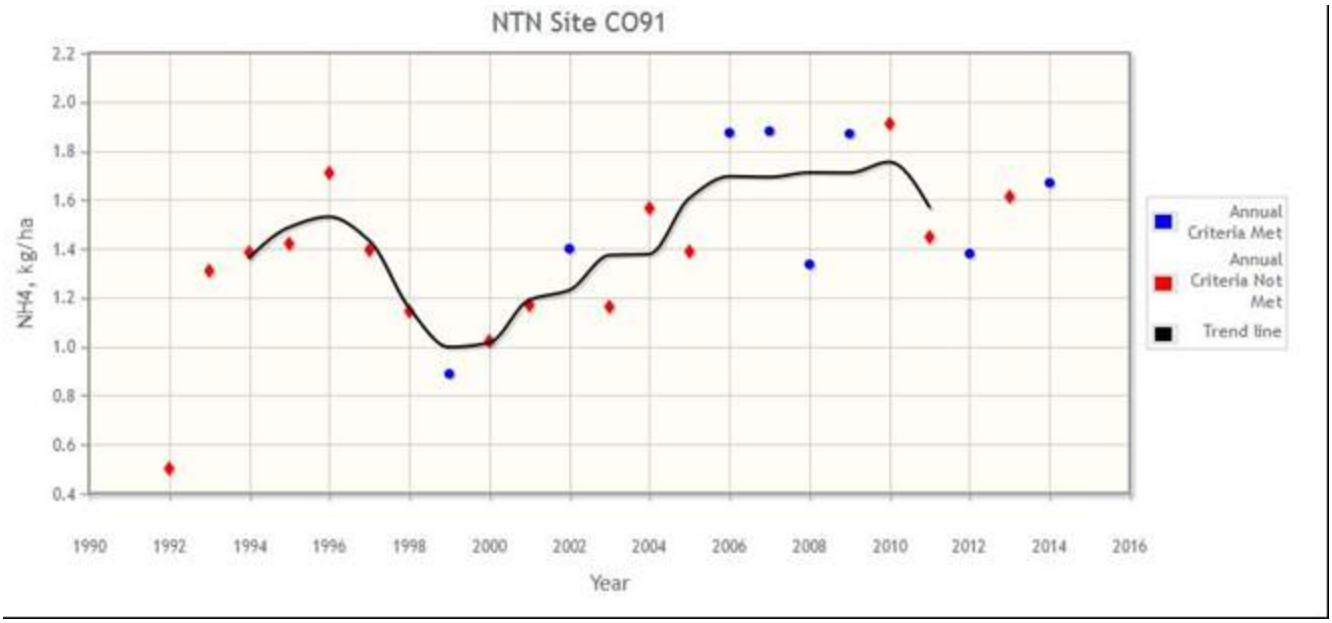

Figure 35. Ammonium deposition trend at Wolf Creek Pass NADP site.

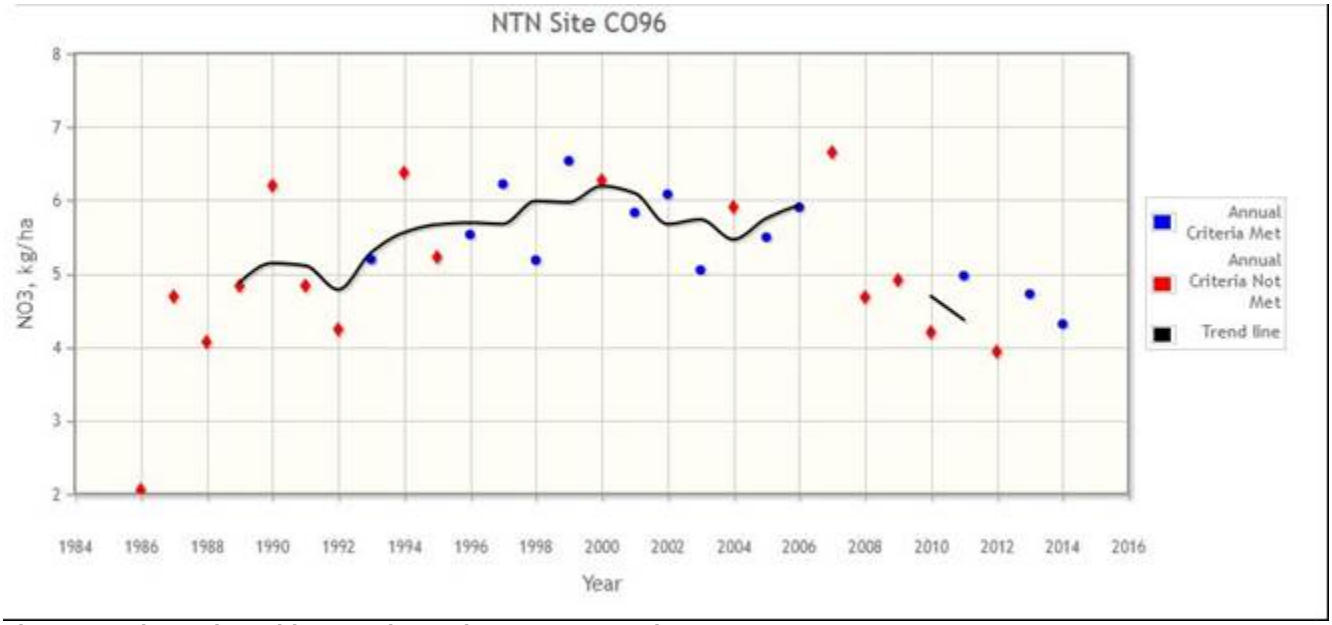

Figure 36. Nitrate deposition trend at Molas Pass NADP site.

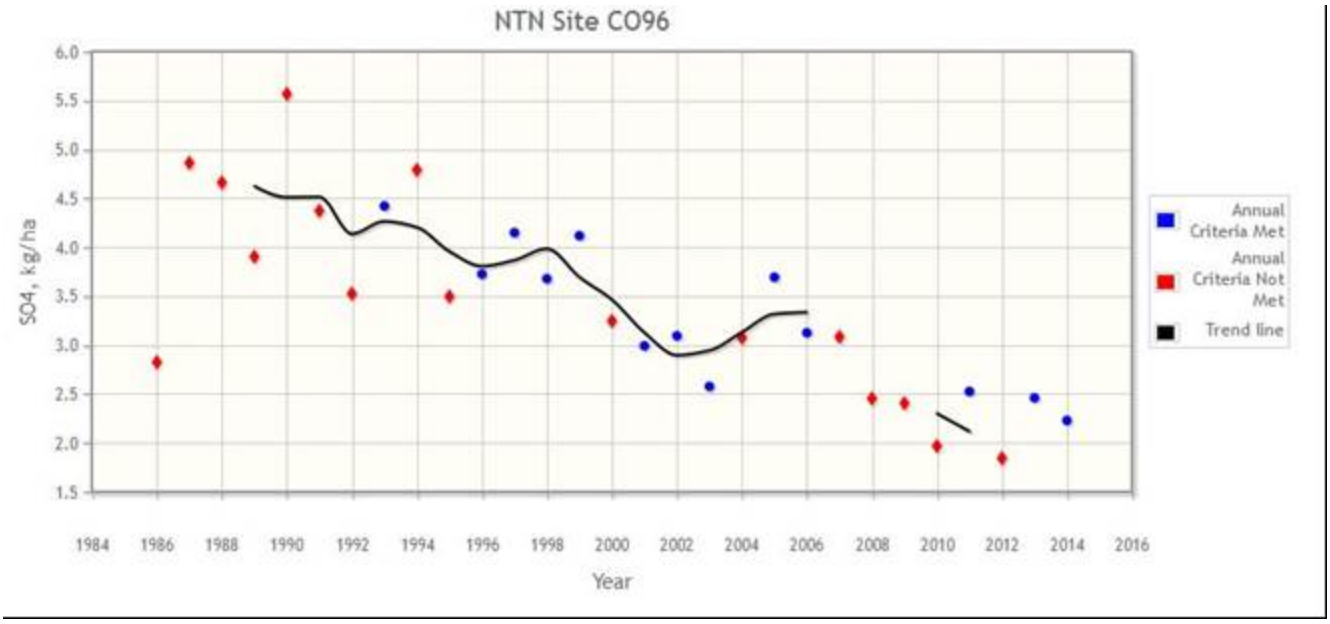

Figure 37. Sulfate deposition trend at Molas Pass NADP site.

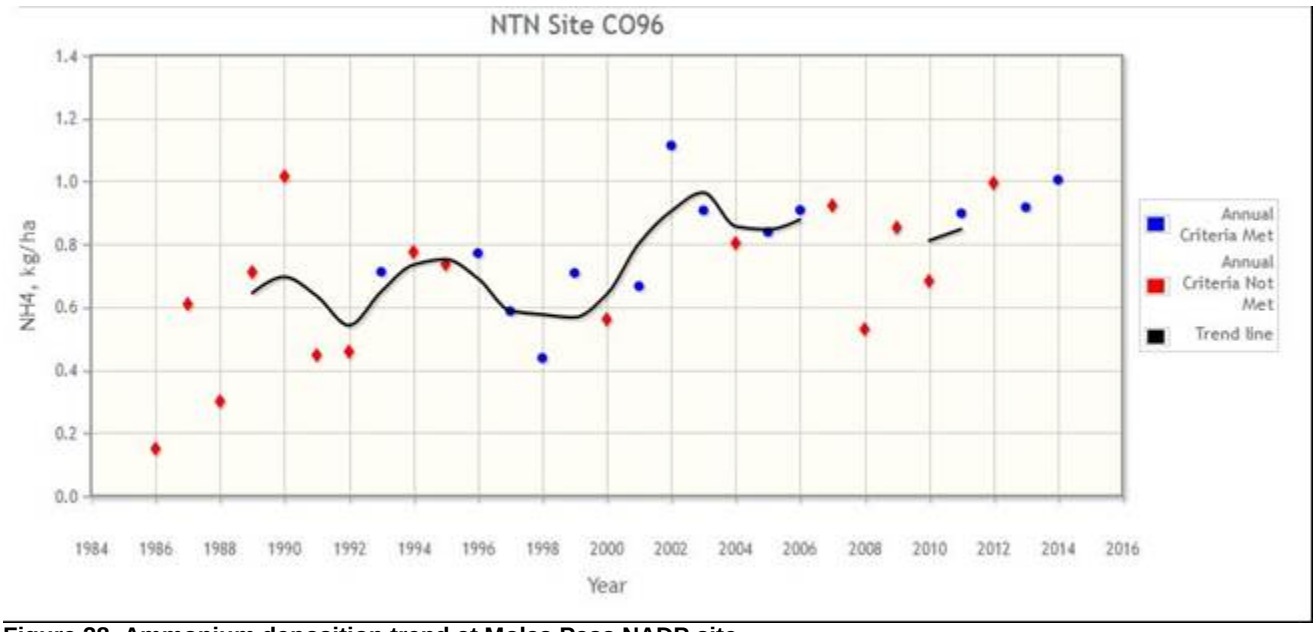

Figure 38. Ammonium deposition trend at Molas Pass NADP site.

Table 3. Apparent (visual) concentration trend at NADP sites near the Rio Grande National Forest.

Apparent Concentration Trend			
Site	Alamosa	Wolf Creek Pass	Molas Pass
NO_3	Up	None	None
SO_4	Down	Down	Down
NH_4	Up	Up	Up

Table 4. Apparent (visual) deposition trend at NADP sites near the Rio Grande National Forest.

Apparent Deposition Trend			
Site	Alamosa	Wolf Creek Pass	Molas Pass
NO_3	None	Down	None
SO_4	Down	Down	Down
NH_4	None	Up	Up

Unfortunately, there are no CASTNet monitoring sites within close proximity to the Rio Grande National Forest. However, the Gothic (GTH161) site near Crested Butte and Mesa Verde (MEV405) site west of Durango are worth noting. Changes in atmospheric deposition at these sites may prove useful to managers on the Forest at some point in the future.

Ozone Monitoring

The nearest active ozone monitoring site to the Rio Grande National Forest is Shamrock Mine (08-067-1004) at Wolf Creek Pass, established in 2004. There is an inactive site at Great Sand Dunes National Monument with data available for 1990 and 1991. Ozone concentrations at Shamrock are within standards, and appear to be cyclical on a 5-year basis, with no apparent trend (Figure 39).

The Forest Service and State of Colorado monitor ozone at multiple rural sites across the southern Rocky Mountains. Musselman and Korfmacher (2014) recently summarized these data. The authors noted many of these locations have, on occasion, O_3 concentrations that exceed the current NAAQS standard but there are significant year-to-year differences, concentration levels are primarily in the mid-concentration range (rarely exceed 100 ppb or drop below 30 ppb), and the small daily fluctuations indicate overall stable concentrations. They also noted stratospheric intrusion may be a contributing factor in that the highest nighttime concentrations occur at the highest elevations. Daytime concentrations apparently are not correlated with elevation. While none of the sites assessed in the study are in or near the Rio Grande National Forest, the results are worth noting from a general monitoring perspective. The Forest should maintain communication with and support the Rocky Mountain Station and State of Colorado as additional rural ozone data are collected, analyzed, and reported.

Watershed Condition Framework

The Watershed Condition Framework characterizes the health and condition of National Forest System lands. The characterization is a reconnaissance-level approach using a comprehensive set of twelve indicators and twenty-four attributes that are surrogate variables representing ecological, hydrological, and geomorphic functions and processes that affect watershed condition. The primary emphasis of the classification is on aquatic and terrestrial processes and conditions that Forest Service management activities can influence. The initial or baseline characterization for the Rio Grande National Forest was completed in 2010.

One attribute within the Forest Health indicator is Ozone. This attribute is rated to address forest mortality impacts to hydrologic and soil function due to air pollution. All watersheds on the Forest were rated “functioning properly” relative to Ozone.

There are two other attributes, i.e., water quality problems and soil contamination, rated in part using data related to air quality. A more current assessment is provided below in the critical loads discussion and should be used when the Forest updates the Watershed Condition Framework.

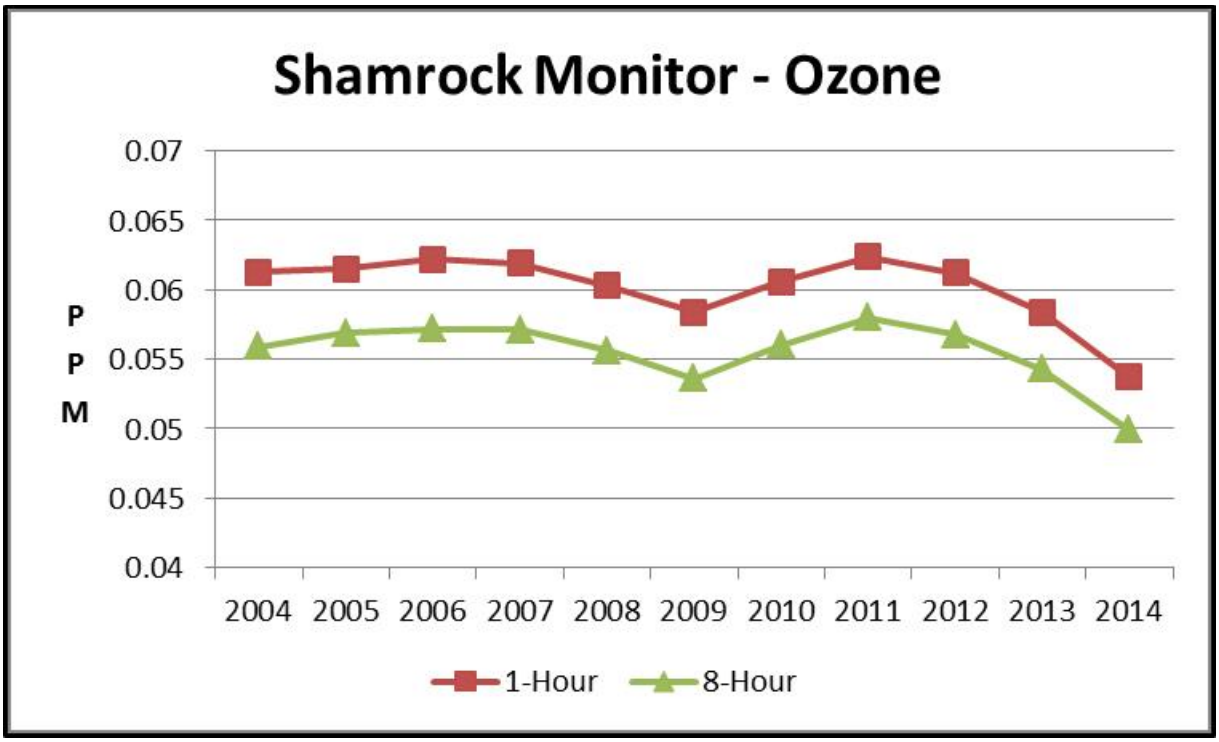

Figure 39. Ozone at Shamrock Mine monitor.

Critical Loads

The Air Quality Portal for Land Management Planning provides guidance on assessing critical loads (CLs) of air pollution http://www.srs.fs.usda.gov/airqualityportal/index.php to determine if concerns exist with acidification, i.e., acid rain, and nutrient loading, e.g., nitrogen saturation, of several ecosystems components. The seven step critical load implementation strategy outlined in the guidance was followed as part of this assessment. Step 1 or the initial screening showed the potential for critical load exceedance on the Rio Grande National Forest. Step 2 indicated ecosystem sensitivity to atmospheric deposition due to potentially elevated deposition of nitrogen at two NADP sites in the vicinity of the Forest (Table 4), and low buffering capacity of high elevation lakes in the Class I Weminuche Wilderness and the Class II South San Juan Wilderness (see narrative under Rio Grande National Forest Lake Monitoring heading above). Step 3 established there are no published regional or local critical load estimates so national estimates should be used, allowing Steps 4 and 5 to be skipped. Steps 6 and 7 involved examination and interpretation of atmospheric pollution impacts on various ecosystem components. Step 6 was a detailed GIS analysis, resulting in numeric output and maps of exceedance information (Table 5 and Maps 1 through 8).

The analysis indicates exceedance of critical loads at certain lakes but buffering by geology and soils should, generally, mitigate any concerns. However, there are small lakes in the Weminuche and South San Juan Wilderness Areas with low acid neutralizing capacity (ANC) where localized geologic and soil material, e.g., excessive exposed bedrock with no soil mantle, may not provide adequate buffering. Thus, current lake monitoring efforts should continue and the Forest should critically review the trend analysis being conducted by the Region (see narrative under San Juan, GMUG, and PSI Lake Monitoring heading above) to determine if current lake monitoring efforts needs to be revised.

The analysis indicates the extent and severity of exceedance for mycorrhizal fungi is low and thus not a concern. Exceedances of the lichen CLs falls within the realm of uncertainty so lichen monitoring in the Class I Weminuche and La Garita Wilderness Areas may be beneficial to measure the extent to which

potential effects have occurred. Exceedances of the minimum CL for herbaceous plants/shrubs and forests occur across twenty-nine percent of the Forest; and for nitrate leaching across forty-one percent of the Forest. While 1.66 kg/ha/yr deposition is not particularly high, it is within the range of CL concerns so the exceedance could be leading toward issues with lower organic soil horizon C:N ratios, higher N mineralization rates, higher potential net nitrification rates and foliar N concentration, and higher N:P, N:Ca, and N:Mg ratios in forested areas, and changes in plant species composition in alpine ecosystems enhancing rates of nitrogen cycling, which could lead to nonlinear increases in nitrate leaching and soil acidification (Pardo et al 2011). Because ammonium (NH_4) deposition at two NADP sites in the vicinity of the Forest visually appears to be on an upward trend (Figure 35 and Figure 38) soil and vegetation monitoring in the Class I Weminuche and La Garita Wilderness Areas may be desirable to measure the extent to which potential effects have occurred. Until additional information becomes available that disputes or supports the results of this critical load assessment, the Forest does not need to establish refined critical loads and target loads at this time; rather, the Forest should continue with development, adjustment, and implementation of its existing air resources program.

Table 5. Implementation Plans

Exceedance Metrics	Critical Loads			
	Acidity: Surface Waters	**Acidity: Forested Ecosystems**	**Nutrient N: Lichens**	**Nutrient N: Mycorrhizal fungi, Herbaceous plants/shrubs, Forests, Leaching**
Extent	5 of 26 lakes (19%) exceed CL	0% exceedance	1% of Forest exceeds maximum CL 65% of Forest exceeds minimum CL	5% of Forest exceeds mycorrhizal fungi CL 29% of Forest exceeds both herbaceous plants/shrubs and forests CL 41% of Forest exceeds nitrate leaching CL
Severity (amount of deposition being received above the CL) – range of exceedance amount	Minimum value = 0 $meq/m^2/yr$ Maximum value = 19 $meq/m^2/yr$	N/A	0 kg/ha/yr for lichen maximum CL 0.01 to 2.73 kg/ha/yr for lichen minimum CL	0 to 0.66 kg/ha/yr for mycorrhizal fungi 0.02 to 1.66 kg/ha/yr for herbaceous plants/shrubs, forests, and nitrate leaching
Severity – 95% exceedance value	N/A due to small sample size	N/A	0 for lichen maximum CL 1.52 for lichen minimum CL	0.04 for mycorrhizal fungi 1.04 for herbaceous plants/shrubs, forests, and nitrate leaching
Reliability	High	Low	High	Variable

Colorado's regional haze State Implementation Plan (SIP) was approved by the Air Quality Control Commission in January 2011 and by EPA in January 2013. Details can be found at http://www.colorado.gov/cs/Satellite?c=Page&childpagename=CDPHE-

AP%2FCBONLayout&cid=1251594862597&pagename=CBONWrapper. The Forest Service worked closely with the State of Colorado during the development of the SIP.

The State of Colorado has developed a natural events action plan for responding to wildfire smoke and focuses only on wildfires that require suppression action. Action plan details can be found at http://www.colorado.gov/cs/Satellite?c=Page&childpagename=CDPHE-AP%2FCBONLayout&cid=1251595265392&pagename=CBONWrapper. The Rio Grande National Forest staff works closely with the State of Colorado to conform to this plan.

Natural Hazards

There are no known large, broad-scale, major geologic hazards within the Rio Grande National Forest that may affect air quality.

