

Chapter 15

Managing air pollution affected forests in the Sierra Nevada

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Abstract

Air pollution impacts in the Sierra Nevada encompass a variety of social and scientific issues that require close coordination of land management agencies. Management approaches are largely opportunistic and include utilizing the legislated mandates and regulatory mechanisms to evaluate impacts and provide recommendations on permit issuance and mitigations to air regulatory agencies, and resource manipulation to slow or reduce effects, such as thinning, prescribed fire, soil treatment, water treatment, and visitor health warnings. The most effective mechanism of managing air resources on national forests in the Sierra is through the federal Clean Air Act and the Prevention of Significant Deterioration process to protect Class I areas. With compelling evidence, air regulatory agencies may have opportunities to strengthen standards and ozone reduction targets based on risk to forest ecosystems.

1. Introduction

Managing the impacts of air pollution in the Sierra Nevada is a complex ecological, political, and regulatory task. The USDI National Park Service and USDA Forest Service manage the vast majority of the Sierra Nevada and together have developed a leadership role in research, monitoring, and development of management strategies to address the effects of air pollution on forest ecosystems. Although both agencies work cooperatively and share most issues and many management strategies, this discussion is limited to the concepts

and strategies of the Forest Service's Air Resource Management Program in the Sierra Nevada.

2. Regional ozone trends

Although stationary sources contribute to the ozone issue, population growth, related mobile sources, and small internal combustion engines are considered the largest contributor to ozone precursor emissions. Air quality in the Sierra Nevada is highly variable: excellent much of the time and in many places, but seriously degraded at other times and places. The ozone damage is both serious and persistent and poses both social and economic costs to the Sierra Nevada (Cahill et al., 1996).

The air regulatory environment surrounding the Sierra involves 6 air basins (San Joaquin Valley, Great Basin Valley, Sacramento Valley, Tahoe Basin, Northeast Plateau, and Mountain Counties) divided into 22 air regulatory districts. The population of the surrounding basins is 5,860,810. Approximately 86% of this population is concentrated in the San Joaquin Valley and Sacramento Valley air basins. The San Joaquin Valley, Mountain Counties and Sacramento Valley air basins are projected to have 20-year growth of 52%, 52%, and 41%, respectively. The Northeast Plateau and Great Basin Valley are projected to have a more modest growth of 28% and 19%, respectively (California Department of Finance, 2000).

From 1980 to 1999, the population of the San Joaquin Valley air basin increased 58%, from about 2 million in 1980 to nearly 3 million in 1999. The Sacramento Valley air basin increased by 52%. The statewide average during this period was 43%. During this same time the daily vehicle miles traveled (VMT) more than doubled in the San Joaquin Valley air basin rising from about 4 million miles in 1980 to over 9 million miles per day in 2000, a 125% rise compared to a statewide average of 87%. Because these growth rates are much higher than the growth rates in other areas, there has not been the same level of air quality improvement in the San Joaquin Valley air basin, especially with respect to ozone (California Air Resources Board, 2001). Although the San Joaquin Valley has received much press about exceeding the federal 8-hour ozone standard—more days than the South Coast air basin in southern California—there has been a steady decline since 1987, with the lowest number of exceedances recorded in 1998.

3. Regulatory structure and guiding legislation

The air quality regulatory structure and agencies responsible for compliance are as follows:

Table 1. National Ambient Air Quality Standards set by the EPA for six principal pollutants

Pollutant	Standard value
Carbon monoxide (CO)	
8-hour average	9 ppm (10 mg/m ³)
1-hour average	35 ppm (40 mg/m ³)
Nitrogen dioxide (NO ₂)	
Annual arithmetic mean	0.053 ppm (100 µg/m ³)
Ozone (O ₃)	
1-hour average	0.12 ppm (235 µg/m ³)
8-hour average	0.08 ppm (157 µg/m ³)
Lead (Pb)	
Quarterly average	1.5 µg/m ³
Particulate matter (PM ₁₀)	10 micrometers or less in diameter
Annual arithmetic mean	50 µg/m ³
24-hour average	150 µg/m ³
Sulfur dioxide (SO ₂)	
24-hour average	0.14 ppm (365 µg/m ³)

- Federal—Environmental Protection Agency (EPA);
- State—California Air Resources Board (CARB);
- Local—Air Pollution Control Districts and Air Quality Management Districts (see Figure 3, Carroll et al., Chapter 2, this volume).

