




**Giant
Sequoia
National
Monument**

**Air Quality
Report**

Signature:

Date:


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AIR QUALITY REPORT

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Introduction

Current Management Direction

Air Quality Monitoring for Smoke

The air quality monitoring program will fulfill the need to keep the public informed, verify the assumptions used in Environmental Assessments, assess potential human health effects impacted by smoke, and evaluate wildland burning smoke impacts on state and federal air quality laws and regulations.

The purposes of a smoke management program are to minimize smoke entering populated areas, to prevent public safety hazards (such as smoke impairment on roadways or runways), to avoid significant deterioration of air quality and National Ambient Air Quality Standards (NAAQS) violations, and to avoid visibility impacts in Class I areas.

The goals for smoke management are to minimize fire emissions, make a smoke dispersion evaluation, notify the public of and have procedures that will reduce the exposure during air pollution episodes or smoke emergencies, and continue air quality monitoring.

Description of Proposal

Affected Environment

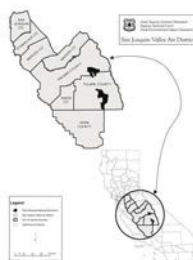
General Meteorology, Climatology, and Transport Mechanisms

The Monument lies in the eastern portion of the San Joaquin Valley Air Pollution Control District (SJVAPCD). The SJVAPCD covers 24,840 square miles, or approximately 16 percent, of the geographic area of California (see map below). The California Department of Finance estimates that the SJVAPCD has a population of about four million people. The San Joaquin Valley has a northwest to southeast orientation, approximately 100 miles wide by 300 miles long. Major urban centers and agricultural areas are located west of the Monument in this valley. The major urban centers include Bakersfield, Fresno, Modesto, and Stockton. The Monument is located generally east (downwind) of the major urban centers.

Air pollution is typically generated in urban and agricultural areas west of the Monument and moved toward the Monument by prevailing west-to-east winds. Air circulation and the movement of smoke and other pollutants in the San Joaquin Valley are restricted in both vertical and horizontal directions. Vertical air movement is restricted by radiation and subsidence inversions. A nocturnal inversion forms in the San Joaquin Valley nearly every day of the year. During all seasons in the valley, the inversion base is 500 feet or less from the ground surface. In the winter, due to lower sun angle, heating is reduced and the inversion base is 1,000 to 1,500 feet above the ground surface. During the rest of the year, the inversion base often lifts to 1,500 to 3,000 feet above the ground surface by mid-day. In the summer, the inversion layer can be entirely destroyed. Air quality in the Monument is typically better when the inversion is lower. Localized night-time radiation inversions in mountain valleys are also common and are normally the main drivers of smoke impacts on public health in the Monument.

Horizontal air movement is restricted on three sides by mountains that surround the San Joaquin Valley. These include the Coastal Mountains to the west, the Tehachapi Mountains to the south, and the Sierra Nevada to the east. In the spring and summer, when the marine layer is shallow, westerly winds enter through low coastal gaps, primarily the Carquinez Straits, and flow toward the southeast of the San Joaquin Valley. During winter months, wind flows in the valley are from the south, with stagnant conditions prevailing except during passage of winter storm systems. Daytime wind speed increases as the valley heats up and is strongest in the afternoon. During storm-free periods in the fall and winter, the airflow is more variable, with light wind speed resulting in less air movement from the valley. At these times, the Monument will typically experience the best air quality. Daily and seasonal variation in air pollution and smoke movement are dependent upon these air transport mechanisms.

**Map 1
California Air
Districts**



During the day, air near the mountain slopes is heated, resulting in upslope and up-valley winds. With the loss of solar heating in the evening as the sun sets, the process is reversed. Terrain-driven winds provide a means to diurnally transport of pollution out of, and back into, the valley (Blumental, et al. 1985). Several studies have demonstrated pollutant transport into the mountains (Lehrman, et al. 1994, Shair 1987, Tracer Technologies 1992). Similarly, other research suggests that pesticides applied in the valley are transported to the Sierra Nevada, with levels decreasing with increasing distance and elevation from the valley floor (Zabik and Seiber 1993).

The meteorology of the San Joaquin Valley has a significant influence on pollutant transport, including ozone and secondary particle formation in the region. Weather patterns moving from the California Central Valley carry pollutants generated in the Valley and deposit them in the central and southern Sierra Nevada foothills and mountains (Zabic and Seiber 1993).

Summer wind patterns in the Sierra Nevada Mountains are complex due to rugged terrain and intense daytime solar radiation. During summer months, the predominant surface wind direction in the San Joaquin Valley is from the northwest to southeast, down valley from Stockton towards Bakersfield. In Fresno, the morning surface flow is frequently from the south or west and is characterized by light wind speeds. Wind speed increases during the day, shifting towards a northwest to southeast direction, and peaking around 5:00 p.m. Pacific Daylight Time (Ewell, et al. 1989.).

The general summer daytime flow can be slightly, but significantly, modified in the late evening and early morning hours. The modified pattern occurs when ozone concentrations in the valley are high. The influence of two major phenomena, the nocturnal jet and the Fresno eddy, which regularly occur during the ozone season, have significant influence on ozone concentrations in the valley (Roberts et al. 1990). The jet stream provides a mechanism for rapid transport of pollutants from north to south, while the eddy cycles pollutants

in the southern part of the valley, possibly leading to increased concentrations. Computer modeling during a summer pollution episode showed that the bay area and Sacramento area contributed 27 percent, 10 percent, and 7 percent to the ozone exceedances in the northern, central, and southern Central Valley, respectively (SJVAPCD 1994). An assessment of impacts of transported pollutants on ozone concentrations by the California Air Resources Board (CARB 1993) indicates that transport of pollutants from the broader Sacramento Area, San Francisco Bay Area, and the San Joaquin Valley has an overwhelming impact on the central and southern Sierra Nevada.