Multiple Uses / Ecosystem Services

The air resource on the Rio Grande National Forest, in conjunction with soil, water and watershed resources, is part of the foundation for providing for the full suite of multiple uses available from national forests. Good to excellent air quality is a prerequisite to many National Forest uses, products, and services. For example, people recreate on the Forest to enjoy clean air and view expansive vistas; water unpolluted by atmospheric deposition provides on- and off-Forest uses such as habitat for aquatic organisms, and drinking, industrial, and agricultural supply; and clean air assists in climate regulation, particularly relative to greenhouse gases.

Conditions and Trends

Overall, air quality within and near the Rio Grande National Forest is good to excellent as the area is minimally developed, has limited local emissions sources, and predominantly very robust air dispersion. Wildfire emissions, depending upon the year, can be the most significant source of pollution within and around the Forest, but are not controllable by management except indirectly, through fire suppression. Prescribed-fire emissions in the area do occur during the spring and late fall. The amount of activity is expected to hold constant, with a few to several hundred acres per year being treated. Smoke management is regulated by permit from the State of Colorado. Overall smoke emissions (wildfire and prescribed) are expected to remain about the same, with the major variable being weather conditions.

Dust generated by winds blowing across the San Luis Valley is also an apparent air quality impact to the Forest, particularly the part of the Forest in the Sangre de Cristo Mountains. Dust generated in the southwestern U.S. and at a global scale also impacts the Forest, most apparent as a dark covering of the snowpack as it melts in the spring.

The greatest threat to air quality within the Forest is from upwind anthropogenic sources. Upwind urban and particularly industrial air pollution, although low to moderate compared with much of the U.S., has a potentially persistent impact, because many of these emissions occur year-round. These sources are managed by the air quality regulatory agencies in Colorado and upwind states, with collaboration from the Forest Service for major sources permitting through the PSD process. Currently, as previously discussed, all Colorado communities are in attainment of all National Ambient Air Quality Standards, with the exception of the Front Range ozone control area, which is in non-attainment for the 8-hour ozone standard. In the past there were several communities across the State in non-attainment for violation of one or more of the federal clean air standards. Implementation plans have since been developed for these communities. These plans show how these communities have attained and will maintain compliance with

the standards. The closest community to the Forest under one of the maintenance plans is Pagosa Springs for particulate matter (PM_{10}).

The largest air quality concern on the Rio Grande National Forest arises from energy development in southwest Colorado and northwest New Mexico, and perhaps the Spanish Peaks area west of Trinidad, Colorado. Continued compliance with NAAQS and protection of Class I and II areas on the Rio Grande National Forest requires continued close coordination between the Forest Service and air quality regulatory agencies in Colorado and upwind states.

There is a considerable amount of historic and current air quality monitoring data available to the Forest for tracking air quality conditions and impacts on air quality values. Some of this information is more valuable than others as previously discussed. IMPROVE sites for the Weminuche Wilderness and Great Sand Dunes National Park are useful for visibility monitoring. The Colorado “scenic and important views” database is useful for PSD permitting efforts the Forest may become engaged with in the future. Historic and on-going lake water chemistry data is useful for tracking atmospheric deposition in terms of acid rain and nutrient loading. Surrounding USGS snowpack chemistry data and NADP deposition data are very useful for atmospheric deposition monitoring.

Haze indices indicate visibility on the clearest days is improving over time but there is no apparent trend in the index on the haziest days. Episodic wind events and associated dust appear to be affecting visibility on the Forest, particularly in the Sangre de Cristo Mountains. Regional and global wind driven dust also appear to be affecting visibility. High elevation lake monitoring indicates there are lakes sensitive to atmospheric deposition in the Weminuche and South San Juan Wilderness Areas but not in the La Garita and Sangre de Cristo Wilderness Areas. These data sets are presently being analyzed for trend, but the results may or may not be available for the current revision effort. Snowpack chemistry monitoring indicates no apparent trend with nitrate concentrations, an apparent downward trend with sulfate concentrations, and no apparent to an apparent upward trend with ammonium and mercury concentrations. NADP site data indicates an apparent downward trend in sulfate concentration and deposition, apparent downward to no trend to upward trend in nitrate concentration and deposition depending upon location, and apparent upward trend in ammonium concentration and deposition. Both the snowpack and NADP datasets should be statistically analyzed to validate whether the apparent trends are real.

Critical load (CL) assessment indicates exceedance of critical loads at certain lakes but buffering by geology and soils should, generally, mitigate any concerns. However, there are small lakes in the Weminuche and South San Juan Wilderness Areas with low acid neutralizing capacity (ANC) where localized geologic and soil material, e.g., excessive exposed bedrock with no soil mantle, may not provide adequate buffering. Thus, current lake monitoring efforts should continue and the Forest should critically review the trend analysis being conducted by the Region (see narrative under San Juan, GMUG, and PSI Lake Monitoring heading above) to determine if current lake monitoring efforts needs to be revised.

The critical load assessment indicates potential concern with nitrogen deposition on lichens, soil quality and vegetation, particularly in the alpine. Monitoring in the Class I Weminuche and La Garita Wilderness Areas may be beneficial to measure the extent to which potential effects have occurred. Until additional information becomes available that disputes or supports the results of the critical load assessment, the Forest does not need to establish refined critical loads and target loads at this time; rather, the Forest should continue with development, adjustment, and implementation of its existing air resources program.

Need for Change

Based on information in this section of the assessment, there is no need for absolute change in the existing Plan because existing direction is being met. Forest managers are in compliance with the Clean Air Act and Colorado Air Quality Control Act, so the existing standard is appropriate. By default, managers are also meeting the Forest-wide objective of protecting the environment from air pollution, at least to the degree required by law. However, the assessment indicates there are off-Forest sources of pollution that may have potential negative effects on air quality and air quality related values across the Forest in the future. The assessment also suggests climate change could have negative effects on air quality. Thus, it is critical the Forest remains diligent in providing the desired condition for air resources. To that end the Forest should continue development, adjustment, and implementation of the air resources program, including updating the existing Forest-wide air monitoring plan. This update could coincide with Forest Plan revision or be conducted separately. In either or both documents the Forest should consider adaptive strategies that address current off-Forest sources of pollution and the potential effects of climate change that are designed to protect and preserve the air resource.

Soils

Introduction

Soil is the foundation of ecosystem function. It acts as a growth medium and provides nutrients for vegetation, stores and filters water, cleans air, contains habitat for billions of organisms, and is a long-term carbon storage reservoir.

Soils can lose much of their function when altered. Alteration can occur through management actions as well as natural events. The greatest threat to soil productivity is soil erosion, because soil is lost from a site and cannot be replaced during human timespans. Erosion removes topsoil, which contains most of the soil's nutrients. Soil can also be compacted, which reduces the soil's porosity and air and water holding capacity. Soils can lose nutrients due to vegetation or litter cover removal, rendering it less capable of supporting some types of vegetation. Further, soil hydrologic function can be affected, through any of the above processes or when a water source is altered, such as when upstream diversions or stream incision in meadows actually reduce the amount of water entering the soil.

The 2012 Planning Rule requires National Forests and Grasslands to consider soil resources when developing plan components. The purpose of this assessment is to evaluate available information about soil resources within the Rio Grande National Forest. This assessment describes current conditions and trends regarding these resources. This information is used to anticipate future conditions, and to determine if trends pose risks to system integrity at the forest level. Additionally, this assessment identifies information gaps and any uncertainty with the data. The information contained in this assessment will be used to inform agency officials whether current direction needs adjustment to protect soil resources and the systems that rely on them.

The following items are addressed in this assessment, as specified by Forest Service Handbook, Chapter 10 Section 12.22.

- Existing inventories of soil conditions and improvement needs
- Important attributes, characteristics, or processes of soils that make them susceptible to loss of integrity resulting from specific uses, disturbances, or environmental change
- Existing conditions and trends of soil resources and soil quality assuming existing plan direction remains in place
- Soil quality/productivity considerations important to consider in providing multiple uses and ecosystem services
- Places on the Forest where soil quality/productivity is at risk, or not adequately protected, and management concerns or ecosystem stressors that limit or reduce soil function

Concepts in Soils Management

Watershed Processes

Watersheds are drained by a stream network of perennial streams that flow year-round, intermittent streams that flow seasonally, and ephemeral streams (including swales) that flow only during runoff events. The stream network expands during runoff events. Most material that enters any part of the network will eventually reach an aquatic ecosystem.

Most material that enters streams comes from an adjacent source zone whose width depends on land form, stability, and ground cover. Sediment is natural, but roads and other disturbed sites can act as channels that multiply sediment loads to the stream network during runoff events. Such "connected disturbed areas" can be a major source of damage to aquatic ecosystems.

If organic ground cover in a watershed is reduced enough to markedly increase the magnitude or duration of high flows, stream channels may erode their banks to damage their stability and aquatic habitat. Direct bank damage may add large amounts of sediment directly into streams. Soil quality depends on soil structure, organic matter, nutrient pools, and biotic processes. Soil quality is impaired when these qualities are markedly degraded for a period of years. Severe disturbances can impair soil quality by heating, displacing, compacting, or eroding the soil.

Historic ranges of native aquatic biota were determined by physiographic and hydrologic boundaries and biotic behavior. These patterns have been changed by fishing pressures, introduction of exotics, and migration barriers such as dams and diversions, as well as by habitat impacts. Biotic strategies that address these relationships are needed as well as watershed conservation practices in order to sustain vigorous populations of desired aquatic communities.

Dynamic Equilibrium

A healthy watershed operates in dynamic equilibrium. Soil and water quality, flow regimes, and aquatic and riparian habitats vary within a certain range of conditions. Large natural disturbance events shift a watershed out of equilibrium. Recovery then begins. Poor land management practices can shift a watershed out of equilibrium.

Laws and common sense direct us to maintain equilibrium conditions between large natural disturbance events, avoid actions that may shift a watershed out of equilibrium or worsen major events, and assist watershed recovery. The natural resilience of the system must be conserved in order to sustain ecosystem health.

Some disturbance can occur and still sustain watershed health. If runoff and sediment regimes, soil and channel conditions, water quality, and aquatic and riparian habitats are maintained between large natural disturbance events, watershed health is conserved.

The concept of dynamic equilibrium can be applied to biological processes as well as physical landform processes. Natural processes are not static or absolutely stable, but there is a tendency for the form to maintain relatively stable characteristics. Natural perturbations influence these natural processes, which then begin the process of moving toward pre-event characteristics. Dynamic equilibrium can be both ‘short-term’ such as life-history changes of fish associated with the annual hydrograph or ‘long-term’ such as the stream channel adjustments following natural fire events.

Land and Stream Types

The goal of watershed conservation is to sustain and restore watershed health in each watershed. Land and water conditions must be kept within the dynamic equilibrium ranges for the local landscape. Land and stream types, and their dynamic equilibrium ranges, vary within and among landscapes due to variations in climate and geology. This variation must be taken into account. In each landscape, dynamic equilibrium conditions vary by land types and stream types. These ranges can be defined by sampling reference land and stream types in that landscape. The efficacy of watershed conservation practices is assessed by comparing each land type and stream type with its own capability.

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Land factors reflecting soil and stream health include ground cover, soil bulk density, connected disturbed areas, and slope stability. Water factors include channel widths-depths, large woody debris, substrate, bank stability, flow regime, and water chemistry. Other factors may also be locally important.

Design and Risk

Watersheds experience periodic disturbance events that vary in their size, duration, and frequency. The randomness of such events implies some level of risk with any design. This risk is a product of the probability of an event occurring and its consequences. Watershed conservation practices are designed to control runoff damage from at least a 10-year storm of any duration.

Legal Framework and Forest Service Policy

The Forest Service has a role in implementing soil management programs. This role is identified in and a result of numerous legislative acts, regulations, and standards.

Organic Act

The Organic Act defines original National Forest purposes to improve and protect the forest, secure favorable conditions of water flows, and furnish a continuous supply of timber. Years of concern about watershed damage led to creation of the National Forest System. Watersheds must be cared for to sustain their hydrologic function as "sponge-and-filter" systems that absorb and store water and naturally regulate runoff. The goals are good vegetation and ground cover, streams in dynamic equilibrium with their channels and flood plains, and natural conveyance of water and sediment.

Multiple-Use Sustained Yield Act

The Multiple-Use Sustained Yield Act established that the sustained yield of goods and services from National Forests must be conducted without permanent impairment of the productivity of the land.

National Forest Management Act

The National Forest Management Act directed each national forest to prepare a land and resource management plan. The Act recognizes national forests are ecosystems and their management requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems. The Act requires Forests to ensure management will not produce substantial and permanent impairment of the productivity of the land.

Rio Grande National Forest Land and Resource Management Plan

The soil resource is a recognized component of the Rio Grande National Forest Land and Resource Management Plan (Forest Service 1996). The Final Environmental Impact Statement (FEIS) for the Forest Plan recognized soils are the foundation of ecosystems, non-renewable by even the most modern technologies, and that soil management on the Forest is to maintain soil productivity and soil health so that ecosystems can be sustained for the many benefits they provide.

Desired conditions, objectives, and standards and guidelines in the Plan are described in a subsequent section of this assessment. Annual Forest Plan monitoring reports provide annual summaries of soil resources on the Forest and indicate soil resources are being adequately protected and no changes in the Forest Plan are needed.

Agency Policy

Forest Service Manual 2550 – Soil Management contains agency direction for managing soil resources. Six soil functions are defined: soil biology, soil hydrology, nutrient cycling, carbon storage, soil stability

and support, and filtering and buffering. The objective of soil management is to maintain or restore soil quality, and manage resource uses and soil resources to sustain ecological processes and function so that desired ecosystem services are provided in perpetuity. Agency policy calls for responsible soil stewardship that promotes biological and hydrologic function.

The Rocky Mountain Region, which includes the Rio Grande National Forest, utilizes Forest Service Handbook 2509.18 – Soil Management Handbook. This handbook established regional soil quality monitoring standards. The policy is to manage activities to not exceed standards in order to protect the soil resource before excessive damage occurs, and where excessive soil impacts already exist from prior activity prevent any additional detrimental impact and reclaim where feasible.

The Rocky Mountain Region also utilizes Forest Service Handbook 2509.25 – Watershed Conservation Practices Handbook. This handbook established regional watershed conservation practices to protect soil, aquatic, and riparian systems. The practices cover five areas: hydrologic function, riparian areas and wetlands, sediment control, soil quality, and water purity. Each practice consists of a management measure, a set of design criteria used to achieve the specific management measure, and guidance for monitoring and restoration. The policy is to apply the practices to sustain healthy soil, riparian, and aquatic systems by adopting a stewardship ethic that treats land and resources as public assets for long-term benefits.

The Forest Service utilizes the National Core Best Management Practices Program as over-arching direction on the importance of prescribing, implementing, and monitoring proven soil and water protection measures at the project-scale on National Forest lands. Agency policy requires the use of Best Management Practices to control nonpoint source pollution to meet applicable water quality standards and other Clean Water Act requirements.

Information Sources and Gaps

Information Sources

Colorado Geological Survey. 1999. United States Forest Service Hazard Abandoned Mine Land Inventory Project. http://coloradogeologicalsurvey.org/water/abandoned-mine-land/united-states-forest-hazard-abandoned-mine-land-inventory-project/.

Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division. 2013. *Preliminary Close-Out Report, Summitville Mine Superfund Site.* 20 pages.

Forest Service. Date unknown. Sangre de Cristo Soil Survey. Unpublished.

Forest Service. 1996a. Rio Grande National Forest Land and Resource Management Plan, FEIS, ROD, and Annual Monitoring Reports.

Forest Service. 1998. Watershed Improvement Needs Inventory and Tracking Spreadsheet. Unpublished.

Forest Service. 2011a. *Watershed Condition Framework.* http://www.fs.fed.us/publications/watershed/.

Forest Service. 2011b. Archuleta/Chama and Middle Fork Carnero Watershed Restoration Action Plans.

Forest Service. 2012. *National Best Management Practices Program.* http://www.fs.fed.us/biology/watershed/BMP.html

Forest Service. Soil Management and Watershed Conservation Practices Handbooks.

Forest Service GIS Library

Gordon, Eric and Dennis Ojima. 2015. *Colorado Climate Change Vulnerability Study.* University of Colorado Boulder and Colorado State University. 190 pages.

Lukas, Jeff, Joseph Barsugli, Nolan Doesken, Imtiaz Rangwala, and Klaus Wolter. 2014. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.* University of Colorado Boulder. 114 pages.

NRCS. Rio Grande NF Area, West Part, Soil Survey. http://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=CO

Numerous websites as shown throughout the document; links to each site are contained in the narrative. Some of the figures are downloaded from these sites.

Data Gaps

There is a lack of quantitative base and trend data on soil productivity in alpine areas, forested areas and rangeland upland areas, on soil compaction in rangeland bottoms such as riparian areas and swales, and on rates of erosion on system and unauthorized roads and trails.

Existing Forest Plan Direction for Soils

The Rio Grande National Forest Plan contains desired conditions, objectives, and standards and guidelines. For soil resources they are:

Desired Conditions

Soils are maintained, or improved to healthy conditions, so that the ecosystems they support can flourish. Healthy soils and ecosystem sustainability will be assured if soil damages, such as erosion, displacement, compaction, scorching, and nutrient drains, are kept within allowable limits.

Ecosystem management activities are harmonious with soil capabilities, potentials, and limitations.

Soils may be periodically disturbed by management activities, but are restored and reclaimed to original potentials after activities have been completed.

Where fire is used to perpetuate an ecosystem, it is done in a way that accomplishes resource objectives without unnecessarily risking or jeopardizing the site's ability to sustain ecosystems.

Healthy soils provide certain products such as wood, forage for livestock and wildlife, water, recreation, minerals, and aesthetic benefits. These benefits can be continued for the long term, provided soil health remains within acceptable limits.

Objective

Maintain or improve long-term soil productivity, and protect against significant or permanent impairment of the land.

- Keep soil losses within tolerance limits, and maintain acceptable amounts of ground cover.
- Re-vegetate disturbed areas.
- Meet the requirements for minimizing soil displacement and compaction.

- Where excessive soil impacts exist from prior activities, emphasize preventing any additional detrimental impacts, and reclamation where feasible.

Standards and Guidelines

There are eight (8) pages of standards and guidelines that cover soil, water, and aquatic resources, including fish, riparian areas and wetlands. These standards and guidelines center around five (5) core areas: hydrologic function, riparian areas, sediment control, soil productivity, and water purity. These core areas, standards, and guidelines were derived from a draft of the original Region 2 Watershed Conservation Practices Handbook. Rather than reiterate eight pages of document the reader should refer to pages III-4 through III-11 of the current Forest Plan.

Scale of Analysis

The characterization of soil resources in this assessment is the area defined by the Rio Grande National Forest boundary. This is because management activities rarely affect soil condition on adjacent land. In those few cases where soil condition can affect adjacent land effects to those lands is discussed.

Existing Condition and Trend of Soils

Inventories

There is a published soil survey for the west part of the Forest. This survey is available at http://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=CO.

There is an unpublished soil survey for the east part of the Forest. Information is available at the Supervisor's Office.

There is a watershed improvement needs inventory in hard copy at the Supervisor's Office. Accompanying this inventory is a spreadsheet being used to track project implementation.

There is the Watershed Condition Framework which characterizes the health and condition of National Forest System lands.

There is an Abandoned Mine Land (AML) inventory.

Important Attributes, Characteristics, and Processes

The Rio Grande National Forest has a wide diversity of soil types, from minimally-developed, nutrient poor soil to deep, fertile soil. Cool temperatures, a short growing season, and relatively steep topography affect soil development at high elevations. Warmer temperatures, a longer growing season, and flatter topography allow for better soil development at mid- to low elevations.

The Forest is in the headwaters of the Rio Grande River in an area known as the San Luis Valley. The valley itself is long, wide, and flat with small amounts of national forest land on the margins. The western and northern part of the Forest is in the San Juan Mountain range bounded by the Continental Divide and Poncha Pass. The eastern part of the Forest is in the Sangre de Cristo Mountain range.

The expansive flat part of the San Luis Valley, which contains little to no National Forest lands, is composed of unconsolidated sediments laid down in the late Tertiary period. The San Juan and Sangre de Cristo mountain ranges provided these materials but the ranges are of very different origin and geologic age. The majority of the San Juan Mountains are volcanic rocks and related shallow intrusive rocks of the mid- to late Tertiary period. These rocks formed as a result of multiple outpourings of lava and ash from a

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cluster of volcanos. Recognized as the San Juan Volcanic Field, it is the largest erosional remnant of a continuous volcanic field that once extended over much of the southern Rocky Mountains in Oligocene times. The volcanic sequence involved initial intermediate lavas and breccias followed by more silicic ash flow tuffs, ending with a combination of basalts and rhyolites. This part of the San Juan range consists of rolling foothills in the east to steep alpine slopes along the Continental Divide.

The Sangre de Cristo Mountain range is of more recent origin than the San Juan Mountains but the rocks themselves are appreciably older. These mountains consist of a very steep, narrow ridge formed as a result of faulting and thrusting along the Rio Grande rift. The mountains are composed of sedimentary rocks of the Pennsylvanian period along with Pre-Cambrian granites, gneisses, and schists. Landforms vary from steep alpine glacial cirques to very broad alluvial fans at the mouth of drainages.

Soils in the San Juan Range are typical of those derived from volcanic material. They are generally shallow to moderately deep, medium textured, and low to moderate in nutrient content. Organic matter and nitrogen levels tend to be low because of low rates of decomposition and nitrogen fixation. Shallow, course textured, rocky soils are found on ridgetops and adjacent steep slopes. The southern part of the San Juan Range near the New Mexico border has volcanic material laid over shale so mass movements are common. There are soils in the Alamosa canyon area that are inherently highly erosive. Also in this area are soils where natural rock acidity results in naturally high levels of leaching of heavy metals.

Soils in the Sangre de Cristo Range tend to be moderately shallow and are course textured. Due to limited moisture, steepness, and course texture these soils are moderately erodible and infertile.

As with many soils, surface disturbing activities such as timber harvest, grazing, recreation developments, road construction, and off-road motorized use, are the greatest threat to loss of soil integrity, primarily due to erosion and soil compaction.

Table 6. Landtype associations on the Rio Grande National Forest and important attributes of each.