3.1. Environmental Protection Agency

The federal government sets air quality standards, oversees state and local actions, and implements programs for toxic air pollutants, heavy duty trucks, locomotives, ships, aircraft, off-road diesel equipment, and some types of industrial equipment. The role of federal, state, and local governments is defined in the Clean Air Act (CAA) and amendments of 1977 and 1990.

Some of the principal components, regulations, and policies related to the CAA that may directly or indirectly affect management in the Sierra Nevada include the following:

- National Ambient Air Quality Standards (NAAQS). These are standards for pollutants considered harmful to public health and the environment. The EPA has set NAAQS for six principal pollutants, which are called “criteria pollutants” (Table 1).

Table 2. Sierra Nevada Class I areas from the Northern Sierra's to the Southern Sierra's. Class I wilderness areas are contained within the larger Class II areas in national forests, but the entire national park area is considered Class I wilderness area

Class I area	Location
South Warner Wilderness	Modoc National Forest
Thousand Lakes Wilderness	Lassen National Forest
Lassen Volcanic National Park	Lassen Volcanic National Park
Caribou Wilderness	Lassen National Forest
Desolation Wilderness	Eldorado National Forest
Mokelumne Wilderness	Stanislaus/Toiyabe/Eldorado National Forests
Emigrant Wilderness	Stanislaus National Forest
Hoover Wilderness	Toiyabe/Inyo National Forests
Yosemite National Park	Yosemite National Park
Ansel Adams Wilderness	Sierra/Inyo National Forests
Kaiser Wilderness	Sierra National Forest
John Muir Wilderness	Inyo/Sierra National Forests
Kings Canyon National Park	Kings Canyon National Park
Sequoia National Park	Sequoia National Park
Dome Land Wilderness	Sequoia National Forest

- **Prevention of Significant Deterioration in Class I areas.** These areas include national parks, wilderness areas, and some US fish and wildlife refuges that were in existence at the passage of the 1977 CAA amendments. They are provided special protection from new and modified major stationary sources. Eleven wilderness areas and four national parks in the Sierra Nevada are classified as Class I (Table 2). The Prevention of Significant Deterioration is the permitting rule and concept for federal attainment areas (areas cleaner than the federal standard). Only a small increment of additional pollution is allowed in these "clean air areas". Federal land managers are mandated an affirmative responsibility to protect air quality related values that might be impacted by air pollution, including visibility. Other values include flora, fauna, soils, water, cultural resources, and geologic features. Sensitive receptors such as species or populations known to have documented sensitivity have been established. Sensitive indicators are measurable elements of injury or change. An example of this concept for ozone might include the following elements: vegetation as an air quality-related value, ponderosa pine as the sensitive receptor, and chlorotic mottle as the sensitive indicator. Although this concept was originally developed to fulfill the mandates of Class I protection, it is used frequently now throughout Class II national forests as well.
- **Regional Haze Rule.** These regulations require states to review how pollution emissions within the state affect visibility at "Class I" areas across a broad region. These rules also require states to make "reasonable progress"

in reducing any effect of this pollution on visibility conditions in Class I areas and to prevent future impairment of visibility. The states are required by the rule to analyze a pathway that converts the Class I areas from current conditions to “natural conditions” in 60 years. “Natural conditions” is a term used in the CAA, which means that human-caused pollution cannot impair visibility. This program, while aimed at Class I areas, will improve regional visibility and air quality throughout the country.

- **Conformity Rule.** This rule implements the Clean Air Act conformity provision, which requires that the federal government not engage, support, or provide financial assistance for licensing or permitting, or approve any activity not conforming to an approved State Implementation Plan (SIP) in federal non-attainment areas.
- **EPA Interim Policy on Wildland and Prescribed Fire.** This EPA interim policy integrates two public policy goals: to allow fire to function, as nearly as possible, in its natural role in maintaining healthy wildland ecosystems; and to protect public health and welfare by mitigating the impacts of air pollutants on air quality and visibility.