Land Type Association	1 – Engelmann Spruce on Mountain Slopes	2 – Aspen on Mountain Slopes	3 – White Fir and Douglas-fir on Mountain Slopes
Extent (Acres and % of Forest)	893,000 and 49	39,121 and 2	93,000 and 5
Elevation Range (feet)	8,600-12,000	9,000-11,000	8,000-11,000
Precipitation Range (inches)	16-40	18-30	12-30
Soil Depth	Shallow to very deep	Shallow to moderately deep	Moderately deep to very deep
Slope (%)	0-60	15-60	2-80
Erosion Hazard	Moderate to High	Moderate to High	Moderate to High
Mass Movement Potential	Very low to low	Low	Very low to low
Timber Productivity (site index)	35-85 for Engelmann spruce (base age 100 years)	30-40 for aspen (base age 80 years)	40-60 for Douglas-fir (base age 100 years)
Range Productivity (dry/average/wet years lbs/acre)	25-100, 50-150, 75-250	100-800, 200-1500, 400-2000	20-100, 30-150, 50-200
Nutrient Cycling Rates	Slow to Moderate	Moderate	Slow to Moderate

Table 7. Landtype associations on the Rio Grande National Forest and important attributes of each (cont.).

Land Type Association	4 – Alpine Sedges and Forbs on Alpine Summits	5 – Ponderosa Pine and Douglas-Fir on Mountain Slopes	6 – Pinyon on Mountain Slopes
Extent (Acres and % of Forest)	250,000 and 14	101,010 and 6	85,000 and 5
Elevation Range (feet)	11,000-14,000	7,600-10,500	7,600-9,500
Precipitation Range (inches)	30-50	12-25	12-20
Soil Depth	Shallow to very deep	Shallow to very deep	Shallow to very deep
Slope (%)	5-90	5-90	10-80
Erosion Hazard	Moderate to High	High	Moderate to High
Mass Movement Potential	Low to High	Very low to moderate	Very low to low
Timber Productivity (site index)	N/A	25-35 for Douglas-fir (base age 100 years)	N/A
Range Productivity (dry/average/wet years lbs/acre)	500-1200, 800-1500, 1000-2000	500-600, 700-1000, 900-1200	400-500, 600-800, 800, 1100
Nutrient Cycling Rates	Moderate	Slow to Moderate	Slow to Moderate

Table 8. Landtype associations on the Rio Grande National Forest and important attributes of each (cont.).

Land Type Association (LTA 7 not included due to small areal extent)	8 – Arizona Fescue on Mountain Slopes	9 – Thurber Fescue on Mountain Slopes	10 – Willow and Sedges on Floodplains
Extent (Acres and % of Forest)	95,000 and 5	102,000 and 6	54,000 and 3
Elevation Range (feet)	8,400 to 10,800	8,400 to 10,800	8,600 to 11,600
Precipitation Range (inches)	14-25	18-45	17-35
Soil Depth	Shallow to very deep	Shallow to deep	Very deep
Slope (%)	5-70	2-70	0-30
Erosion Hazard	Moderate	Moderate (High in Chama Basin)	Low to Moderate
Mass Movement Potential	Very low to low	Very low to low (High in Chama Basin)	Very low to moderate
Timber Productivity (site index)	N/A	N/A	N/A
Range Productivity (dry/average/wet years lbs/acre)	700-1200, 1400-1500, 1800	1200-2000, 1500-2500, 1800-3000	1200-2000, 1800-3000, 2500-4000
Nutrient Cycling Rates	Rapid	Rapid	Rapid

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Table 9. Landtype associations on the Rio Grande National Forest and important attributes of each (cont.).

Land Type Association (LTA 7 not included due to small areal extent)	11 – Non-vegetated Areas on Mountain Slopes	12 – Western Wheatgrass and other Low-Elevation Grasslands on Alluvial Fans	13 – Engelmann Spruce on Landslides
Extent (Acres and % of Forest)	46,000 and 3	25,000 and 1	37,000 and 2
Elevation Range (feet)	8,400 to 14,000	8,800 to 9,300	8,800 to 11,800
Precipitation Range (inches)	12-30	12-18	20-45
Soil Depth	N/A	Very deep	Very deep
Slope (%)	2-200	0-40	2-60
Erosion Hazard	N/A	Low to Moderate	Moderate
Mass Movement Potential	N/A	Very low	Moderate to high
Timber Productivity (site index)	N/A	N/A	55-95 for Engelmann spruce (base age 100 years)
Range Productivity (dry/average/wet years lbs/acre)	N/A	350-1000, 600-1500, 800-1800	50-100, 75-150, 100-200
Nutrient Cycling Rates	N/A	Rapid	Slow to moderate

As previously mentioned soil surveys exist for the Forest. These surveys delineate the Forest into map units. Each map unit has detailed information about the soils within the unit, as well as management interpretations. Summarizing this voluminous amount of information into this assessment would be unwieldy. In lieu of that, land type associations (LTAs) and key elements of them, are presented to paint a generalized picture of soils across the Forest (Table 6 through Table 9 and Map 9). There are thirteen land type associations. The tables include twelve of the thirteen. LTA 7, Gambel Oak on Mountain Slopes, is not presented because it comprises well less than one percent of the Forest.

Table 10. Watershed Condition Framework ratings by Indicator and Attributes. The first number represents the number of watersheds rated as such; the second number represents the percent of all watersheds on the Forest rated as such.

	Indicator	Attributes		
	Soils Condition	Productivity	Erosion	Chemical Contamination
Good	34 (22%)	38 (25%)	28 (18%)	52 (34%)
Fair	117 (77%)	113 (74%)	123 (81%)	100 (56%)
Poor	1 (1%)	1 (1%)	1 (1%)	0 (0%)

Conditions

Watershed Condition Framework

The Watershed Condition Framework characterizes the health and condition of National Forest System lands. The characterization is a reconnaissance-level approach using a comprehensive set of twelve indicators and twenty-four attributes that are surrogate variables representing ecological, hydrological,

and geomorphic functions and processes that affect watershed condition. The primary emphasis of the classification is on aquatic and terrestrial processes and conditions that Forest Service management activities can influence. The initial or baseline characterization for the Rio Grande National Forest was completed in 2011.

One of the twelve indicators is Soils Condition. This indicator addresses alteration to natural soil condition, including productivity, erosion, and chemical contamination. Each of the 152 sub-watersheds on the Forest is assigned a rating of Good (Functioning Properly), Fair (Functioning at Risk), or Poor (Impaired Function). Roughly one-third of the watersheds on the Forest are functioning properly relative to overall soils condition (Table 10). Roughly two-thirds of the watersheds are functioning at risk due to productivity, erosion, and/or chemical contamination concerns. Productivity concerns are related to soil nutrient and hydrologic cycling processes due to past and present management activities such as livestock grazing, timber harvest, and wildfire. Erosion concerns relate to areas where there is evidence of accelerated surface erosion, or rills and gullies are present but are generally small, disconnected, poorly defined, and not connected into any pattern. Soil contamination concerns relate primarily to areas where atmospheric deposition may be a source of contamination but at this point is not having a substantial effect on overall soil quality. The one watershed that is rated impaired function is Cottonwood Creek/Kirby Creek where there are concerns with historical mining.

There are other indicators and attributes within the Watershed Condition Framework indirectly related to soils. Summary information for these indicators and attributes is in the Air and Watersheds and Water Resources section of this assessment.

Other

The Forest conducts soil health assessments on timber sales, commercial livestock grazing allotments, burn areas, mining areas and recreation areas. For the most part these assessments indicate impacts to soil integrity are prevented. Some project assessments have resulted in identification of concerns, at which time mitigation is applied to correct deficiencies and protect soil health.

Trends

Livestock grazing, timber harvest, mining, and wildfires were the dominant activities on the Rio Grande National Forest historically. These activities resulted in considerable amounts of bare soil resulting from destruction of soil protective layers such as leaf litter and vegetation. Significant erosion resulted and soil productivity was likely affected. Ocular monitoring and professional judgement by soil scientists in more recent times indicate vegetative recovery has stabilized soils across the Forest to the extent expected and soil processes have returned but productivity may never completely return to pre-disturbance levels. Appendix A in the current Forest Plan provides a good history and summary of these historical impacts.

Little to no information exists on current trends in soil condition other than conditions now are generally better than they were in the past. While current activities can result in soil compaction, erosion, and loss of organic matter, such effects are generally more localized than they were historically and current technology and restoration techniques provide better opportunity to mitigate the effects.

The potential effects of a changing climate on soil conditions across the Forest are not well known and at this point are more hypothetical than not. Colorado's climate has warmed in recent decades, and climate models unanimously project this warming trend will continue into the future (Lukas et al 2014)). Climate change has and will continue to impact resources in the State, likely including soil condition on the Rio Grande National Forest. Gordon and Ojima (2015) synthesized observed climate and projected future climate for the State of Colorado (Table 11).The projected changes in climate and associated hydrology serve as a good proxy to potential direct, indirect, and cumulative effects on soil conditions. Gordon and

Ojima's report also discusses key ecosystem vulnerabilities, which relate to potential future soil conditions (Table 12).

Multiple Uses / Ecosystem Services

The soil resource on the Rio Grande National Forest, in conjunction with air, water and watershed resources, is part of the foundation for providing for the full suite of multiple uses available from national forests. Productive and stable soils are the building blocks for most all uses, products, and services the Forest provides. For example, soils provide the growth medium for vegetation found on timber and rangelands; soils are important in nutrient cycling and providing carbon sinks, which helps with climate regulation; and soils filter, purify and store water for on-Forest and downstream uses.

Local Soil Resource Concerns

As a general rule soil quality and productivity concerns exist with existing system roads and trails, uncontrolled motorized use on unauthorized roads and trails, and livestock grazing in riparian areas. The first two concerns relate to accelerated soil erosion and effects on soil productivity. The third concern relates to soil compaction and effects on soil productivity and infiltration of water. Adequate protection of soil quality and productivity exists in the form of Best Management Practices, which are proven measures that protect the soil resource if properly implemented and monitored. The concern is that formal and informal monitoring indicates the practices are not always being fully and properly implemented at the project level.

Table 11. Historic climate observations and projected climate for the State of Colorado.

Historic Climate Observations	Projected Climate
An increase in statewide annual average temperatures of 2 degrees F over the past 30 years and 2.5 degrees F over the past 50 years, with minimum temperatures increasing more than daily maximum temperatures over the past 30 years	An increase in statewide average annual temperatures of 2.5F to 5.5F relative to a 1971-2000 baseline. Summers are projected to warm slightly more than winters. Typical summer temperatures in 2050 are projected to be warmer than in all but the very hottest summers in the observed record.
An increase in temperatures in all seasons, with the largest trend in summer, followed by fall, spring, and winter.	Climate projections do not agree on whether average annual precipitation will increase or decrease statewide, though winter precipitation is likely to increase by mid-century.
No long-term trends in average annual precipitation statewide.	Most projections show that April 1 snowpack will decline by mid-century due to the large projected warming.
Below-average snowpack since 2000 in all eight major river basins in Colorado, although there are not trends over the past 30 or 50 years.	Spring runoff is projected to shift 1-3 weeks earlier due to warming, with late summer flows likely to decrease as the peak shifts earlier.
Snowmelt and peak runoff have shifted 1-4 weeks earlier across Colorado's river basins over the past 30 years due to the combination of lower snow-water equivalent (SWE) since 2000, warming spring temperatures, and enhanced solar absorption from dust-on-snow.	Most projections of future hydrology show decreases in annual streamflow by 2050 for Colorado's major rivers. In some projections, however, the projected increases in precipitation are large enough to overcome the effect of warming, and so these projections show increased streamflow.
A trend toward more frequent soil moisture drought conditions in Colorado over the past 30 years.	Heat waves, droughts and wildfires are projected to increase in frequency and severity due to the projected overall warming.
No evidence of increasing trends in heavy precipitation events or flooding statewide.	Winter precipitation events are projected to increase in frequency and magnitude, but projections currently show no changes in summertime convective storms by mid-century.

Historic Climate Observations	Projected Climate
Multiple droughts prior to 1900 that were more severe and sustained than any in the observed record, as seen in tree-ring records.	

There may be a developing concern with atmospheric deposition of nitrogen and its effects on soil chemistry and productivity as discussed in the air section of this assessment. Monitoring is needed to confirm or dispute this potential concern.

Table 12. Key ecosystem sector vulnerabilities for the State of Colorado.

Landscape	Vulnerability
Forests	Due to longer and more severe droughts, more frequent and severe fires, and conditions more suitable to insect outbreaks and spread of no-native plant species, individual trees and forested landscapes will likely become more vulnerable to insect and pathogen invasions. If wildfires become more frequent and severe, landscapes will be vulnerable to changes in connectivity, shifts from carbon sinks to carbon sources, and shifts in vegetation distribution and type.
Alpine	Alpine plants are vulnerable to phenology shifts caused by rising spring temperatures and earlier snowmelt onset, potentially leading to mid-summer declines.
Grasslands	Grass types that fare better in drought conditions are likely to become more dominant; less drought-tolerant species are therefore vulnerable to increased frequency and severity of drought.

Need for Change

Based on information in this section of the assessment, there is little to no need for change in the existing Plan. As a general rule monitoring indicates existing direction is being met when best management practices at the project level are properly implemented. There are occasions when soil resources concerns are identified during project reviews but these concerns are not Forest Plan standard related; rather they are related to lack of proper implementation of one or more watershed conservation practices, i.e., Best Management Practices, which is a contract or permit administration issue, e.g., compliance with term grazing permit conditions, or a specific program area issue, e.g., road and trail maintenance.

The standards and guides section of the existing plan does need to be updated to incorporate the Watershed Conservation Practices Handbook, the National Best Management Practices program, and the Watershed Condition Framework. At the time the current plan was written the WCP handbook was in draft form and neither the national BMP program nor the Watershed Condition Framework existed. All three of these items are key parts of the 2012 Planning Rule.

As mentioned previously in both this soils section and in the air quality section of this assessment there may be a developing concern with atmospheric deposition of nitrogen and its effects on soil chemistry and productivity. Monitoring is needed to confirm or dispute this potential concern. This assessment also suggests climate change could have negative effects on soil resources. Thus, it is critical the Forest remains diligent in providing the desired condition for soil resources. To that end the Forest should continue development, adjustment, and implementation of the soil resources program, and consider preparing a Forest-wide soil resource monitoring plan. The preparation of this resource specific monitoring plan could coincide with Forest Plan revision or be conducted separately. This plan should consider adaptive strategies that address current off-Forest sources of nitrate pollution and the potential effects of climate change that are designed to protect and preserve the soil resource.

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Watersheds and Water Resources

Introduction

Watersheds and water resources are credibly the most important resources of and provided by the Rio Grande National Forest. Protection of water quantity, quality, and timing of flows, and the watersheds from which water resources are derived, remains critical to sustaining ecosystem function of the Forest itself and the socio-economics of the San Luis Valley and areas further downstream. Because of this, watersheds and water resources have been and will continue to be a significant part of the history of the Rio Grande National Forest.

The 2012 Planning Rule requires National Forests and Grasslands to consider watersheds and water resources when developing plan components. The purpose of this assessment is to evaluate available information about watersheds and water resources within the Rio Grande National Forest. This assessment describes current conditions and trends regarding these resources. This information is used to anticipate future conditions, and to determine if trends pose risks to system integrity at the forest level. Additionally, this assessment identifies information gaps and any uncertainty with the data. The information contained in this assessment will be used to inform agency officials whether current direction needs adjustment to protect watersheds and water resources and the systems that rely on them.

The following items are addressed in this assessment, as specified by Forest Service Handbook, Chapter 10 Section 12.23.

- Condition and trend of watersheds, water quality, and quantity in the plan area as well as those that extend outside the plan area that influence the plan area or vice versa, assuming existing plan direction remains in place
- Surface and groundwater resources, including identification of impaired and/or contaminated surface and groundwater, and sources of impairment.
- Quantity, quality, timing, and distribution of water across the plan area and the area of analysis, including groundwater resources and groundwater-dependent ecosystems
- Flow regimes needed to sustain ecosystems
- Historical context for ecological conditions under which the hydrologic systems developed
- The nature, extent, and role of existing and reasonably foreseeable future consumptive uses and non-consumptive uses
- The nature and distribution of Federal and non-Federal water rights across the plan area
- The reasonably anticipated future patterns of perturbation (such as altered precipitation, changing climate, drought, evapotranspiration patterns, flood, and temperature changes), and how these disturbances may affect watersheds, water quality and/or quantity
- The municipal watersheds, sole source aquifers, and source water protection areas within the plan area and area of analysis, and any management concerns related to these resources
- The effects of land use, projects, and activities, and reasonably foreseeable future water withdrawals and diversions, and water storage facilities (surface and subsurface) on hydrologic and geomorphic processes and water resources
- Ecological, social, and economic roles that water resources play in the context of the broader landscape

- Places on the Forest where water resources are at risk or not adequately protected, and associated management concerns or ecosystem stressors/threats

Concepts in Watershed and Water Resources Management

Watershed Processes

Watersheds are drained by a stream network of perennial streams that flow year-round, intermittent streams that flow seasonally, and ephemeral streams (including swales) that flow only during runoff events. The stream network expands during runoff events. Most material that enters any part of the network will eventually reach an aquatic ecosystem.

Most material that enters streams comes from an adjacent source zone whose width depends on land form, stability, and ground cover. Sediment is natural, but roads and other disturbed sites can act as channels that multiply sediment loads to the stream network during runoff events. Such "connected disturbed areas" can be a major source of damage to aquatic ecosystems.

If organic ground cover in a watershed is reduced enough to markedly increase the magnitude or duration of high flows, stream channels may erode their banks to damage their stability and aquatic habitat. Direct bank damage may add large amounts of sediment directly into streams. Soil quality depends on soil structure, organic matter, nutrient pools, and biotic processes. Soil quality is impaired when these qualities are markedly degraded for a period of years. Severe disturbances can impair soil quality by heating, displacing, compacting, or eroding the soil.

Historic ranges of native aquatic biota were determined by physiographic and hydrologic boundaries and biotic behavior. These patterns have been changed by fishing pressures, introduction of exotics, and migration barriers such as dams and diversions, as well as by habitat impacts. Biotic strategies that address these relationships are needed as well as watershed conservation practices in order to sustain vigorous populations of desired aquatic communities.

Dynamic Equilibrium

A healthy watershed operates in dynamic equilibrium. Soil and water quality, flow regimes, and aquatic and riparian habitats vary within a certain range of conditions. Large natural disturbance events shift a watershed out of equilibrium. Recovery then begins. Poor land management practices can shift a watershed out of equilibrium.

Laws and common sense direct us to maintain equilibrium conditions between large natural disturbance events, avoid actions that may shift a watershed out of equilibrium or worsen major events, and assist watershed recovery. The natural resilience of the system must be conserved in order to sustain ecosystem health.

Some disturbance can occur and still sustain watershed health. If runoff and sediment regimes, soil and channel conditions, water quality, and aquatic and riparian habitats are maintained between large natural disturbance events, watershed health is conserved.

The concept of dynamic equilibrium can be applied to biological processes as well as physical landform processes. Natural processes are not static or absolutely stable, but there is a tendency for the form to maintain relatively stable characteristics. Natural perturbations influence these natural processes, which then begin the process of moving toward pre-event characteristics. Dynamic equilibrium can be both ‘short-term’ such as life-history changes of fish associated with the annual hydrograph or ‘long-term’ such as the stream channel adjustments following natural fire events.

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Land and Stream Types

The goal of watershed conservation is to sustain and restore watershed health in each watershed. Land and water conditions must be kept within the dynamic equilibrium ranges for the local landscape. Land and stream types, and their dynamic equilibrium ranges, vary within and among landscapes due to variations in climate and geology. This variation must be taken into account. In each landscape, dynamic equilibrium conditions vary by land types and stream types. These ranges can be defined by sampling reference land and stream types in that landscape. The efficacy of watershed conservation practices is assessed by comparing each land type and stream type with its own capability.

Land factors reflecting soil and stream health include ground cover, soil bulk density, connected disturbed areas, and slope stability. Water factors include channel widths-depths, large woody debris, substrate, bank stability, flow regime, and water chemistry. Other factors may also be locally important.

Design and Risk

Watersheds experience periodic disturbance events that vary in their size, duration, and frequency. The randomness of such events implies some level of risk with any design. This risk is a product of the probability of an event occurring and its consequences. Watershed conservation practices are designed to control runoff damage from at least a 10-year storm of any duration.

Legal Framework and Forest Service Policy

The Forest Service has a role in implementing watershed and water resources management programs. This role is identified in and a result of numerous legislative acts, regulations, and standards.

Organic Act

The Organic Act defines original National Forest purposes to improve and protect the forest, secure favorable conditions of water flows, and furnish a continuous supply of timber. Years of concern about watershed damage led to creation of the National Forest System. Watersheds must be cared for to sustain their hydrologic function as "sponge-and-filter" systems that absorb and store water and naturally regulate runoff. The goals are good vegetation and ground cover, streams in dynamic equilibrium with their channels and flood plains, and natural conveyance of water and sediment.

Multiple-Use Sustained Yield Act

The Multiple-Use Sustained Yield Act established that the sustained yield of goods and services from National Forests must be conducted without permanent impairment of the productivity of the land.

National Forest Management Act

The National Forest Management Act directed each national forest to prepare a land and resource management plan. The Act recognizes national forests are ecosystems and their management requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems. The Act requires Forests to ensure management will not produce substantial and permanent impairment of the productivity of the land.

Rio Grande National Forest Land and Resource Management Plan

The water resource is a recognized component of the Rio Grande National Forest Land and Resource Management Plan (Forest Service 1996). The Final Environmental Impact Statement (FEIS) for the Forest Plan recognized watersheds and streams can retain a healthy balance provided resource use and disturbance is properly managed and with this watersheds will be protected in four important ways:

- Assessing risk resulting from past, present, and foreseeable future impacts and the presence of sensitive areas
- Using watershed conservation practices (Best Management Practices) to minimize the impacts of disturbances
- Disconnecting disturbances from streams, wetlands, and riparian areas
- Using reference streams as benchmarks to ensure all streams are adequately protected

Desired conditions, objectives, and standards and guidelines in the Plan are described in a subsequent section of this assessment. Annual Forest Plan monitoring reports provide annual summaries of water resources on the Forest and indicate water resources are being adequately protected and no changes in the Forest Plan are needed.

Agency Policy

The Rocky Mountain Region utilizes Forest Service Handbook 2509.25 – Watershed Conservation Practices Handbook. This handbook established regional watershed conservation practices to protect soil, aquatic, and riparian systems. The practices cover five areas: hydrologic function, riparian areas and wetlands, sediment control, soil quality, and water purity. Each practice consists of a management measure, a set of design criteria used to achieve the specific management measure, and guidance for monitoring and restoration. The policy is to apply the practices to sustain healthy soil, riparian, and aquatic systems by adopting a stewardship ethic that treats land and resources as public assets for long-term benefits.