3.2. California Air Resources Board

State governments are responsible for developing State Implementation Plans (SIP) that describe how each state will achieve the requirements of the CAA. In California the SIP is a collection of regulations used to clean up polluted areas. The EPA maintains oversight authority, must approve each SIP, and can take over enforcement action if reasonable progress is not made. The CARB has set more stringent standards, oversees state and local actions, and implements programs for toxic air pollutants, heavy-duty trucks, locomotives, ships, aircraft, off-road diesel equipment, and some types of industrial equipment.

3.3. Air pollution control districts

Local air pollution control districts in California develop plans and implement control measures in their areas of jurisdiction. These collectively make up California’s SIP. These controls primarily affect stationary sources but do include sources of dust and smoke. Air pollution control districts are classified as attainment (meeting the standard) or non-attainment (not meeting the standard) for each criteria pollutant including ozone (Table 3).

4. An overall strategy of air resource management

Management techniques are probably best categorized into direct and indirect opportunities. Direct would include utilizing the legislated mandates and

Table 3. Ozone status by districts in California

Air pollution control district	Federal ozone attainment status	California ozone attainment status
San Joaquin Valley	NA ^a —Severe	NA—Severe
Kern	NA—Serious	NA—Moderate
Mojave	NA—Severe	NA—Moderate
Great Basin	Unclassified	Inyo Co.—Unclassified Mono Co.—NA
Siskiyou	Unclassified	Attainment
Modoc	Unclassified	Attainment
Shasta	Unclassified	NA—Moderate
Lassen	Unclassified	Attainment
Tehama	Unclassified	NA—Moderate
Butte	Attainment	NA—Moderate
Glenn	Unclassified	NA—Moderate
Colusa	Unclassified	NA—Transitional
Yolo/Solano	NA—Severe	NA—Serious
Feather River	NA	NA—Serious
Sacramento	NA—Severe	NA—Serious
Northern Sierra	Unclassified	Unclassified
Placer	NA—Severe	NA
El Dorado	NA—Severe	NA
Amador	Unclassified	NA
Calaveras	Unclassified	NA
Tuolumne	Unclassified	NA
Mariposa	Unclassified	NA

^aNA = Non-attainment.

regulatory mechanisms to evaluate impacts and provide recommendations on permit issuance and mitigations to air regulatory agencies. These are actions that are coordinated with air regulatory agencies and directly reduce emissions from contributing sources. Indirect management might include resource manipulation to slow or reduce effects, such as thinning, prescribed fire, soil treatment, water treatment, and visitor health warnings. These indirect measures attempt to cope with the stress to forest ecosystems and visitor health, require long-term commitment, and risk further complications to ecological imbalance. Further studies are necessary to understand the effects of these actions (Bytnerowicz et al., 1999).

The primary issues facing land managers in the Sierra are well characterized in the Forest Service, Pacific Southwest Region's "A Regional Strategy for Air Resource Management" (1998). The program elements are summarized below and provide some insight to the scope of a resource that is deeply integrated in overall ecosystem health and management issues.

- **Regulatory Compliance.** This element includes management actions needed to update, interpret, and comply with laws, regulations, and rules that apply to management or activities on national forests.
- **Protect and Manage Resources.** This element is targeted at developing air quality into the traditional suite of resources considered in the overall stewardship of public land. Air quality management on public lands developed shortly after the 1977 amendments to the Clean Air Act and the subsequent focus on Class I areas. This element is designed to recognize the importance of air in sustaining forest ecosystems throughout the national forest system, including Class II areas.
- **National Environmental Policy Act (NEPA).** This element involves developing the standards and guidance necessary to allow Forest staff to analyze air quality effects from proposed actions on national forests.
- **Prevention of Significant Deterioration (PSD) and New Source Review.** This element is in response to the 1977 Clean Air Act authority to review proposals for new and modified major sources of criteria pollutants in federal attainment areas. Recommendations on permit issuance are based on potential effects to Class I areas.
- **Research.** This element recognizes the value of close coordination with the research community to develop proposals that support the needs of air resource management.
- **Prescribed Fire and Air Quality.** Land management agencies are examining opportunities to increase the utility of prescribed fire to treat heavy fuels in the Sierra. As a result a need has emerged to coordinate with air regulators, increase air monitoring efforts, and develop dispersion modeling skills to manage smoke and minimize public health impacts.
- **Inventory and Monitoring.** The Forest Service is required to make credible recommendations on permits and provide information to the public and air quality regulators concerning the status and change of resources that may be affected by air pollution.
- **Information Management.** Information management embodies the notion that information should be managed like any other resource. Effective use of information management concepts will minimize the amount of data collected while maximizing use of data.
- **Technical Training.** Air Resource Management staff requires a wide range of skills, and training is critical to meet the demands of the programs objectives.
- **Budget and Staffing.** As a late (1977) addition to the Forest Service program of resource responsibilities, air quality programs have developed in lean budget years. Some modest additions to budgets and staffing are necessary to carry out the strategies and objectives of the Sierra Nevada Framework Project and the Sierra Framework Environmental Impact Statement (EIS).