The Forest Service utilizes the National Core Best Management Practices Program as over-arching direction on the importance of prescribing, implementing, and monitoring proven soil and water protection measures at the project-scale on National Forest lands. Agency policy requires the use of Best Management Practices to control nonpoint source pollution to meet applicable water quality standards and other Clean Water Act requirements.

Information Sources and Gaps

Information Sources

Carlson, Joan. 2008. White Paper - Potential Risks and Impacts to Soil and Water Resources from Mountain Pine Beetle Mortality, Treatments and Wildfire in Colorado and Wyoming National Forests. USDA Forest Service, Rocky Mountain Region. 40 pages.

Carlson, Joan. 2010. White Paper - Livestock Grazing and Bacterial Water Quality: Supporting documentation for the Rocky Mountain Region Bacteria Analysis Strategy for Rangeland Management Projects. USDA Forest Service, Rocky Mountain Region. 64 pages.

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Forest Service. Watershed Conservation Practices Handbook.

Forest Service GIS Library

Furniss, Michael J., Ken B. Roby, Dan Cenderelli, John Chatel, Caty F, Clifton, Alan Clingenpeel, Polly E. Hays, Dale Higgins, Ken Hodges, Carol Howe, Laura Jungst, Joan Louie, Christine Mai, Ralph Martinez, Kerry Overton, Brian Staab, Rory Steinke, and Mark Weinhold. 2013. *Assessing the Vulnerability of Watersheds to Climate Change: Results of National Forest Watershed Vulnerability Pilot Assessments.* Gen. Tech. Rep. PNW-GTR-884. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 pages plus appendix.

Gordon, Eric and Dennis Ojima. 2015. *Colorado Climate Change Vulnerability Study.* University of Colorado Boulder and Colorado State University. 190 pages.

Lukas, Jeff, Joseph Barsugli, Nolan Doesken, Imtiaz Rangwala, and Klaus Wolter. 2014. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.* University of Colorado Boulder. 114 pages.

MacDonald, Lee H. and John D. Stednick. 2003. Forests and Water: A State-of-the-Art Review for Colorado. Colorado State University. 65 pages.

Troendle, C.A. and G.S. Bevenger. 1996. *Effect of Fire on Streamflow and Sediment Transport in the Shoshone National Forest*. The Ecological Implications of Fire in Greater Yellowstone. Second Biennial Conference on the Greater Yellowstone Ecosystem. Yellowstone National Park, Wyoming.

USGS and NRCS. 2013. *Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD)* (4 ed.): U.S. Geological Survey Techniques and Methods 11-A3. 63 pages.

Numerous websites as shown throughout the document; links to each site are contained in the narrative. Some of the figures are downloaded from these sites.

Data Gaps

There is a lack of quantitative base and trend data on stream health, particularly physical function, i.e., stream pattern, profile, and dimension.

There is a lack of quantitative information on groundwater resources, particularly groundwater dependent ecosystems (GDEs).

Existing Forest Plan Direction for Watersheds and Water Resources

Desired Conditions

Healthy watersheds operate in a dynamic equilibrium between extreme natural events. Surface-disturbing activities are managed so that floods, droughts, sediment loads, bank erosion, rills, gullies, and landslides are not markedly increased.

Water quality is maintained or improved, with all stream segments having a near-reference stream appearance. Water is suitable for municipal water supplies after normal treatment, including those using shallow alluvial aquifers. Chemical, physical, and biological attributes are improved and maintained in a healthy condition, ensuring future use.

Stream health is maintained through natural processes without artificial controls. Streams have the expected range of habitat features, (for example, healthy riparian vegetation, stable banks, overwintering pools and healthy aquatic organisms).

Riparian areas and floodplains are healthy, fully functioning ecosystems. Vegetation is diverse and is generally in a later-seral condition, to provide site stability.

Fish thrive in Forest lakes and streams due to adequate habitat and water quality. Natural fish habitat is preferred and promoted over human-made habitat.

Objectives

Maintain or improve the integrity of aquatic ecosystems to provide for good water quality, stream-channel stability, water yield, and aquatic resources.

- Manage for sustained water flows according to negotiated agreements with water users.
- Improve watershed conditions to restore favorable soil relationships with water quality.
- Mitigate impacts from ground-disturbing activities before closing out project activities.
- Maintain chemical, physical, and biological stream attributes in a healthy condition. If necessary, improve them.

Maintain sport-fishing opportunities by providing quality fishery habitat. Support the maintenance of native fish species by protecting existing suitable habitats for both natural and reintroduced populations.

Cooperate with other federal and state agencies to control and clean up hazardous mining waste and mine drainage.

Protect the integrity of the soil and water resources by discouraging motorized-vehicle use in wetlands, wet meadows, and riparian areas.

Standards and Guidelines

There are eight (8) pages of standards and guidelines that cover soil, water, and aquatic resources, including fish, riparian areas and wetlands. These standards and guidelines center around five (5) core areas: hydrologic function, riparian areas, sediment control, soil productivity, and water purity. These core areas, standards, and guidelines were derived from a draft of the original Region 2 Watershed Conservation Practices Handbook. Rather than reiterate eight pages of document the reader should refer to pages III-4 through III-11 of the current Forest Plan.

Scale of Analysis

The Rio Grande National Forest lies at the headwaters of the Rio Grande River. The Rio Grande River drainage begins at the Continental Divide along the west edge of the Forest and flows to the Gulf of Mexico. River basins or watersheds are delineated into a nested hierarchy represented by Hydrologic Unit Codes (HUCs) numbered with 2 to 12 digits, which are then categorized with names into regions, sub-regions, basins, sub-basins, watersheds and sub-watersheds (USGS et al 2013). The Rio Grande National Forest lies within six sub-basins (4th-level or 8-digit):

- Rio Grande Headwaters, HUC 13010001
- Alamosa-Trinchera, HUC 13010002
- San Luis, HUC 13010003
- Saquache, HUC 13010004
- Conejos, HUC 13010005
- Rio Chama, HUC 13020102

Relative to the Forest, these sub-basins are further divided into 38 watersheds (generally 40,000 to 250,000 acres) and 166 sub-watersheds (10,000 to 40,000 acres) (Map 10).

The characterization of watersheds and water resources in this assessment is bound by the six sub-basins listed above, but focuses on conditions and trends within the Rio Grande National Forest at the sub-watershed scale.

Existing Condition and Trend of Watersheds and Water Resources

Inventories

There is a watershed improvement needs inventory in hard copy at the Supervisor's Office. Accompanying this inventory is a spreadsheet being used to track project implementation.

There is the Watershed Condition Framework which characterizes the health and condition of National Forest System lands.

There is a water rights inventory which contains information on Forest Service water uses and rights.

There are stream health surveys for a limited number of stream segments across the Forest. Some of these locations are considered reference reaches (see Forest Plan Appendix J).

There are Proper Functioning Condition (PFC) assessments and Multiple Indicator Monitoring (MIM) sites for a limited number of riparian areas across the Forest.

There is an Abandoned Mine Land (AML) inventory.

Important Attributes, Characteristics, and Processes

The Forest is in the headwaters of the Rio Grande River in an area known as the San Luis Valley. The valley itself is long, wide, and flat with small amounts of national forest land on the margins. The western and northern part of the Forest is in the San Juan Mountain range bounded by the Continental Divide and Poncha Pass. The eastern part of the Forest is in the Sangre de Cristo Mountain range.

The expansive flat part of the San Luis Valley, which contains little to no National Forest lands, is composed of unconsolidated sediments laid down in the late Tertiary period. The San Juan and Sangre de Cristo mountain ranges provided these materials but the ranges are of very different origin and geologic age. The majority of the San Juan Mountains are volcanic rocks and related shallow intrusive rocks of the mid- to late Tertiary period. These rocks formed as a result of multiple outpourings of lava and ash from a cluster of volcanos. Recognized as the San Juan Volcanic Field, it is the largest erosional remnant of a continuous volcanic field that once extended over much of the southern Rocky Mountains in Oligocene times. The volcanic sequence involved initial intermediate lavas and breccias followed by more silicic ash flow tuffs, ending with a combination of basalts and rhyolites. This part of the San Juan range consists of rolling foothills in the east to steep alpine slopes along the Continental Divide.

The Sangre de Cristo Mountain range is of more recent origin than the San Juan Mountains but the rocks themselves are appreciably older. These mountains consist of a very steep, narrow ridge formed as a result of faulting and thrusting along the Rio Grande rift. The mountains are composed of sedimentary rocks of the Pennsylvanian period along with Pre-Cambrian granites, gneisses, and schists. Landforms vary from steep alpine glacial cirques to very broad alluvial fans at the mouth of drainages.

Soils in the San Juan Range are typical of those derived from volcanic material. They are generally shallow to moderately deep, medium textured, and low to moderate in nutrient content. Organic matter and nitrogen levels tend to be low because of low rates of decomposition and nitrogen fixation. Shallow, course textured, rocky soils are found on ridgetops and adjacent steep slopes. The southern part of the San Juan Range near the New Mexico border has volcanic material laid over shale so mass movements are common. There are soils in the Alamosa area that are inherently highly erosive. Also in this area are soils where natural rock acidity results in naturally high levels of leaching of heavy metals.

Soils in the Sangre de Cristo Range tend to be moderately shallow and are course textured. Due to limited moisture, steepness, and course texture these soils are moderately erodible and infertile.

Annual precipitation across the Forest varies from 12 inches at lower elevations to over 50 inches at higher elevations; generally, precipitation increases 4 to 6 inches for each 1000-foot gain in elevation. In the 12 to 18 inch zone (roughly 8,000 to 9,000 feet), most, if not all, the precipitation goes to satisfying evapotranspiration demands so little to no runoff is generated; an exception can be when summer thunderstorm rainfall intensity exceeds the soil infiltration rate, resulting in overland flow potentially reaching stream channels). Above 9,000 feet the Forest is considered a snow-dominated system in that the majority of the annual precipitation falls in the form of snow, while the remainder is from late spring to early fall rains. Summer thunderstorms can produce short-duration, high-intensity precipitation.

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Using an existing NRCS SNOTEL site at Lily Pond as typical representation for precipitation on the Rio Grande National Forest, monthly totals are variable, with early and late winter being the wet months and late spring to early summer being the dry months (Figure 40 and Figure 41). Rains in July and August are considered monsoonal events typical of the southwestern United States.

Snowfall typically begins in October and extends through May. The snowpack builds through this time period, acting as a water storage reservoir that begins to melt in April, causing streams across the Forest to rise accordingly. By late May the majority of the snowpack has melted out, but elevated streamflow continues into August (Figure 42).

The Forest lies within all or part of 166 6th-level size watersheds or hydrologic units (Map 10). These watersheds on average generate 1.5 million acre-feet of water per year. Roughly 1.3 million acre-feet flows from the San Juan Range while the remaining 200,000 acre-feet flows from the Sangre de Cristo Range. There are 11,027 miles of stream channel across the Forest; 1,820 miles are perennial flow (Table 13 and Map 11). There are hundreds of waterbodies that total 3,160 acres; 2,893 acres are perennial (Table 14 and Map 11).

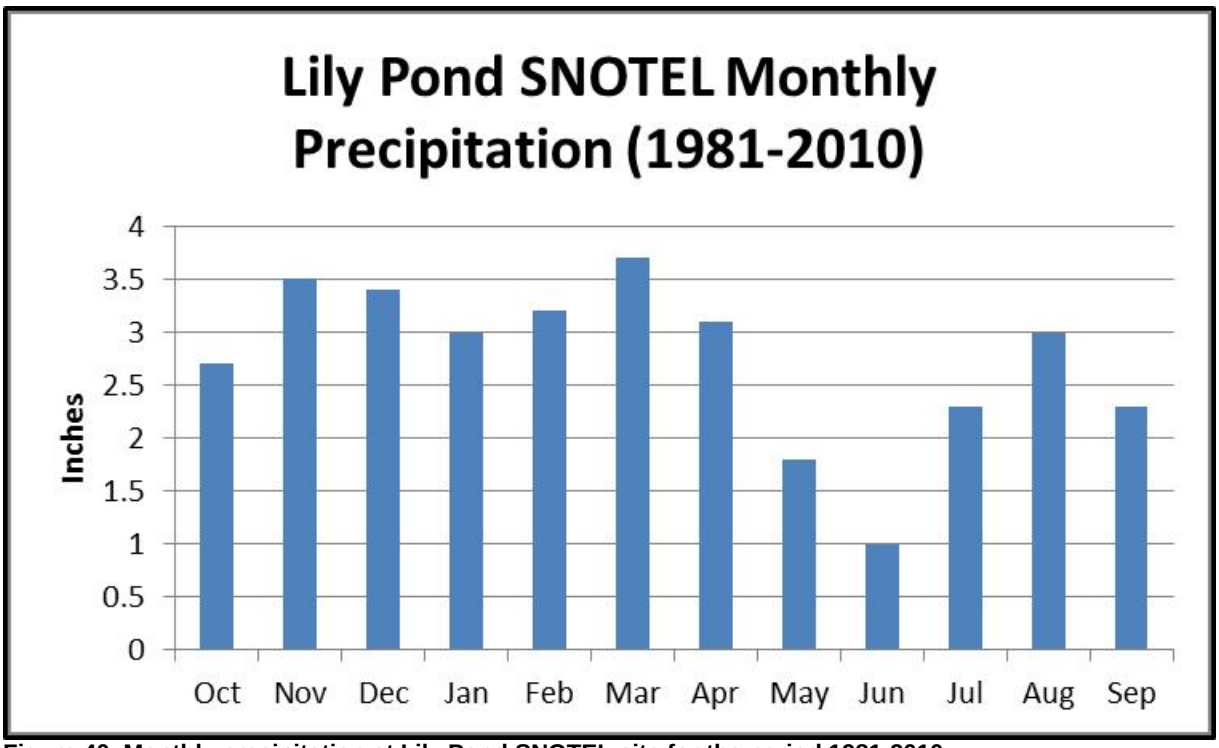

Figure 40. Monthly precipitation at Lily Pond SNOTEL site for the period 1981-2010.

Using a historical USGS gage on the Alamosa River above Terrace Reservoir (USGS gage 08236000) as typical representation for water quantity and timing of flows, i.e., flow regime, on the Rio Grande National Forest, streamflow is predominately from annual snowmelt runoff, but there can be small increases in flow for short periods of time due to summer thunderstorm activity (Figure 43). The volume of water contained within these spikes typically represent only a small percentage of the thunderstorm precipitation total, roughly equivalent to the watershed area occupied by stream channels (Troendle and Bevenger 1996). Annual snowmelt flows typically start to increase in late March to early April, peak in late May to early June, and return to baseflow levels in late August to early September. There is considerable year to year variability in the shape of the annual hydrograph and the number of peak flows

during the snowmelt period (Figure 44). The magnitude of annual peaks also exhibits considerable variability (Figure 45). Flow duration for perennial streams on the Forest is typical of snowmelt dominated areas where the high flow period is relatively short and gradual release of groundwater maintains a baseflow for the remainder of the water year (Figure 46). The flow regime described here is critical for sustaining current ecosystems across the Forest. Conversely, the current ecosystems also result in and sustain the current flow regimes across the Forest. In other words, a change in one results in a corresponding change to the other.

The San Luis Valley is a nationally recognized groundwater resource important to agriculture and local communities (CGS 2003). Basin-fill deposits approach 30,000 feet in depth and support two major hydrogeologic units; an upper unconfined aquifer and a lower confined aquifer (Figure 47). A series of clay layers in the upper part of the confined aquifer defines the confining layer between the upper and lower aquifers. The depth to the confining layers varies from about 100 feet in the northern part of the valley to about 40 feet in the southern part. The northern one-half of the valley has no natural surface or shallow groundwater outlet and is thus a closed basin (Figure 48). This closed basin is a unique geological structure that is hydrologically disconnected from the Rio Grande River. Water from the closed basin is pumped into the Rio Grande River to help meet the needs of the Rio Grande Compact.

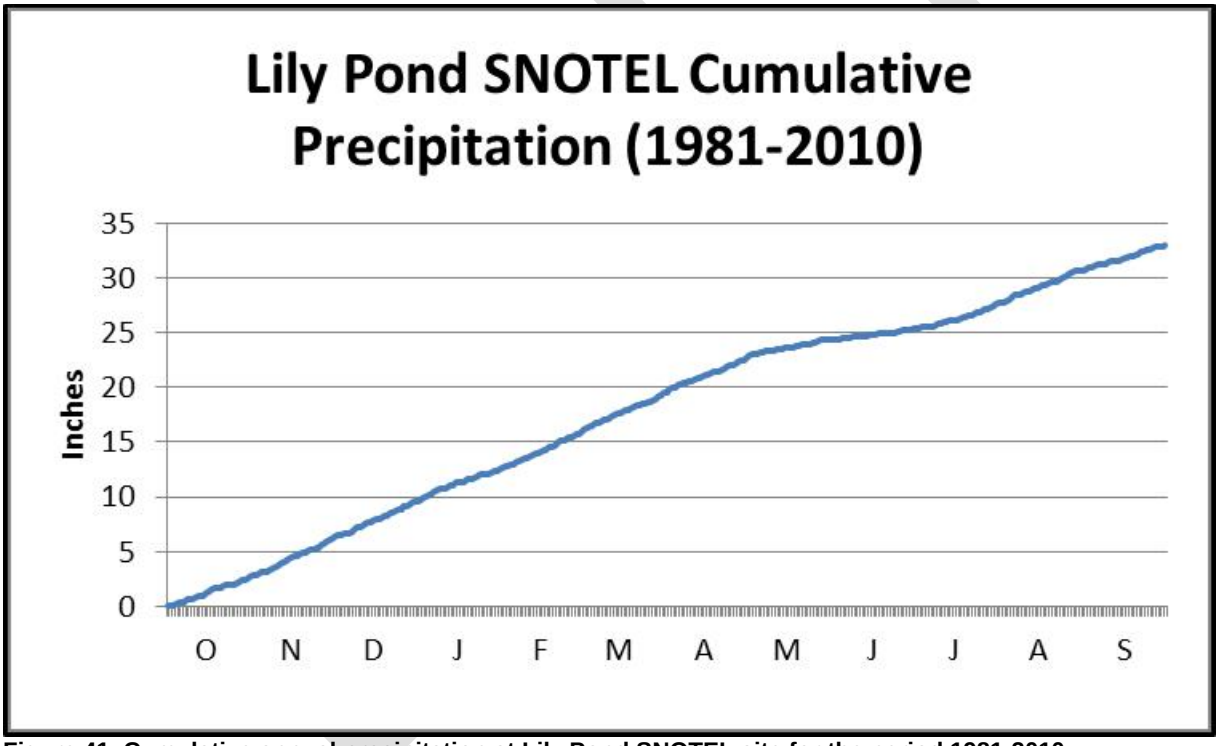

Figure 41. Cumulative annual precipitation at Lily Pond SNOTEL site for the period 1981-2010.

Table 13. Miles of stream by type and Ranger District.

District	Ephemeral	Intermittent	Perennial	Total
Conejos Peak	1095	1094	348	2537
Divide	2423	2554	1006	5983
Saguache	848	1193	465	2506
Total	4366	4841	1819	11026

Table 14. Acres of waterbodies by type and Ranger District.

District	Intermittent	Perennial	Total
Conejos Peak	182	956	1138
Divide	60	1701	1761
Saguache	25	236	261
Total	267	2893	3161

In addition to the two aquifers in the valley proper, there are shallow alluvial deposits along major streams and rivers in the Rio Grande basin, e.g., upper Saguache Creek, upper Rio Grande River, and upper Conejos Creek, which are hydraulically connected with the basin-fill deposits (Figure 49). In the mountainous areas, i.e., the Rio Grande National Forest, the alluvium is separate from underlying crystalline-rock aquifers.

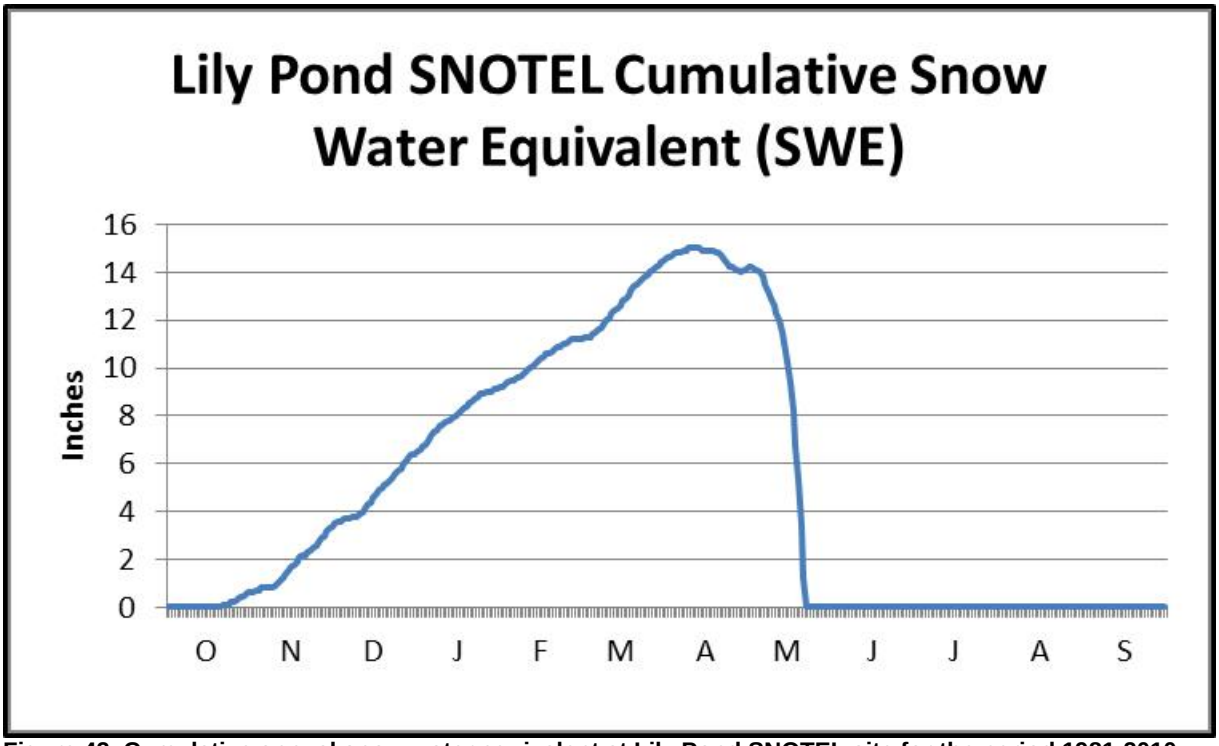

Figure 42. Cumulative annual snow water equivalent at Lily Pond SNOTEL site for the period 1981-2010.