- External Relations. The success of air resource management depends highly on close coordination with air regulatory agencies, as well as public and private organizations with interests in environmental protection.
- Education and Awareness. This element includes actions necessary to inform Forest Service employees, groups, and organizations about the importance of understanding the sensitivity of resources, the extent of existing impacts, and opportunities to reduce emissions.

5. Management strategies specific to ozone and impacts to vegetation

5.1. Sources of ozone outside national forests

Required consultation with PSD permit applicants only provides for interaction with proposals for major stationary sources. Although occasionally significant, most contributions to the regional ozone load in the Sierra Nevada come from a multitude of small and mobile sources. In order to provide effective protection it is increasingly important to compliment PSD permit reviews with status and trend information to the CARB which, in addition to public health, is responsible for protecting California's ecological values. In order to successfully characterize the condition, sensitivity, and trends of national forests it is valuable to have:

- An inventory of species known to be ozone sensitive and express chlorotic mottle or oxidant stipple symptoms.
- Monitoring to detect injury or change.
- Sensitive indicator damage thresholds or deposition critical loading that allows for analysis of additional new sources.
- Monitoring to characterize ambient air and meteorology.

In April, 1997, an interagency workgroup known as the Federal Land Managers Air Quality Related Values Workgroup (FLAG, 2000) was formed with representatives from the Forest Service, National Park Service, and Fish and Wildlife Service to achieve greater consistency in the procedures each agency uses in identifying and evaluating air quality related values. FLAG developed assistance and support from the EPA, US Geological Survey (USGS), and some state air agencies. The objectives of the interagency group was to develop guidance for:

- Defining sensitive air quality related values.
- Identifying the critical loads (or pollutant levels) that would protect an area, and identifying the criteria that define adverse impacts.
- Standardizing the methods and procedures for conducting air quality related value analyses.

FLAG recommendations for evaluating ozone impacts to vegetation include:

- Because single-source receptor modeling for ozone is not presently feasible, federal land manager actions should be implemented on the basis of ozone damage to vegetation in the area and if ozone exposure is high enough to cause damage.
- Oxidant stipple necrosis on plant foliage and ozone-induced senescence infer adverse physiological or ecological effects and are considered damage if they are determined to have negative aesthetic value.
- The W126 ozone metric should be used to describe ozone exposure, based on a 24-hour, seasonal (April through October) period of measurement. The number of hours in this period of time greater than or equal to 100 ppb (N100) will also be determined, in recognition of the importance of peak concentrations in plant response.
- Nitrogen oxides (NO_x) emission sources should be controlled, since current information indicate most of the interagency areas are NO_x limited.

FLAG also suggests some general guidance with regard to PSD permit responses that may assist in mitigating or evaluating impacts:

- Application of control measures stricter than best available control technology (BACT), which could be lowest achievable emission rate (LAER).
- NO_x emission offsets that benefit the affected Class I area.
- Reduction of emissions from other sources contributing to ozone-associated impacts.
- Applicants calculate ozone exposure for the affected area.
- Post-construction ambient ozone monitoring in the affected area.
- Post-construction ozone effects surveys in the affected area.
- Post-construction ozone exposure/response effects research.

5.2. Sources of ozone on national forests

Although evidence suggests that ozone sources to the Sierra Nevada are primarily from highly urbanized areas (Cahill et al., 1996), some activities permitted on national forests might contribute small amounts of NO_x that may affect ozone concentrations in the range. These activities include prescribed fire, recreational development, mining, boilers, and road construction.

One opportunity to analyze these impacts is through the National Environmental Policy Act (NEPA) process, which is required of significant federal actions. Through this process, it is possible to evaluate the impact potential and develop mitigations.