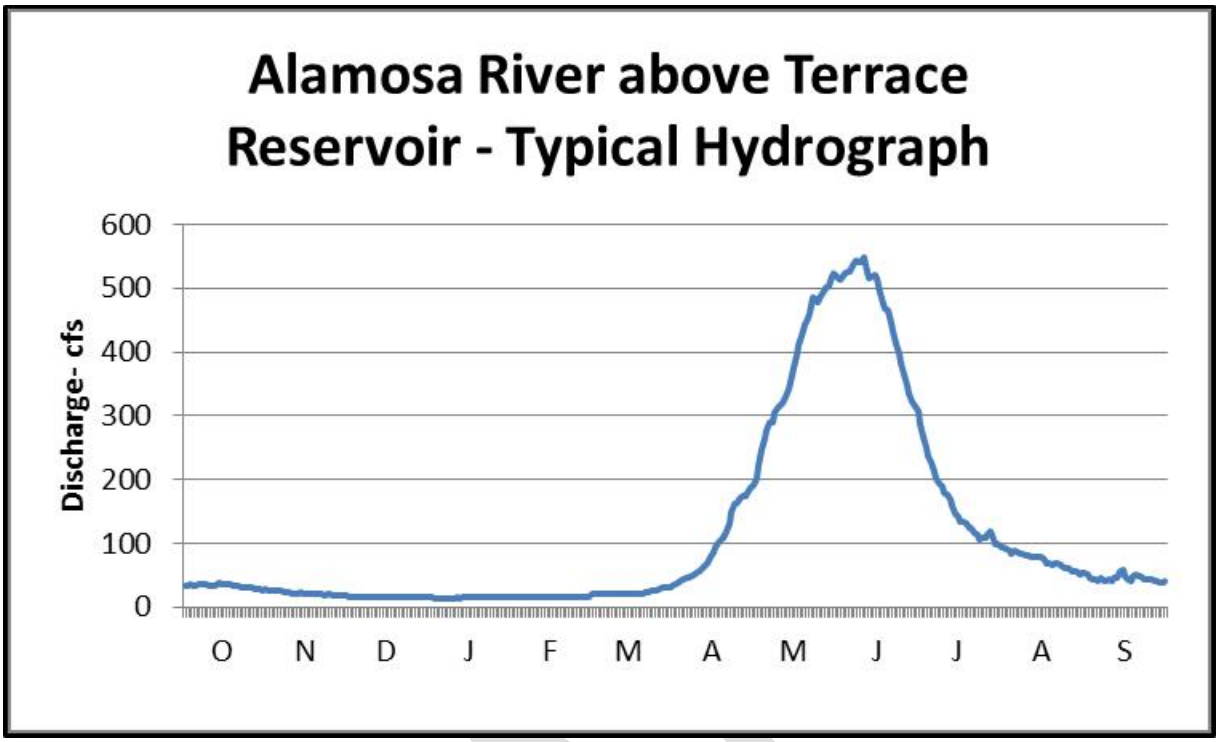

Figure 43. Average annual hydrograph for the Alamosa River above Terrace Reservoir for the period of record 1935-1982.

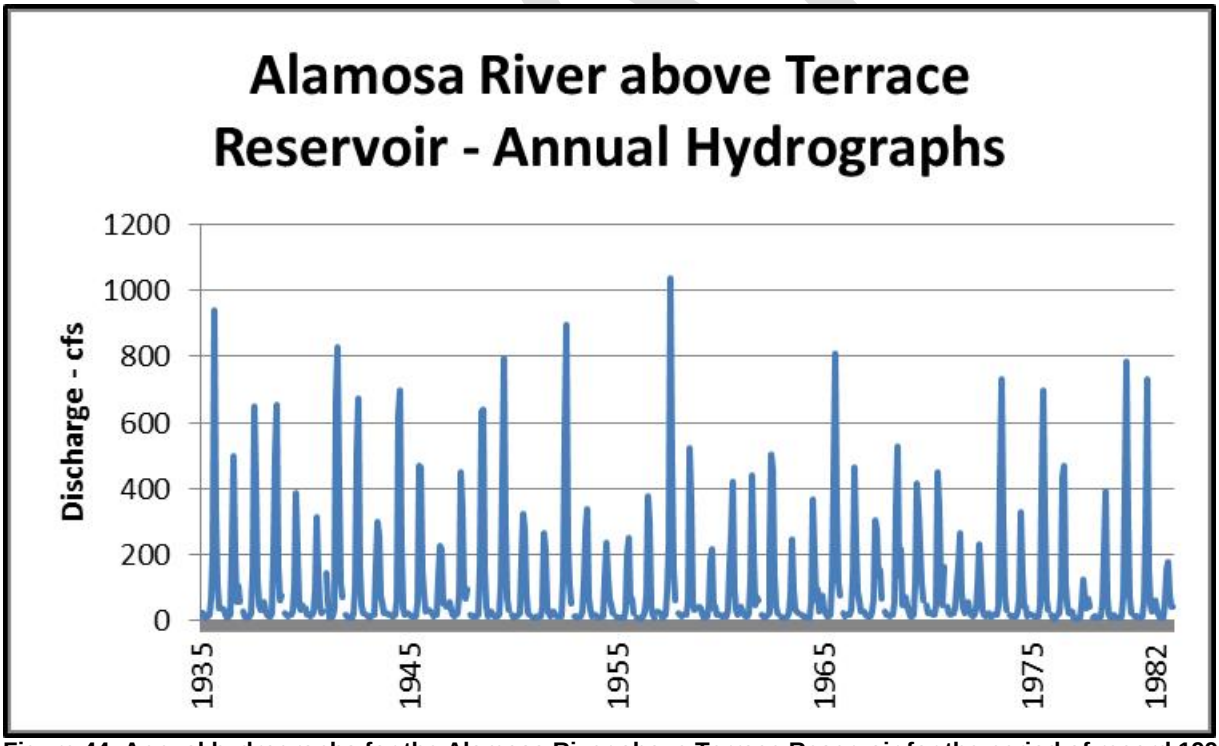

Figure 44. Annual hydrographs for the Alamosa River above Terrace Reservoir for the period of record 1995-1982.

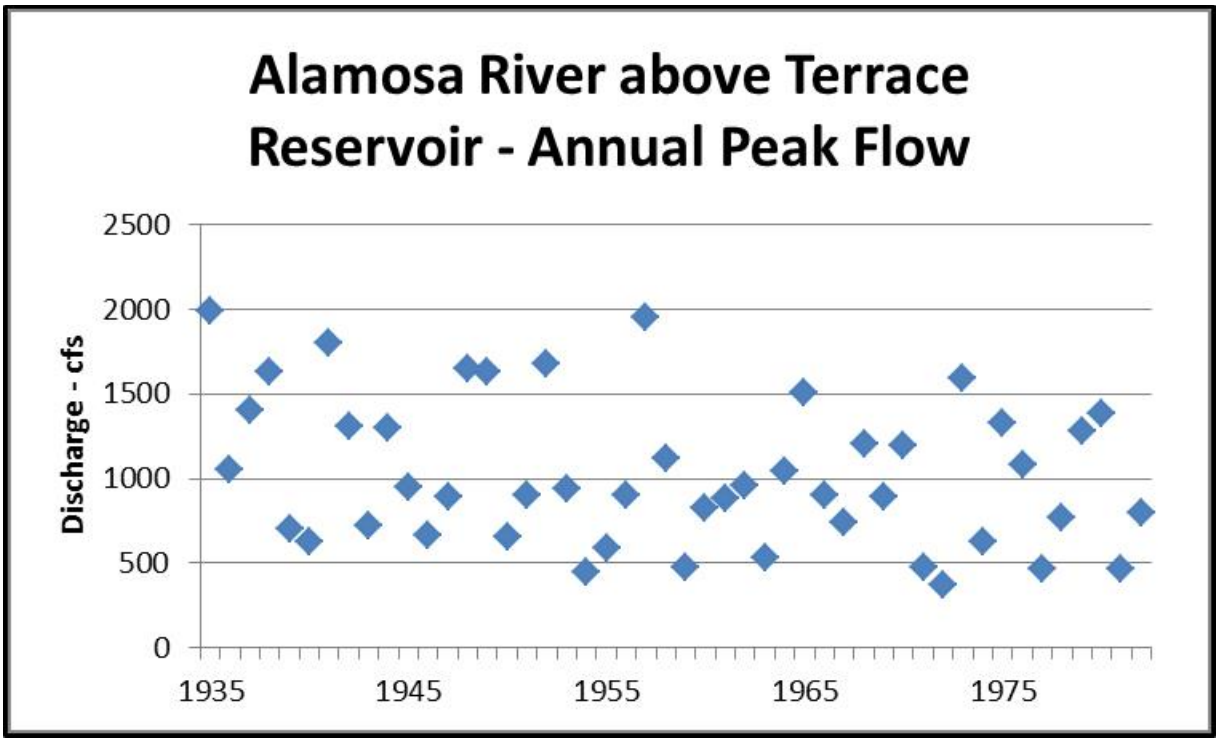

Figure 45. Annual peak flows for the Alamosa River above Terrace Reservoir for the period of record 1935-1982.

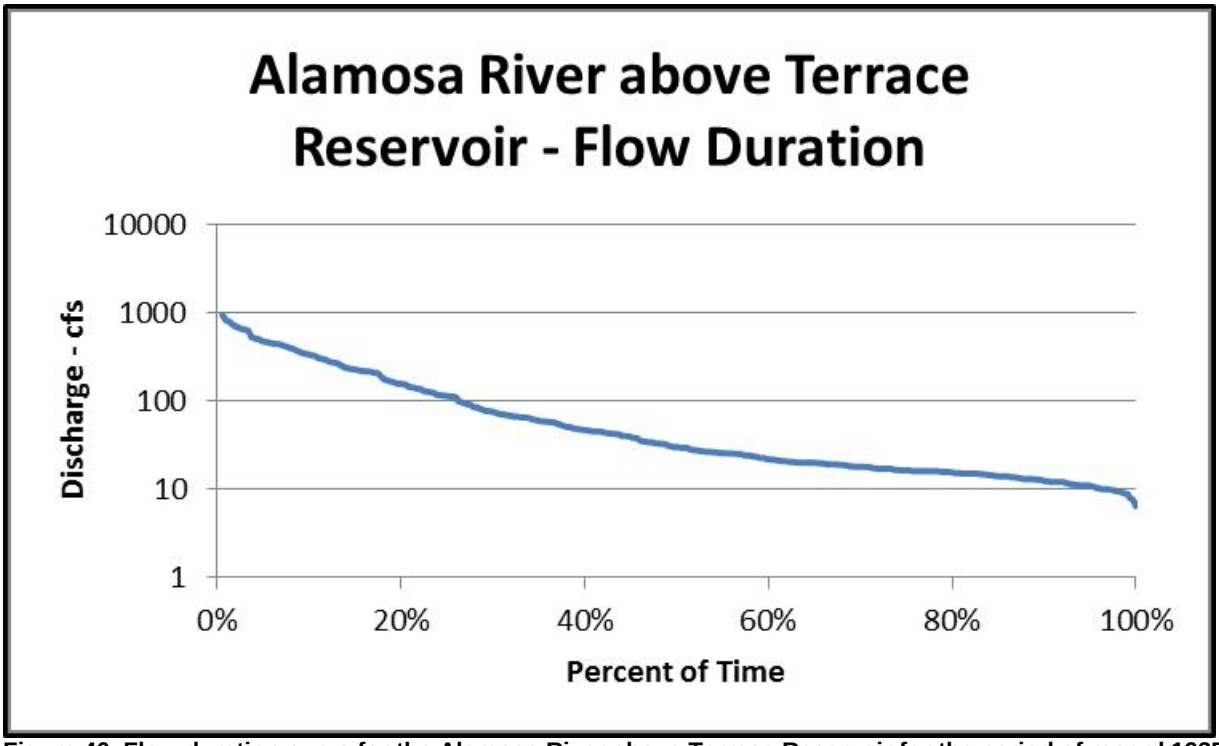

Figure 46. Flow duration curve for the Alamosa River above Terrace Reservoir for the period of record 1935-1982.

Groundwater recharge to the aquifers is a combination of mountain-front recharge, annual precipitation, irrigation return flow, streambed infiltration, and down valley groundwater flow. Thus watersheds across the Rio Grande National Forest are major sources of water to the aquifers.

Groundwater supports many wetlands, springs, and seeps across the Forest. A portion of these are groundwater dependent ecosystems (GDEs), which are communities of plants, animals, and other organisms whose existence and distribution depends on access to or discharge of groundwater. There is no inventory of GDEs on the Forest but the National Hydrography Dataset (NHD) and the National Wetlands Inventory (NWI) provide information about their potential extent (Maps 12 and 13 and Table 15). More specifically, springs/seeps in the NHD and PEMB wetland types in the NWI serve as representations for GDEs. Springs/seeps are classified as points where water issues from the ground naturally. PEMB wetlands are saturated non-tidal areas characterized by erect, rooted, herbaceous hydrophytes where the substrate is saturated to the surface for extended periods during the growing season but no surface water is typically present. A query of the NHD indicates there are 125 springs/seeps across the Forest. A query of the NWI indicates there are 23,479 acres of palustrine emergent (PEMB) wetlands across the Forest; this equates to 1.2 percent of the Forest acreage.

Table 15. Potential extent of Groundwater Dependent Ecosystems (GDEs).

District	PEMB (acres)	Springs/seeps
Conejos	7,785	15
Divide	13,030	66
Saguache	2,664	44
Total	23,479	125

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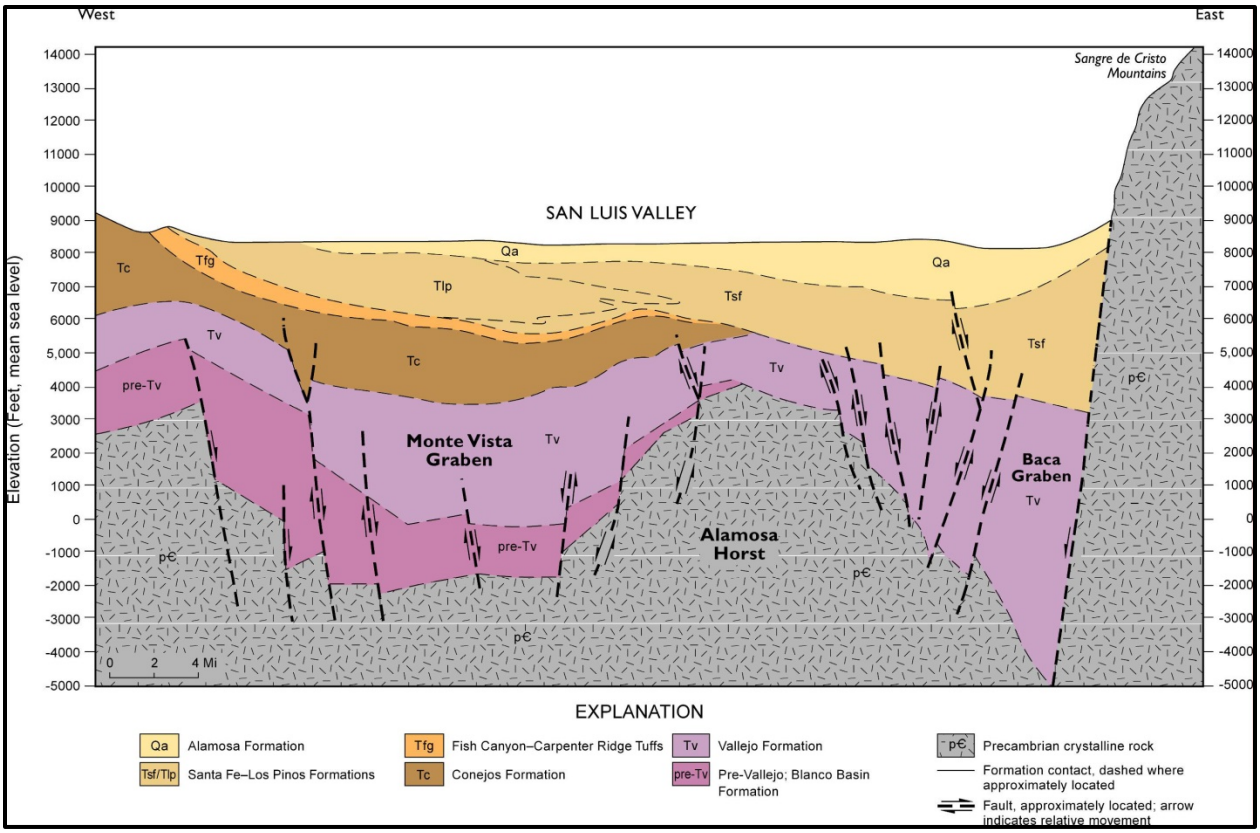

Figure 47. San Luis Valley generalized geologic cross-section.

Streams across the Forest have a low-flow channel, a high-flow or bankfull channel, and a floodplain to handle above bankfull flows. Flooding is a natural part of the hydrologic cycle and access to the floodplain is critical. The width of the flood prone area varies by stream and valley type and can be relatively narrow, i.e., tens of feet, to very wide, i.e., hundreds of feet. Maps that show the 100-year floodplain are available at local county planning and zoning offices.

Floodplains and their associated riparian areas are very important in regulating water quality and how water is distributed over time. Healthy stream and riparian systems dissipate flood energy and recharge alluvial aquifers. Water is then slowly released from the aquifers back to the channel during drier periods of the year (Figure 46).

The streams across the Forest transport the water and sediment delivered to them from the watershed, meaning they are self-formed and self-maintained. Increases or decreases in either the amount of water or sediment can result in stream channel aggradation or degradation, resulting in stream widening or down-cutting, leading to a whole host of negative effects on stream and riparian area health. Human occupancy and use along the channel or in the floodplain can upset water and sediment transport, also resulting in stream widening or down-cutting, leading to a whole host of negative effects on stream and riparian area health.

The State of Colorado Integrated Water Quality Monitoring and Assessment Report (CDPHE 2012a), commonly called the 303(d)/305(b) report, indicates 74% of the stream miles in the Rio Grande Basin either fully support all classified uses of water (54 of the 74%) or support at least one classified use (20 of the 74%). Because most of the stream miles in the basin are on the Rio Grande National Forest, these percentages likely represent stream water quality across the Forest, at least in terms of chemical and

biological quality. Physical quality, i.e., stream pattern, profile, and dimension, may be under-represented in the State report as monitoring across the Forest by Forest Service staff suggests historical grazing, and in some allotments, current ungulate grazing is negatively affecting stream physical function.

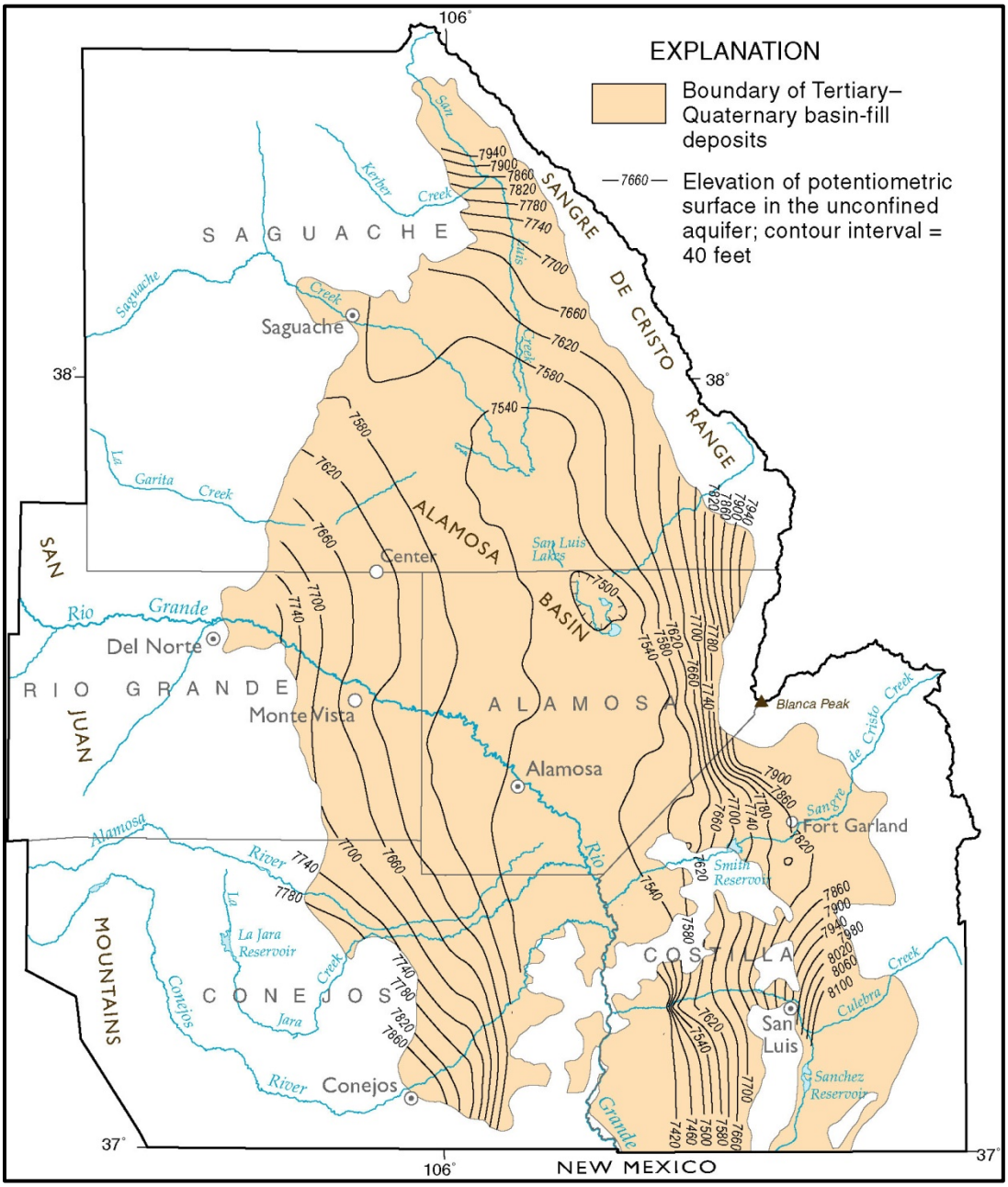

Figure 48. Water table elevations of the San Luis Valley unconfined aquifer late 1996-early 1997.