Another check on federal actions contributing to ozone episodes is through the conformity regulation. This rule applies to federal actions in federal non-attainment areas and clearly states that federal actions will not:

- Cause or contribute to new violations
- Increase the frequency of severity of existing violations
- Delay timely attainment or interim emission reductions.

5.3. Examples of ozone management issues affecting forest protection

5.3.1. Ozone modeling

Ozone modeling is normally a complex regional scale effort, and it is impossible to estimate the contribution of a single source with any degree of confidence (FLAG, 2000). Quantified documentation of air quality impacts and the effect on state or local ability to attain standards is required of federal actions in federal non-attainment areas. In federal ozone non-attainment areas, such as those listed in Table 3, proposed federal actions are required to demonstrate the proposal will not impede progress towards attainment of the standards. Types of projects that might emit ozone precursor pollutants and could occur on Sierra Nevada national forests include prescribed fire and recreational development that might increase vehicle miles traveled. Demonstration of a proposed action suggests modeling to estimate source contribution. The lack of reliable source-specific ozone modeling can lead to very weak determinations that may be successfully challenged.

The inability to determine single source contribution to ozone also inhibits federal land managers in the review of PSD permit applications. Proposed new and modified major stationary sources of ozone cannot be reliably analyzed to understand the potential for impact to vegetation or other resources in Class I areas.

5.3.2. Ozone indicators specific to Class I areas

Forest Service Class I areas in the Sierra are dominated by high alpine ecosystems and often lack pines or have low populations not sufficient to characterize ozone impacts. Ozone research in the Sierra Nevada has historically focused on pines with great success and has allowed extremely good characterization of injury throughout the range. However, ozone impacts specific to national forest Class I areas lack the focus necessary to develop a reasonable characterization specific to these protected wilderness areas. Current research examining other potential indicator species is critical to eventual development of PSD permit recommendations for ozone sources that are credible with respect to a specific Class I wilderness area. After the development of potential indicators in each Class I area, FLAG recommends that surveys should be conducted to detect the presence of ozone-induced foliar injury on selected species. It is also rec-

ommended that fumigation studies should be carried out to verify suspected symptoms.

5.4. Air quality research and data needed to support management strategies

The highly technical nature and evolving science related to air quality requires a highly coordinated effort to ensure the success of protecting Sierra Nevada resources. Management strategies and objectives must be clearly articulated to allow research questions and needs to be well defined.

The following air pollution research questions were developed during the Sierra Nevada Framework Environmental Impact Statement formulation and represent a partial but not comprehensive list of research needs related to ozone:

- What are the mass transport patterns, spatial and temporal distributions, and deposition rates of ecologically significant pollutants to the Sierra Nevada?
- What are the effects of ozone, long-term deposition, and the interactions among nitrogen compounds, sulfur compounds, ozone, drought, and pests on the composition, structure, and function of Sierra Nevada ecosystems?
- Are models used to examine emissions production and transport adequately representing conditions in the Sierra?
- What are the transport processes that control ambient air pollutant concentrations and delivery in the Sierra Nevada?
- How can we better model/understand future patterns of air pollution from downwind sources?
- What is the natural background of ozone in the Sierra Nevada?
- What are the appropriate methods of monitoring other (non-pine) ozone bio-indicators in the Sierra?
- What are the appropriate methods of monitoring the effects of ozone on cultural sites in the Sierra?
- Are the current critical loads, thresholds, and sensitive receptors sufficient for the protection of wilderness and ecosystem values?
- What are the effects of atmospheric pollutants on terrestrial wildlife, insect species, soil invertebrates, and soil micro-fauna?

6. Conclusions

The most effective mechanism of managing air resources on national forests in the Sierra Nevada is through the federal CAA and the PSD process to protect Class I areas. However, this legislation restricts recommendations to major new and modified sources of criteria pollutants in federal attainment areas. In

addition, it restricts recommendations to those based on Class I areas. The vast majority of ozone sources are not effectively influenced through this process. The appropriate strategy presently seems to be continued documentation of ozone injury and trends in partnership with EPA and CARB. With compelling evidence air regulatory agencies may have opportunities to strengthen standards and ozone reduction targets based on risk to forest ecosystems.

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