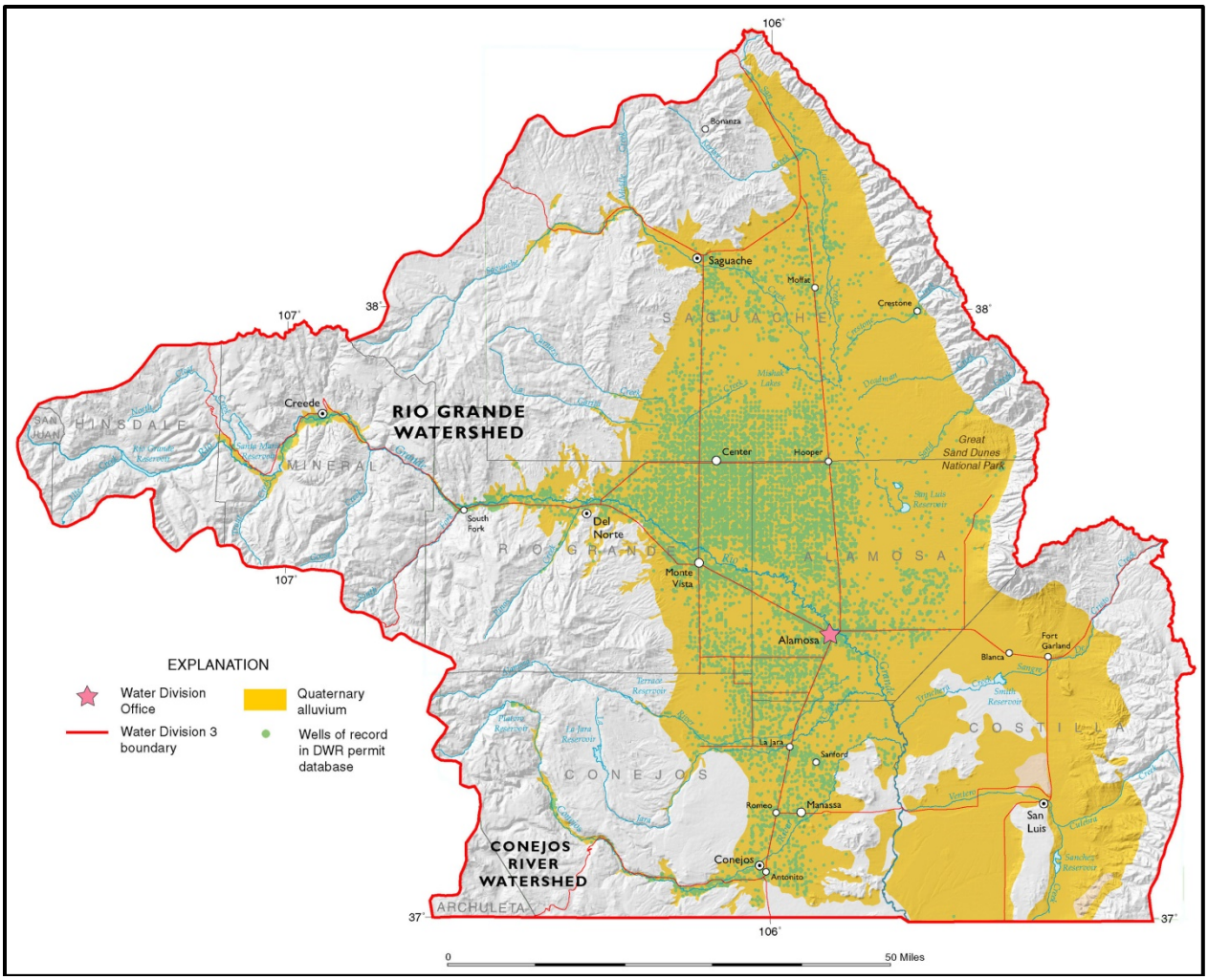

Figure 49. San Luis Valley location and extent of Quaternary alluvium and permitted water wells.

There are impaired waterbodies (303(d) listed) within the Rio Grande River Basin, some of which are within the Rio Grande National Forest (CDPHE 2012b). These listed waterbodies are mostly associated with historical mining and are in the Alamosa, Willow, and Kerber Creek watersheds. Total Maximum Daily Loads (TMDLs) exist for some of these listed waterbodies (Table 16) and are available at https://www.colorado.gov/pacific/cdphe/tmdl-rio-grande-river-basin. Heavy metals and pH are the primary water quality concerns. There are also multiple stream segments across the Forest on the monitoring and evaluation list maintained by the State of Colorado. The Alamosa River area around Summitville is an EPA Superfund site and considerable restoration work has taken place to improve water quality in the river and its tributaries http://www2.epa.gov/region8/summitville-mine. Restoration work has also taken place on Willow Creek near Creede http://www.willowcreede.org/ (CDPHE 2013).

For lake acreage, the 303(d)/305(b) report indicates only 9% of the lakes in the Rio Grande Basin fully support all classified uses, while an additional 21% support at least one classified use. Most lake acreage however in the basin is either off-Forest or within private in-holdings within the Forest and thus are not representative of lake water quality within the Forest. Water quality monitoring conducted as part of the Forest air program (see air section) indicates lake water chemistry is good to excellent.

Table 16. TMDLs in the Rio Grande Basin.

TMDL	Location
CORGAL03a	Alamosa River, Alum Creek to Wightman Form
CORGAL03b	Alamosa River, Wightman Fork to Fern Creek
CORGAL03c	Alamosa River, Fern Creek to Ranger Creek
CORGAL03d	Alamosa River, Ranger Creek to inlet of Terrace Reservoir
CORGAL05	Wightman Fork above Summitville
CORGAL08(1)	Terrace Reservoir
CORGAL08(2)	Terrace Reservoir
CORGAL09	Alamosa River, outlet of Terrace Reservoir to Highway 15
CORGRG04	Rio Grande River, Willow Creek to Alamosa County line
CORGRG30	Sanchez Reservoir
CORGCB09a	Kerber Creek, source to Brewery Creek
CORGCB09b	Kerber Creek, Brewery Creek to San Luis Creek

Conditions

Watershed Disturbance Analysis

In the current Forest Plan, watershed condition was assessed by analysis area, i.e., planning watersheds and not hydrologic areas, using an equivalent disturbed area approach. The outcome was identification of watersheds of concern, which are described in Appendix J. When projects are proposed in these watersheds, the fact they are of concern is factored into project design. There may be utility in plan revision to revisit this analysis and determine if it should be updated and carried forward into the revised plan.

Watershed Condition Framework

The Watershed Condition Framework (WCF) is a comprehensive six-step approach for proactively implementing integrated restoration on priority watersheds on national forests and grasslands. The first step of the framework characterizes the health and condition of watersheds at the 6th-level HUC scale. The classification uses a comprehensive set of four process categories, twelve indicators and twenty-four attributes that are surrogate variables representing ecological, hydrological, and geomorphic functions and processes that affect watershed condition. The primary emphasis of the classification is on aquatic and terrestrial processes and conditions that Forest Service management activities can influence. The classification provides a consistent way to evaluate watershed condition at the forest level, making it especially useful for forest planning. The initial or baseline characterization for the Rio Grande National Forest was completed in 2011. Only watersheds that have five percent or more national forest lands were rated; for the Rio Grande National Forest 152 of the 166 6th-level HUCs was characterized.

The Forest Service uses three classes to describe watershed condition. Class 1 or Good condition watersheds are functioning properly because they exhibit high geomorphic, hydrologic, and biotic integrity relative to their natural potential condition. Class 2 or Fair condition watersheds are functioning at-risk because they exhibit moderate geomorphic, hydrologic, and biotic integrity relative to their natural potential condition. Class 3 or Poor condition watersheds are at impaired function because they exhibit low geomorphic, hydrologic, and biotic integrity relative to their natural potential condition.

Each of the 24 attributes for each of the 152 watersheds were assigned a score of 1 (good), 2 (fair), or 3 (poor) by a Forest interdisciplinary team. Scores were then aggregated by watershed into indicator scores,

process category scores, and an overall condition score. Indicator and process category scores, as well as the overall score, were then assigned condition ratings. Scores between 1.0 and 1.6 are properly functioning watersheds, scores between 1.7 and 2.2 are functioning at-risk watersheds, and scores between 2.3 and 3.0 are impaired function watersheds.

Overall Watershed Condition and Process Category Summary

Overall, seventy-seven (50%) of the 152 watersheds are functioning properly, another 74 (49%) are functioning at risk, and only one watershed has impaired function (Table 17, Figure 50 and Figure 51, and Maps 14 and 15). The watershed with impaired function is Cottonwood Creek-Kerber Creek (HUC 130100030102). Concerns with water quality, aquatic habitat, aquatic biota, riparian and wetland vegetation, soils, and rangeland vegetation condition are the driving indicators in this watershed.

Interestingly, the distribution of overall scores follows a bell-shaped curve with 85 (56%) of the 152 watersheds straddling the break, i.e., ±0.2 units or 1.5 through 1.8, between properly functioning and functioning at-risk watershed condition (Figure 51). What this implies is that changes in one or more attributes through either improved land management or through mismanagement could cause a functioning at-risk watershed to be re-classified to properly functioning or a properly functioning watershed to be re-classified to functioning at-risk. The Forest may want to pursue this as priority watersheds are selected in the plan revision process.

From a process category standpoint, a majority of the 152 watersheds are functioning properly relative to aquatic physical and terrestrial biological indicators (Table 17, Figure 52, Figure 53 and Figure 56, and Maps 16, 17, 22 and 23). Relative to aquatic biological and terrestrial physical processes a majority of the watersheds are functioning at risk (Table 17, Figure 52, Figure 54 and Figure 55, and Maps 18, 19, 20 and 21). There are no watersheds with impaired terrestrial physical and biological function (Table 17). There are two watersheds with impaired aquatic physical function (Table 17 and Table 18). The concern in both of these watersheds is with water quality problems, flow characteristics, habitat fragmentation, and channel shape and function. There are eighteen watersheds with impaired aquatic biological function (Table 17 and Table 18). The concern in these watersheds is predominately with exotic and/or aquatic invasive species and riparian/wetland vegetation condition. In some of the watersheds there is also a concern with life form presence.

Table 17. WCF overall watershed condition and process category summary.

Watershed Condition Class		Watershed Condition Process Categories			
	Forestwide	**Aquatic Physical**	**Aquatic Biological**	**Terrestrial Physical**	**Terrestrial Biological**
Good	77 (50%)	135 (89%)	35 (23%)	35 (23%)	148 (97%)
Fair	74 (49%)	15 (10%)	99 (65%)	117 (77%)	4 (3%)
Poor	1 (1%)	2 (1%)	18 (12%)	0 (0%)	0 (0%)

Table 18. Watersheds with Impaired Aquatic Physical Function and Impaired Aquatic Biological Function

Watershed Designation	Watershed Designation
Impaired Aquatic Physical Function	
Continental Reservoir-North Clear Creek (130100010201)	Spring Creek (130100010303)
Impaired Aquatic Biological Function	
North Clear Creek (HUC 130100010202)	Poso Creek (HUC 130100020405)
Middle Creek (HUC 130100010502)	Little Kerber Creek (HUC 130100030101)

Watershed Designation	Watershed Designation
West Willow Creek-Willow Creek (HUC 130100010702)	Cottonwood Creek-Kerber Creek (HUC 130100030102)
Park Creek (HUC 130100011103)	Horse Canyon (HUC 130100040102)
Headwaters Embargo Creek (HUC 130100011202)	Mill Creek (HUC 130100040304)
Wrightman Fork (HUC 130100020301)	Little La Garita Creek-La Garita Creek (HUC 130100040502)
Jasper Creek-Alamosa River (HUC 130100020303)	Castor Creek-La Garita Creek (HUC 130100040503)
French Creek-Alamosa River (HUC 130100020304)	Cottonwood Creek-San Juan Creek (HUC 130100040603)
Headwaters La Jara Creek (HUC 130100020402)	Findley Gulch (HUC 130100040703)

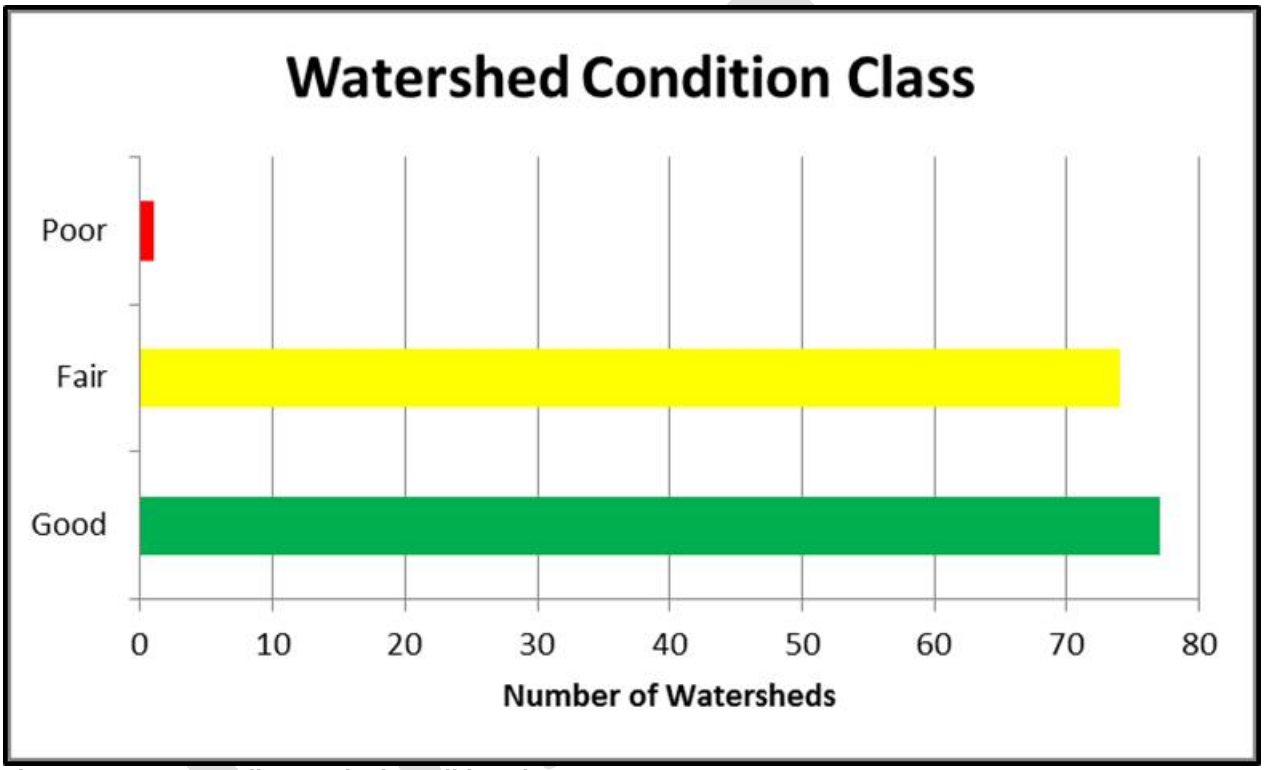

Figure 50. WCF overall watershed condition class

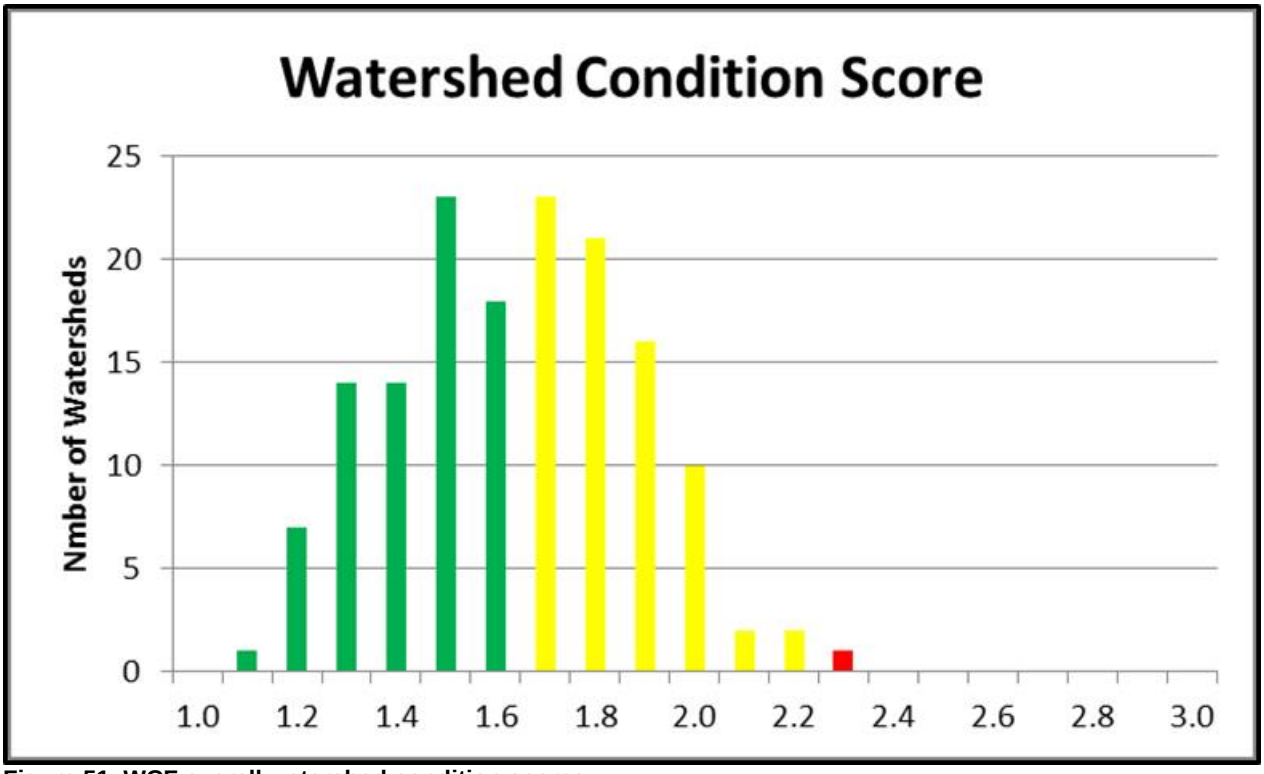

Figure 51. WCF overall watershed condition scores.

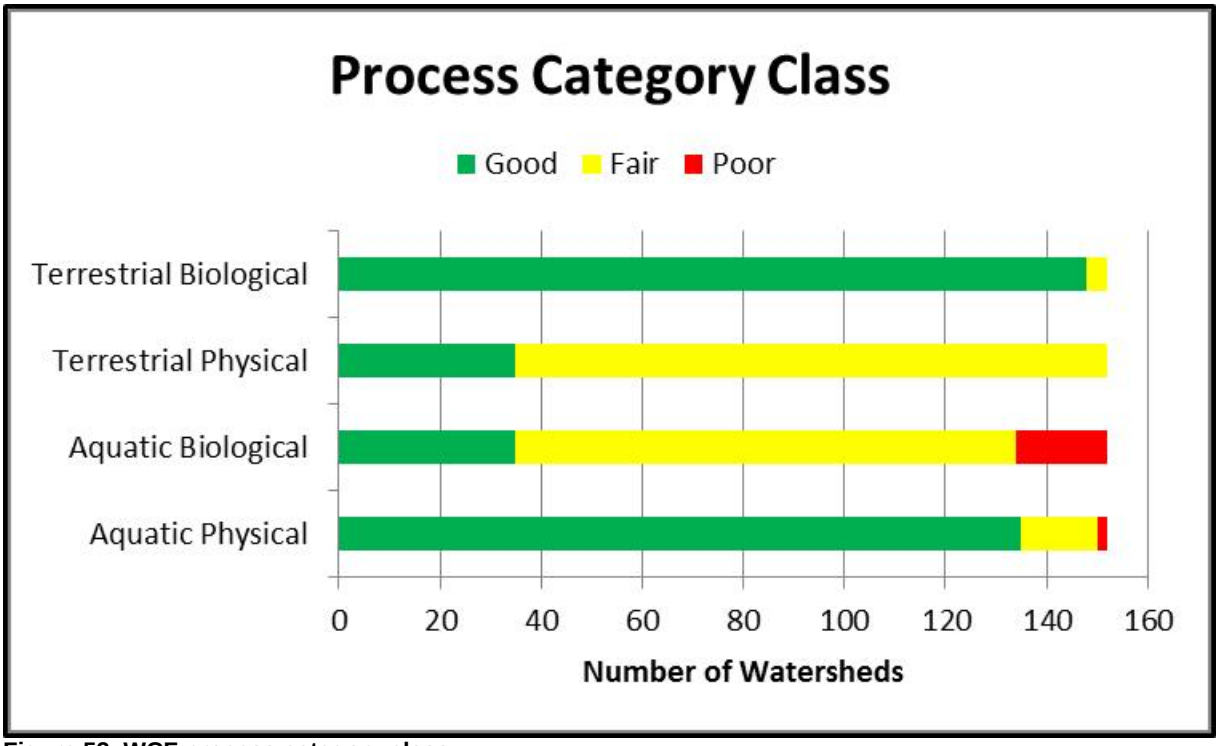

Figure 52. WCF process category class.

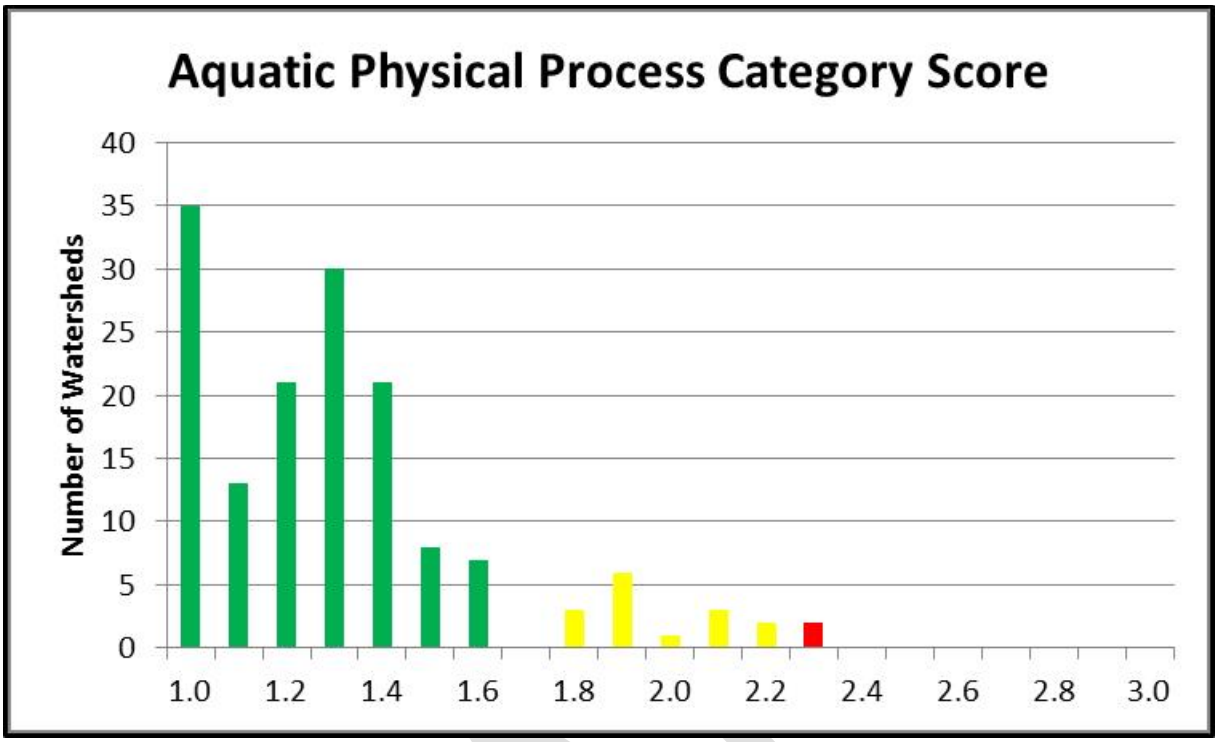

Figure 53. WCF Aquatic Physical Process Category Scores.

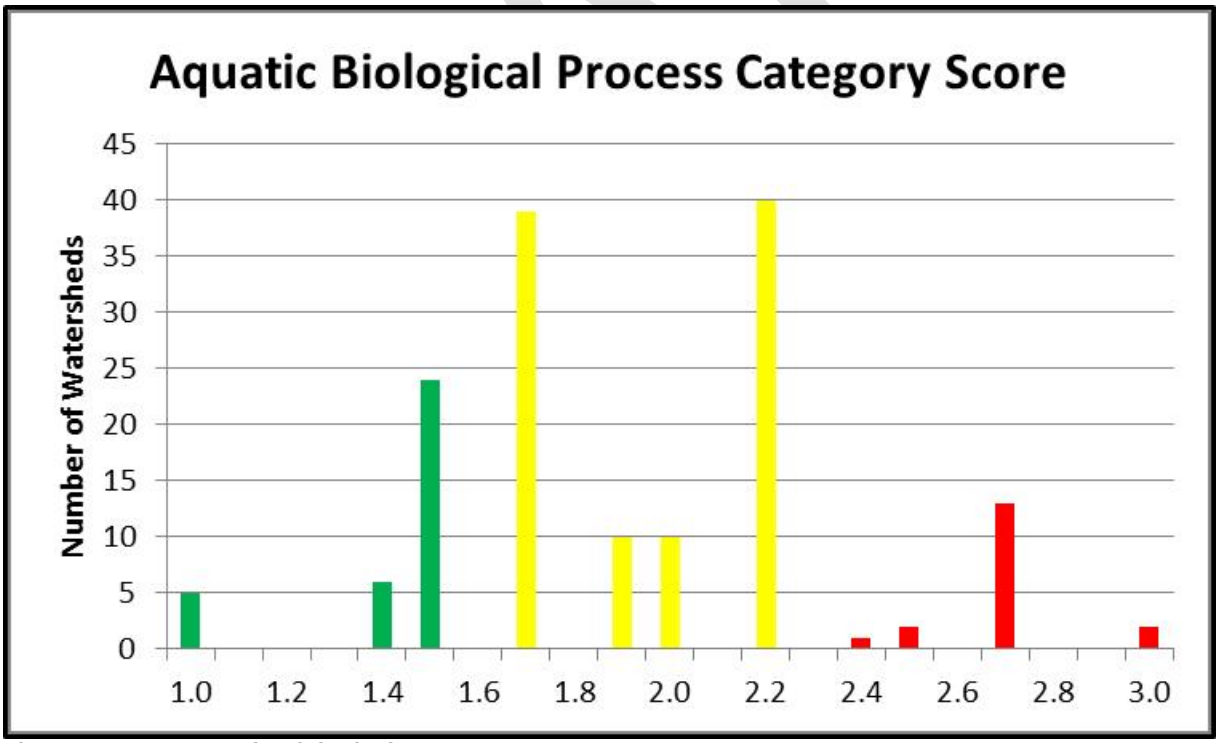

Figure 54. WCF Aquatic Biological Category Scores.

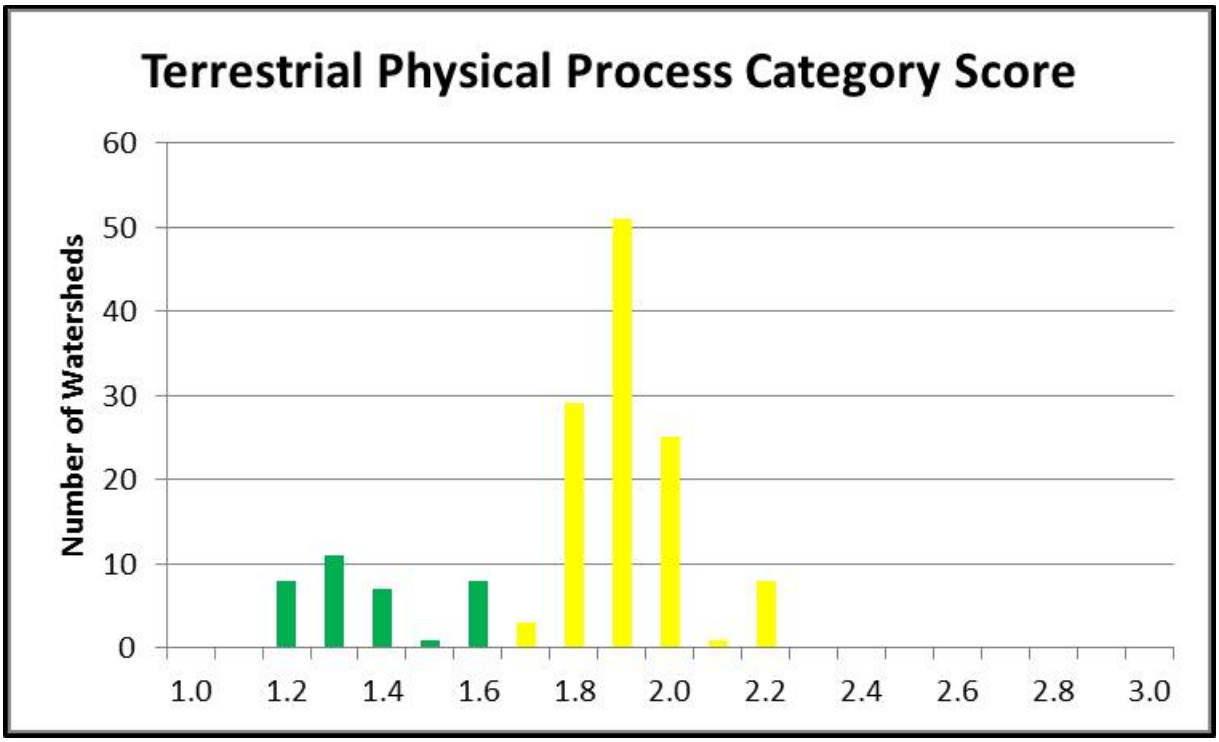

Figure 55. Terrestrial Physical Process Category Scores.

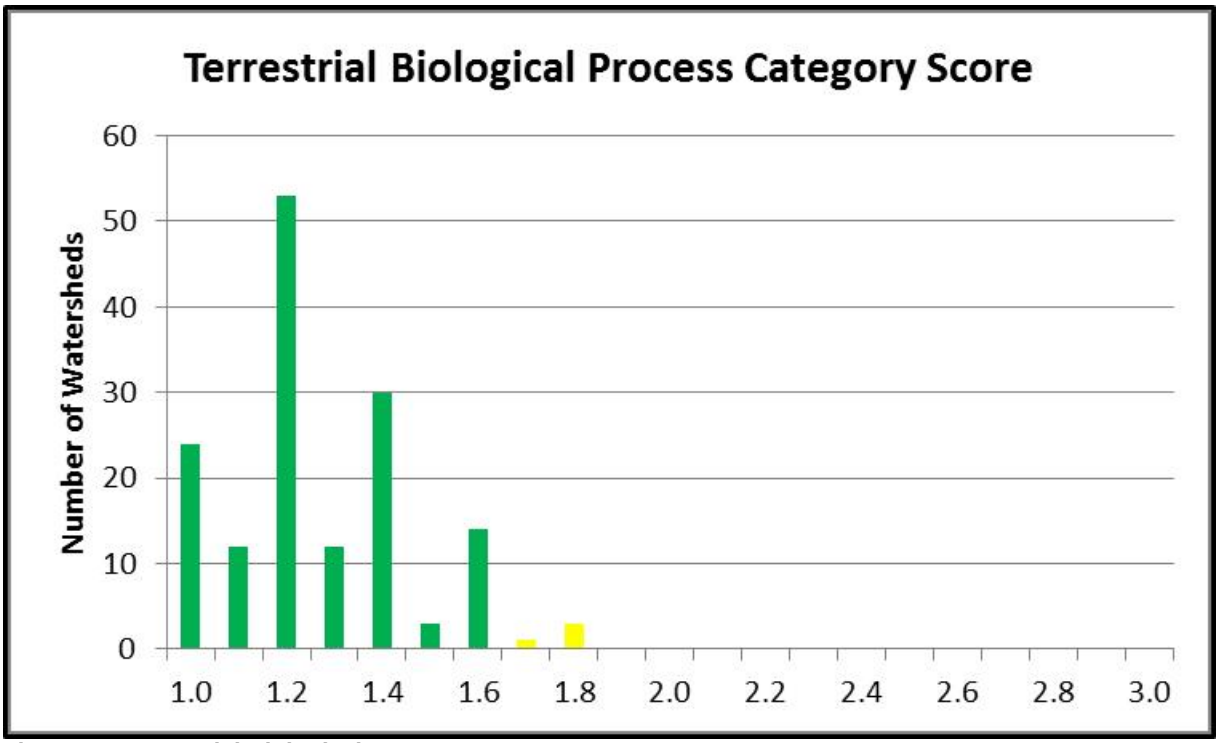

Figure 56. Terrestrial Biological Process Category Scores.

Process Categories, Indicators, and Attributes Summary

The majority of watersheds are functioning properly relative to the water quality, water quantity, and aquatic habitat indicators (Table 19). Roughly one-fourth of the watersheds are functioning at-risk relative

to the aquatic habitat indicator, with the concerns primarily centered on channel shape and function (Table 23 through Table 25). A small percentage of watersheds are functioning at-risk relative to the water quality and water quantity indicators due to listed and un-listed water quality segments and flow characteristics. A small percentage of watersheds show impaired function relative to all three aquatic physical indicators with channel shape and function being the primary driver and some concern with habitat fragmentation.

Table 19. WCF Aquatic Physical Indicator Class.

Aquatic Physical Process Category		Aquatic Physical Indicators		
	Forestwide	Water Quality	Water Quantity	Aquatic Habitat
Good	135 (89%)	139 (92%)	136 (89%)	101 (66%)
Fair	15 (10%)	5 (3%)	9 (6%)	42 (28%)
Poor	2 (1%)	8 (5%)	7 (5%)	9 (6%)

Most watersheds across the Forest are functioning at-risk or at impaired function relative to the aquatic biota and riparian/wetland vegetation indicators (Table 20, Table 26 and Table 27). Lack of native aquatic species, presence of exotic and/or aquatic invasive species, and vegetation condition in riparian/wetland areas are the driving concerns.

Table 20. WCF Aquatic Biological Indicator Class.

Aquatic Biological Process Category		Aquatic Biological Indicators	
	Forestwide	Aquatic Biota	Riparian/Wetland Vegetation
Good	35 (23%)	20 (13%)	60 (39%)
Fair	99 (65%)	36 (24%)	76 (50%)
Poor	18 (12%)	96 (63%)	16 (11%)

The majority of the watersheds are functioning at-risk relative to the road and trails and soils indicators (Table 21, Table 28 and Table 29). Lack of road and trail maintenance and soil productivity, erosion, and contamination are the primary drivers. The soils concerns are discussed in detail in the air and soils section of this assessment. A small percentage of watersheds are at impaired function relative to the road and trails indicators primarily due to proximity to water, but also due to lack of maintenance.

Table 21. WCF Terrestrial Physical Indicator Class

Terrestrial Physical Process Category		Terrestrial Physical Indicators	
	Forestwide	Roads and Trails	Soils
Good	35 (23%)	29 (19%)	34 (22%)
Fair	117 (77%)	113 (74%)	117 (77%)
Poor	0 (0%)	10 (7%)	1 (1%)

The majority of watersheds are functioning properly relative to all five terrestrial biological indicators (Table 22 and Table 30through Table 34). There are fire regime condition class concerns in thirty-three

watersheds. Almost one-half of the watersheds are functioning at-risk due to rangeland vegetation condition concerns. Four watersheds are at impaired function due to rangeland vegetation condition concerns. There are forty-three watersheds functioning at-risk due to concerns with the extent and spread of terrestrial invasive species. There are two watersheds at impaired function due to concerns with the extent and spread of terrestrial invasive species. There are twenty-eight watersheds functioning at-risk due to concerns with insects and disease effects on forest health.

Table 22. Terrestrial Biological Indicator Class.

Terrestrial Biological Process Category	Terrestrial Biological Indicators					
	Forestwide	Fire Regime or Wildfire	Forest Cover	Rangeland Vegetation	Terrestrial Invasive Species	Forest Health
Good	148 (97%)	119 (78%)	151 (99%)	77 (50%)	107 (69%)	124 (82%)
Fair	4 (3%)	33 (22%)	1 (1%)	71 (47%)	43 (28%)	28 (18%)
Poor	0 (0%)	0 (0%)	0 (0%)	4 (3%)	2 (1%)	0 (0%)

Table 23. WCF Water Quality Condition Attributes Class.

	Indicator	Attributes	
	Water Quality Condition	Impaired Waters (303(d) listed)	Water Quality Problems (not listed)
Good	139 (92%)	139 (92%)	73 (48%)
Fair	5 (3%)	5 (3%)	71 (47%)
Poor	8 (5%)	8 (5%)	8 (5%)

Table 24. WCF Water Quantity Attribute Class.

	Indicator	Attributes
	Water Quantity	Flow Characteristics
Good	136 (89%)	136 (89%)
Fair	9 (6%)	9 (6%)
Poor	7 (5%)	7 (5%)

Table 25. WCF Aquatic Habitat Attributes Class.

	Indicator	Attributes		
	Aquatic Habitat	Habitat Fragmentation	Large Woody Debris	Channel Shape and Function
Good	101 (66%)	118 (78%)	127 (84%)	49 (32%)
Fair	42 (28%)	23 (15%)	3 (2%)	73 (48%)
Poor	9 (6%)	11 (7%)	2 (1%)	30 (20%)

Table 26. WCF Aquatic Biota Attributes Class.

	Indicator	Attributes		
	Aquatic Biota	**Life Form Presence**	**Native Species**	**Exotic and/or Aquatic Invasive Species**
Good	20 (13%)	144 (95%)	20 (13%)	20 (13%)
Fair	36 (24%)	5 (3%)	39 (26%)	14 (9%)
Poor	96 (63%)	3 (2%)	93 (61%)	118 (78%)

Table 27. WCF Riparian/Wetland Vegetation Attribute Class.

	Indicator	Attributes
	Riparian/Wetland Vegetation	**Vegetation Condition**
Good	60 (39%)	60 (39%)
Fair	76 (50%)	76 (50%)
Poor	16 (11%)	16 (11%)

Table 28. WCF Roads and Trails Attributes Class.

	Indicator	Attributes			
	Roads and Trails	**Open Road Density**	**Road and Trail Maintenance**	**Proximity to Water**	**Mass Wasting**
Good	29 (19%)	121 (80%)	10 (7%)	23 (15%)	144 (94%)
Fair	113 (74%)	31 (20%)	125 (82%)	1 (1%)	7 (5%)
Poor	10 (7%)	0 (0%)	17 (11%)	128 (84%)	1 (1%)

Table 29. WCF Soils Condition Attributes Class.

	Indicator	Attributes		
	Soils Condition	**Productivity**	**Erosion**	**Chemical Contamination**
Good	34 (22%)	38 (25%)	28 (18%)	52 (34%)
Fair	117 (77%)	113 (74%)	123 (81%)	100 (56%)
Poor	1 (1%)	1 (1%)	1 (1%)	0 (0%)

Table 30. WCF Fire Regime or Wildfire Attribute Class.

	Indicator	Attributes	
	Fire Regime or Wildfire	**Fire Regime Condition Class**	**Wildfire Effects**
Good	119 (78%)	119 (78%)	0 (0%)
Fair	33 (22%)	33 (22%)	0 (0%)
Poor	0 (0%)	0 (0%)	0 (0%)

Table 31. WCF Forest Cover Attribute Class.

	Indicator	Attributes
	Forest Cover	**Loss of Forest Cover**
Good	151 (99%)	151 (99%)
Fair	1 (1%)	1 (1%)
Poor	0 (0%)	0 (0%)

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Table 32. WCF Rangeland Vegetation Attribute Class.

	Indicator	Attributes
	Rangeland Vegetation	**Rangeland Vegetation Condition**
Good	77 (50%)	77 (50%)
Fair	71 (47%)	71 (47%)
Poor	4 (3%)	4 (3%)

Table 33. WCF Terrestrial Invasive Species Attribute Class.

	Indicator	Attributes
	Terrestrial Invasive Species	**Extent and Ratio of Spread**
Good	107 (69%)	107 (69%)
Fair	43 (28%)	43 (28%)
Poor	2 (1%)	2 (1%)

Table 34. WCF Forest Health Attribute Class.

	Indicator	Attributes	
	Forest Health	**Insects and Disease**	**Ozone**
Good	124 (82%)	96 (64%)	152 (0%)
Fair	28 (18%)	28 (18%)	0 (0%)
Poor	0 (0%)	28 (18%)	0 (0%)

WCF Summary

When looking at overall watershed condition across the Rio Grande Forest one-half of the 152 watersheds rated in 2011 are functioning properly, 49% are functioning at-risk, and only one watershed has impaired function. Attribute and indicator ratings for three of the four process categories - Aquatic Physical, and in particular, Aquatic Biological and Terrestrial Physical - are the driving influences behind the overall condition scores.

Further dissection of the classification shows summed and averaged attribute ratings for seven of the twelve indicators are influencing watershed condition across the Forest most significantly. These indicators are Water Quality, Aquatic Habitat, Aquatic Biota, Riparian/Wetland Vegetation, Roads and Trails, Soils, and Rangeland Vegetation.

Sixteen of the twenty-four attributes are the major influences on overall watershed condition. These are Water quality problems (not listed), Channel shape and function, Native species, Exotic and/or aquatic invasive species, Vegetation condition, Open road density, Road and trail maintenance, Proximity to water, Soil productivity, Soil erosion, Soil contamination, Fire Regime Condition Class, Rangeland vegetation condition, Extent and ratio of spread, and Insects and disease. Land use and activities that are influencing these attributes the most are uncontrolled motorized recreation, historical and current livestock grazing in both uplands and riparian areas/wetlands, lack of road and trail maintenance, introduction of exotic and invasive aquatic and terrestrial species, atmospheric deposition of nitrates, and natural range of variability issues relative to fire regimes and insect and disease activity.

As a critical part of the WCF, i.e., step 3 of 6, two Watershed Restoration Action Plans (WRAPs) have been prepared by the Forest to address watershed condition. One WRAP is for watersheds 130201020201 (Headwaters of Rio Chama) and 130201020202 (Archeluta Creek). Nine essential projects are in various

stages of implementation to address stream bank stability, riparian vegetation extent/vigor, fine sediment from roads and trails, and soil erosion/compaction concerns.

The other WRAP is for watershed 130100040401 (Middle Fork Carnero). Nine essential projects are in various stages of implementation to address excessive width/depth ratio, fine sediment, and riparian vegetation extent/vigor concerns.

Historical Context

An assessment of the natural range of variability (NRV) of the Rio Grande National Forest was written for the current Forest Plan and published in Appendix A of that plan. The assessment provides inferences about how the ecosystem and associated hydrology developed and functioned since the beginning of the Holocene, with particular emphasis on the period from 1600 to the early 1870s, just before modern settlement of the area. This roughly three century period was believed to best describe baseline ecological conditions for use in that planning effort. The assessment also describes activities and conditions from the 1870s through the mid-1990s, making comparisons to the baseline period, to describe how the ecosystem had changed under the influence of modern settlement.

The assessment summarized climate, fire history, forested and non-forested communities, wildlife, and insects and disease, leading to a list of conclusions with synthesis and implications. The assessment provides good context for how pre-settlement hydrologic systems across the Forest developed and then changed post-settlement. This assessment is still very useful to the current revision effort. Some notable conclusions from the assessment related to watersheds and water resources include:

- The influx of humans and apparent increase in fires between 1875 and 1908 indicates a disruption of the fire cycle. Following this period was decades of purposeful fire suppression. During these two time periods there was also considerable logging activity across the Forest; for fuelwood during initial settlement, for railroad ties during the railroad construction era, and for a full range of forest products well into the 1990s. Intuitively, the associated changes to the vegetative community caused by these activities affected the hydrologic cycle, most notably relative to snow redistribution, soil infiltration rates, evapotranspiration and streamflow. Additionally, because these activities needed roads, there were likely additional effects on the water cycle and watershed health from accelerated erosion and runoff.
- Large numbers of sheep and cattle grazed on the Forest, particularly between 1875 and 1960. Notable changes in upland rangeland vegetation and bottomland riparian area vegetation were noted throughout this time period. The excessive grazing in the uplands resulted in considerable soil erosion and the amount of sediment delivered to streams, which affected soil productivity, and water quality. There were also changes in soil infiltration rates which led to increased flooding and associated changes to stream channel stability. The excessive grazing in bottomlands also led to changes in soil infiltration and stream channel stability, resulting in stream channel aggradation and degradation. In essence, most every component of the water cycle was affected by this overgrazing and the effects are still seen in certain areas of the Forest.
- Early mining had devastating effects on water quality, primarily from heavy metals. Mine drainage and erosion of tailings continued well after this early mining activity ended and the effects are still seen in certain areas of the Forest.

Much work is presently taking place across the western United States on the effects and implications of a changing climate. In order to put the effects and implications in context this work typically makes comparisons to historical climate, which provides useful information in describing the historical context for ecological conditions under which the hydrologic systems across the Rio Grande National Forest

developed. Furthermore, this work helps fill the gap in time between the current Forest plan NRV assessment discussed above and the present day, i.e., 1995 to 2015.

Lukas et al (2014) synthesized much of the current climate change literature to support climate change water resources management and adaptation particular to the State of Colorado. Gordon and Ojima (2015) expanded on this work to produce a Colorado specific climate change vulnerability report. Notable conclusions of the historical record used in these documents relative to the natural range of variability across the Rio Grande National Forest and associated implications on the water cycle are summarized in the climate change disturbance part of this assessment (Table 36).

Consumptive and Non-Consumptive Water Uses

The Rio Grande National Forest, being at the headwaters of the Rio Grande River, generates approximately 1.5 million acre-feet of water per year. A portion of this water is used by wildlife, livestock, the recreating public and administrative uses across the Forest, but the majority of the water flows downstream and off-Forest and is used in the San Luis Valley and other downstream locations along the length of the Rio Grande River. A small portion of the water is used on private lands, i.e., in-holdings, interior to the Forest administrative boundary.

Use of water, both on and off the Forest, is governed by treaty, compact, and decree. A 1906 treaty with Mexico established an allocation of 60,000 acre-feet of water each year for Mexico. The 1938 Rio Grande Compact allocates water among users in Colorado, New Mexico, and Texas on a sliding scale of allocations depending on how much water is flowing in the Rio Grande River. The Compact seeks to maintain historic consumptive use. The terms of the Compact are flexible to allow for annual variations of water supply. A Colorado Water Division 3 decree governs Rio Grande National Forest water uses and rights and is discussed in more detail in a subsequent section of this assessment.

Rights to water in the two rivers are held by individuals, ditch companies, and reservoir management companies. Roughly one-third of the most senior water right holders in the San Luis Valley are almost always assured their rights after Colorado’s obligation to New Mexico is fulfilled. The most junior water right holders almost never receive any water. The middle-third holders of water rights receive water only when there is more than normal flow in the two rivers.

As the amount of water in the rivers increase, the amount of water which must be delivered to New Mexico also increases, but the increased obligation is not proportional to the increased amount of available water. Approximately thirty percent of the increase is delivered to New Mexico with the remainder, or seventy percent, available for use in the San Luis Valley. This use is allocated by the Colorado State Engineer according to priority.

Some of the more junior users are reservoirs on the Forest. Many of these users store water in the spring and release it downstream in the summer and fall. Because of their junior status there must be a large volume of water in the streams for them to receive an allocation. These reservoirs were designed and constructed to hold far more water than is normally available so it is unlikely capacity would ever be reached. In addition to the on-Forest reservoirs there are numerous small water collection and distribution systems across the Forest. These uses are under special use permits administered by the Forest Service. The water rights themselves are administered by the Colorado State Engineer.

The Rio Grande National Forest has 735 water developments, used in a variety of settings, such as special use sites, camp and picnic grounds, rangeland stock water, and administrative sites (Table 35). These uses are governed by the above mentioned Water Division 3 decree or State of Colorado water law.

There are twenty-one major reservoirs and nine trans-basin diversions across the Forest (see appendix J in the Forest Plan). Seven of the nine diversions add water to Forest streams. The other two divert water from Forest streams. About thirty other ditches and pipelines divert water from Forest streams for irrigation, recreation, and domestic purposes. These uses are not considered major.

Table 35. Water uses on the Rio Grande National Forest.

Water Use Type	Number of Uses
Domestic	105
Recreation	11
Stockwater	594
Unclassified and Other	25

Water Rights

The Rio Grande National Forest was decreed water rights by the District Court, Water Division No. 3, State of Colorado on March 30, 2000 as outlined in the Findings of Fact, Conclusions of Law, and Judgment and Decree for Case No. 81-CW-183 (Consolidated) (DC 2000). This decree is the final judgment concerning United States' claims for appropriated water rights, federal reserved water rights and instream flow rights for the Rio Grande National Forest. The quantities of water decreed are fully sufficient to fulfill any and all federal reserved instream flow water rights and all appropriative instream flow water rights. The decree however does not preclude the United States from acquiring water or water rights by means other than appropriation.

The decreed rights allow for improving and protecting the forests within the administrative boundary, securing favorable conditions of water flows, and furnishing a continuous supply of timber for the use and necessities of the citizens of the United States. The rights also allow for

- maintaining, improving, protecting, and minimizing damage to:
    - riparian ecosystems, including stream dependent wetlands
    - the natural physical function of stream channels
    - viable and diverse populations of fish and wildlife, including all habitat necessary for such populations
    - scenic and aesthetic conditions and values
    - public opportunities for outdoor recreation
    - soil conservation and preservation of the quality of soil resources
- range uses
- prevention and control of forest fires

There are options for re-opening the Decree but those options are limited and discussed in detail in the Decree. There is also a limit on future federal reserved consumptive uses by the United States, for which quantities are discussed in detail in the Decree.

The Decree notes the principal water use in the Water Division is irrigation in the San Luis Valley and because of the physiographic setting most existing diversions are on the flat valley floor and not the Forest. The Decree further notes there are only four large reservoirs and 181 other existing water rights located on or upstream of the Forest and most of these rights predate the reservation of the Forest,

meaning they are more senior in priority. Additionally, to meet the demands of fully-appropriated downstream senior water rights and requirements in the 1938 Rio Grande Compact, the Decree notes water must be delivered through the Forest. These three noted items means there is limited potential for new water development, such as reservoirs and diversions, within the Forest, reducing the potential for future conflicts.

The Decree provides the Forest 252 reserved instream flow water rights. These rights are quantified in terms of their location and amount of flow that must be satisfied at and upstream of the location, i.e., quantification point. During the period of annual snowmelt runoff the Forest has the right to all flow up to and including the flow equal to two times bankfull flow, i.e., $Q_{1.5}$ until such time the natural flow decreases to 60 percent of bankfull flow, i.e., $Q_{1.5}$. For times outside annual snowmelt runoff the Forest has the right to base flows. For the months of January, February, March, and December it is flow available in priority up to a flow equal to the median monthly discharge rate for that month. For April through November it is flow available in priority up to a flow equal to 80 percent of the mean monthly discharge rate for that month. The median monthly discharge is defined as the 50 percent exceedance value of all mean daily flows for the entire period of record for a particular month. Mean daily flow is defined as the average discharge in cubic feet per second for the time period from midnight to midnight.

Disturbances

Bark Beetles

Bark beetle activity on the Forest has been at epidemic levels during the recent past, particularly in Englemann spruce stands. Because spruce stands grow in areas of the Forest with the greatest precipitation and because evapotranspiration (ET) rates are greater in spruce than other conifer types, there is potential for increased stream flow from this bark beetle activity. Historical watershed studies have shown that manipulation of conifer vegetation, e.g., timber harvest, can lead to measurable, i.e., detectable, increases in streamflow at the sub-watershed scale (MacDonald and Stednick 2003)[2]. However, timber harvest results in the removal of biomass so comparing beetle kill to timber harvest is not entirely appropriate. In other words, both types of disturbance change the ET component of the water cycle but interception and evaporation processes change less under beetle kill.

More recent watershed studies, conducted after the start of the current beetle infestations, have failed to detect consistent changes in streamflow (Gordon and Ojima 2015). However, much of this work has been in lodgepole pine stands, which grow in areas of lower precipitation; additionally evapotranspiration demands of this forest type are less. Modeling efforts of bark beetle infestation indicate there may be a 5-10% increase in runoff. Such a small change may be real but watershed studies have clearly shown that an increase of at least 15% is necessary to be able to detect the change at the sub-watershed scale (MacDonald and Stednick 2003). All said, without specific studies on the Forest, it is unknown if recent insect activity has changed ET and thus streamflow or not.

Wildfire

Watershed studies and post-fire monitoring in snow-dominated hydrologic systems indicate wildfire can result in increases in annual water yield proportional to that seen from timber harvest (Troendle and Bevenger 1996). Wildfire can also change, sometimes significantly, the response to short-duration, high-intensity summer thunderstorms, resulting in considerable soil erosion, sediment delivery, flash floods,

[2] Even though timber harvest can increase streamflow the Rocky Mountain Region has determined purposefully doing so is not a management emphasis; rather, any water yield increase that results from timber harvest is a by-product of the harvest. See Regional Forester letter dated 2002.

higher peak flows, and down cutting of stream channels (Carlson 2008). High severity fire consumes ground cover and alters the soil surface creating water repellency. The water repellency reduces infiltration rates, resulting in erosion and overland flow to channels. The increased delivery of sediment and streamflow produces debris flows and floods that down cut channels and produce floods. These responses are typically a part of the ecosystem but can result in issues and concerns in the wildland-urban interface. Such responses and associated effects however are usually only seen for the first three to five years after a significant high-severity fire due to vegetative recovery and its ability to assimilate thunderstorm intensity, duration, and volume.

Dust

In recent years, late-spring snowpack across the Forest has had a brownish color due to heavy deposition of desert dust. This dust has been shown in field studies to alter the energy balance, resulting in enhanced snowmelt rates and earlier melt of the snowpack (Gordon and Ojima 2015). Modeling indicates that in moderately dusty year's snowmelt and the peak occur about three weeks earlier and extreme dust loading can add another three weeks, or a total of six weeks of earlier melt and peak. Modeling also indicates that due to changes in evapotranspiration overall runoff can be reduced by roughly 5%. Extreme dust can increase evapotranspiration 6%; even though the amount of dust is substantial evapotranspiration change is minor because the energy of the sun in early spring is not sufficient to drive additional ET. Gordon and Ojima suggest the spatial and year-to-year variability in dust loading, and resulting impacts on the water cycle, complicate watershed management. Complicating the dust issue is the interaction of climate change effects on the water cycle.

Climate Change

The effects of a changing climate on watersheds and water resources across the Forest are not well known but global climate change modeling and down-scaling efforts provide insight into potential effects. Colorado's climate has warmed in recent decades, and climate models unanimously project this warming trend will continue into the future (Lukas et al 2014)). Climate change has and will continue to impact resources in the State, likely including watersheds and water resources on the Rio Grande National Forest. Gordon and Ojima (2015) synthesized observed climate and projected future climate for the State of Colorado (Table 36).The projected changes in climate and associated hydrology serve as a good proxy of potential direct, indirect, and cumulative effects on watersheds and water resources. Gordon and Ojima's report also discusses key ecosystem vulnerabilities, which relate to potential future conditions with watersheds and water resources (Table 37).

Municipal watersheds, sole source aquifers, and source water protection areas

There is a 2014 Memorandum of Understanding between the Rocky Mountain Region of the Forest Service and the Colorado Department of Public Health and Environment that addresses management and protection of source water areas on National Forest System lands in Colorado (CDPHE 2014). CDPHE has delineated source water areas across the State. These delineations are considered confidential but are available to the Forest for internal use. There are source water assessments for these areas, copies of which are available on the CDPHE website.

Per the MOU these areas are recognized as Municipal Supply Watershed per the definition in Forest Service Manual 2542. In the MOU the Forest Service agrees, among other things, to provide direction and desired conditions for municipal supply watersheds/source water areas in revised Forest Plans to protect water quality while allowing for multiple use outputs. The primary concerns related to source water protection areas within or directly downstream of the Rio Grande National Forest is two-fold: the effect of

large-scale wildfire on water quality and hazardous material spills. Information is available at https://www.colorado.gov/pacific/cdphe/source-water-assessment-and-protection-swap.

Effects from Land Use

In short, surface disturbing activities such as timber harvest, grazing, mining, recreation developments, road construction, and off-road motorized use, are the greatest current and potential threats to loss of watershed and water resources integrity across the Forest. The effects, many of which have been described throughout this assessment, can be direct, indirect, or cumulative. The scientific literature that supports this is voluminous but can be summarized by stating the effects are due primarily to soil erosion and compaction in uplands and riparian areas, changes in the amount of water and sediment delivery to streams and wetlands and associated adjustments then made by the stream systems. The literature also clearly shows that application of watershed conservation practices (WCPs), also known as best management practices (BMPs), mitigate the effects of land use, allowing for watershed protection.

As stated earlier, the use of water, both on and off the Forest, is governed by treaty, compact, and decree. Because of this future water withdrawal and diversion opportunities, as well as water storage opportunities, within the Rio Grande National Forest are very unlikely.

Ecological, Social and Economic Sustainability

As has been noted throughout this assessment, watersheds and water resources on the Rio Grande National Forest, in conjunction with air and soil resources, are part of the foundation for providing for the full suite of multiple uses available from national forests. Healthy watersheds across the Forest, and the associated properly functioning hydrologic cycle, provide ecological sustainability, which in turn provides the socio-economic setting of the Plan area and areas downstream. Watersheds within the Forest are the headwaters of the Rio Grande River basin and the quantity and quality of water, as well as the timing of stream flows, from these watersheds drives human activity not only in the agriculturally important San Luis Valley, but in many areas further downstream. For example, people recreate on the Forest to enjoy clean water, flowing streams, and high elevation scenic lakes; annual snowmelt and unpolluted water provides on- and off-Forest uses such as habitat for aquatic organisms, and drinking, industrial, and agricultural supply; and healthy watersheds assist in climate regulation, serving as a sponge and filter system.

Table 36. Historic climate observations and projected climate for the State of Colorado.

Historic Climate Observations	Projected Climate
An increase in statewide annual average temperatures of 2 degrees F over the past 30 years and 2.5 degrees F over the past 50 years, with minimum temperatures increasing more than daily maximum temperatures over the past 30 years	An increase in statewide average annual temperatures of 2.5F to 5.5F relative to a 1971-2000 baseline. Summers are projected to warm slightly more than winters. Typical summer temperatures in 2050 are projected to be warmer than in all but the very hottest summers in the observed record.
An increase in temperatures in all seasons, with the largest trend in summer, followed by fall, spring, and winter.	Climate projections do not agree on whether average annual precipitation will increase or decrease statewide, though winter precipitation is likely to increase by mid-century.
No long-term trends in average annual precipitation statewide.	Most projections show that April 1 snowpack will decline by mid-century due to the large projected warming.
Below-average snowpack since 2000 in all eight major river basins in Colorado, although there are not trends over the past 30 or 50 years.	Spring runoff is projected to shift 1-3 weeks earlier due to warming, with late summer flows likely to decrease as the peak shifts earlier.

Historic Climate Observations	Projected Climate
Snowmelt and peak runoff have shifted 1-4 weeks earlier across Colorado's river basins over the past 30 years due to the combination of lower snow-water equivalent (SWE) since 2000, warming spring temperatures, and enhanced solar absorption from dust-on-snow.	Most projections of future hydrology show decreases in annual streamflow by 2050 for Colorado's major rivers. In some projections, however, the projected increases in precipitation are large enough to overcome the effect of warming, and so these projections show increased streamflow.
A trend toward more frequent soil moisture drought conditions in Colorado over the past 30 years.	Heat waves, droughts and wildfires are projected to increase in frequency and severity due to the projected overall warming.
No evidence of increasing trends in heavy precipitation events or flooding statewide.	Winter precipitation events are projected to increase in frequency and magnitude, but projections currently show no changes in summertime convective storms by mid-century.
Multiple droughts prior to 1900 that were more severe and sustained than any in the observed record, as seen in tree-ring records.	

Table 37. Key ecosystem and water sector vulnerabilities for the State of Colorado.

Landscape	Vulnerability
Forests	Due to longer and more severe droughts, more frequent and severe fires, and conditions more suitable to insect outbreaks and spread of no-native plant species, individual trees and forested landscapes will likely become more vulnerable to insect and pathogen invasions. If wildfires become more frequent and severe, landscapes will be vulnerable to changes in connectivity, shifts from carbon sinks to carbon sources, and shifts in vegetation distribution and type.
Alpine	Alpine plants are vulnerable to phenology shifts caused by rising spring temperatures and earlier snowmelt onset, potentially leading to mid-summer declines.
Grasslands	Grass types that fare better in drought conditions are likely to become more dominant; less drought-tolerant species are therefore vulnerable to increased frequency and severity of drought.
Wildlife	Aquatic species are vulnerable to decline due to reductions in habitat suitability, especially connected to rising water temperatures as well as more frequent and sever fires, forest fragmentation and other changes in habitats.
Water Supply	Water supply entities with inadequate storage, especially agriculture water supplies and small Municipal and Industrial (M&I) utilities, are vulnerable to earlier snowmelt timing and runoff. Entities with junior rights or little storage are potentially vulnerable to future low flows. Virtually all water supply entities and their customers are vulnerable to longer and more intense droughts, especially mega-droughts. Water supply entities in areas like the San Luis Valley or South Metro that rely heavily on groundwater to supplement surface water supplies, as well as private homes and small community water supplies that rely on groundwater, are vulnerable to potential reductions in groundwater recharge. Elements of water supply infrastructure such as older dams, ditches, and canals, as well as reservoirs in areas with high potential for wildfire, are vulnerable to extreme events and increased wildfire risk.
Water Demand	Agriculture producers needing late summer irrigation and some M&I utilities with junior rights are vulnerable to earlier snowmelt timing and lower late summer flows. Those with junior rights facing greater competition among multiple sectors are vulnerable to interaction of heat and lower flows with existing demand trends.

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Landscape	Vulnerability
Water Quality	M&I utilities with older treatment technology or lower treatment capacity, as well as aquatic organisms and ecosystems, are vulnerable to lower flows and higher water temperatures resulting in greater concentrations of pollutants. Water treatment facilities in fire-prone areas are vulnerable to greater likelihood of wildfire leading to higher chances of erosion.
Flood Mitigation	Large portions of the state that exist in areas of high flood risk and have engaged in little mitigation are vulnerable to continued high risk of extreme precipitation events.
Nonconsumptive Uses	Earlier and faster runoff may create vulnerabilities for rafting, fishing, and other recreation activities by reducing appropriate flows. Endangered fish recover programs are vulnerable to potentially reduced average streamflow.

Places at Risk

As a general rule watershed and stream health concerns currently exist with existing system roads and trails, uncontrolled motorized use on unauthorized roads and trails, and livestock grazing in riparian areas. These concerns relate to accelerated soil erosion and compaction, sediment delivered to streams and wetlands, stream channel aggradation and degradation, and the direct, indirect, and cumulative effects on the water cycle and water quality.

Need for Change

Based on information in this section of the assessment, there is little to no need for change in the existing Plan. As a general rule monitoring indicates existing direction is being met when best management practices at the project level are properly implemented. There are occasions when watershed and water resources concerns are identified during project reviews but these concerns are not Forest Plan standard related; rather they are related to lack of proper implementation of one or more watershed conservation practices, i.e., best management practices, which is a contract or permit administration issue, e.g., compliance with term grazing permit conditions, or a specific program area issue, e.g., road and trail maintenance.

The standards and guides section of the existing plan does need to be updated to incorporate the Watershed Conservation Practices Handbook, the National Best Management Practices program, and the Watershed Condition Framework. At the time the current plan was written the WCP handbook was in draft form and neither the national BMP program nor the Watershed Condition Framework existed. All three of these items are key parts of the 2012 Planning Rule.

There is also a need to update the water uses and rights information in the existing Forest plan to incorporate the Water Division 3 Decree. At the time the current plan was written the adjudication of water rights was still in the water court.

As the revised plan is being prepared the Forest should consider adaptive strategies for climate change that are designed to protect and preserve watersheds and water resources.

As mentioned previously in the soil and air quality sections of this assessment there may be a developing concern with atmospheric deposition of nitrogen and its effects on water chemistry. Continued monitoring is needed to confirm or dispute this potential concern. This assessment also suggests climate change could have negative effects on watersheds and water resources. Thus, it is critical the Forest remains diligent in providing the desired condition for these resources. To that end the Forest should continue development, adjustment, and implementation of the watershed and water resources program, and consider preparing a Forest-wide water resources monitoring plan. The preparation of this resource specific monitoring plan

could coincide with Forest Plan revision or be conducted separately. This plan should consider adaptive strategies that address current off-Forest sources of nitrate pollution and the potential effects of climate change that are designed to protect and preserve watersheds and the water resource.

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Appendix

Maps

Map 1. Critical load exceedance for surface water acidity.

Map 2. Critical load exceedance for terrestrial acidity.

Map 3. Critical load exceedance for mycorrhizal fungi.

Map 4. Critical load exceedance for herbaceous plants and shrubs.

Map 5. Critical load exceedance for nitrate leaching.

Map 6. Critical load exceedance for lichens.

Map 7. Critical load minimum exceedance for lichens.

Map 8. Critical load maximum exceedance for lichens.

Map 9. Land type associations.

Map 10. Watersheds at the HUC5 and HUC6 level.

Map 11. Perennial and intermittent streams and water bodies.

Map 12. NHD springs and seeps Potential Groundwater Dependent Ecosystems (GDEs).

Map 13. NWI PEMB wetlands Potential Groundwater Dependent Ecosystems (GDEs).

Map 14. Watershed Condition Framework Overall Class.

Map 15. Watershed Condition Framework Overall Scores.

Map 16. Watershed Condition Framework Aquatic Physical Class.

Map 17. Watershed Condition Framework Aquatic Physical Scores.

Map 18. Watershed Condition Framework Aquatic Biological Class.

Map 19. Watershed Condition Framework Aquatic Biological Scores.

Map 20. Watershed Condition Framework Terrestrial Physical Class.

Map 21. Watershed Condition Framework Terrestrial Physical Scores.

Map 22. Watershed Condition Framework Terrestrial Biological Class.

Map 23. Watershed Condition Framework Terrestrial Biological Scores.