Demographics

Population growth plays an important role in the competition for air pollution capacity and the frequency of smoke-induced public nuisance episodes. The California Department of Finance estimates that the population in the San Joaquin Valley is expected to reach 4.2 million by 2010, 5.3 million by 2020, 6.5 million by 2030, and 7.9 million by 2040. In the San Joaquin Valley daily vehicle miles traveled has increased 210 percent from 1980 to 2009. These current growth trends are higher than other parts of the state. This has limited improvement in the San Joaquin Valley Unified Air District compared to the rest of the state, especially for ozone (CARB 2001).

Air Regulatory Structure, Principal Legislation, and Policy

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

- Federal – Environmental Protection Agency (EPA).
- State – California Air Resources Board (CARB).
- Local – San Joaquin Valley Air Pollution Control District (District).

Environmental Protection Agency (EPA). 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 and its amendments of 1977 and 1990.

Some of the principal components, regulations, and policies related to the Clean Air Act that may directly or indirectly affect planning in the Giant Sequoia National Monument are discussed below.

- *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” (see Table III-2: National Ambient Air Quality Standards). Smoke contributes to PM₁₀, PM_{2.5}, and to a lesser degree NO₂, CO, and O₃.
- *Class I Areas* – These include National Parks, Wilderness Areas, and some U.S. Fish and Wildlife Refugees that were in existence at the passage of the 1977 Clean Air Act amendments. These areas are provided special protection from new and modified major stationary sources. Federal land managers are mandated an affirmative responsibility to protect values that might be impacted by air pollution, including visibility (air quality-related values).

- *Regional Haze Rule* – These regulations require states to review how pollution emissions within the state affect visibility at “Class I” areas across the region. These rules also require states to make “reasonable progress” in reducing effects from this pollution on visibility conditions in Class I Areas and to prevent the future impairment of visibility. The states are required by the rule to analyze a pathway that takes the Class I Areas from current conditions to “natural conditions” in 60 years. “Natural conditions” is a term used in the Clean Air Act that means that no human-caused pollution can 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 mandates 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. Federal actions will not:
 - Cause or contribute to new violations,
 - Increase the frequency or severity of existing violations, or
 - Delay timely attainment or interim emission reductions.

- *EPA Interim Policy on Wildland and Prescribed Fire* – This EPA interim policy integrates two public policy goals: (1) to allow fire to function, as nearly as possible, in its natural role in maintaining healthy wildland ecosystems, and (2) to protect public health and welfare by mitigating the impacts of air pollutants on air quality and visibility.

Table III-2: National Ambient Air Quality Standards

Pollutant	Averaging Time	Federal Standards
Ozone	8-Hour	0.075 ppm
Respirable Particulate Matter (PM ₁₀)	24-Hour	150 µg/m ³
Nitrogen Dioxide (NO ₂)	Annual Arithmetic Mean	.053 ppm
Fine Particulate Matter (PM _{2.5})	24-Hour	35 µg/m ³
	Annual Arithmetic Mean	15 µg/m ³
Carbon Monoxide (CO)	8-Hour	9 ppm
	1-Hour	35 ppm
Sulfur Dioxide (SO ₂)	Annual Arithmetic Mean	.030 ppm
	24-Hour	.14 ppm
Lead	Rolling 3 month average	.15 µg/m ³
	Quarterly average	1.5 µg/m ³

Source: EPA. Accessed online 2/04/2009 at <http://www.epa.gov/air/criteria>.

California Air Resources Board (CARB). State governments are responsible for developing State Implementation Plans (SIP). These describe how each state will achieve the requirements of the Clean Air Act. In California, the SIP is a collection of regulations used to clean up polluted areas. EPA maintains oversight authority, must approve each SIP, and can take over enforcement action if reasonable progress is not made. 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.

Table III-2: California Air Quality Standards

Pollutant	Averaging Time	State Standards
Ozone	1-hour	0.09 ppm
	8-Hour	0.07 ppm
Respirable Particulate Matter (PM ₁₀)	24-Hour	50 µg/m ³
	Annual Arithmetic Mean	20 µg/m ³
Nitrogen Dioxide (NO ₂)	Annual Arithmetic Mean	0.030 ppm
	1-Hour	0.18 ppm
Fine Particulate Matter (PM _{2.5})	Annual Arithmetic Mean	12 µg/m ³
Carbon Monoxide (CO)	8-Hour	9 ppm
	1-Hour	20 ppm
Sulfur Dioxide (SO ₂)	24-Hour	.04 ppm
	1-Hour	.25 ppm
Lead	30 Day average	1.5 µg/m ³

The Smoke Management Guidelines for Agricultural and Prescribed Burning (Title 17) are the regulatory basis for California’s Smoke Management Program. Amendments to California’s Title 17 may directly or indirectly affect planning in the Giant Sequoia National Monument. The smoke management guidelines became effective on March 14, 2001. Local air pollution control districts use these guidelines in local rule development.

San Joaquin Valley Air Pollution Control District (District). 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 also include non-stationary sources of dust and smoke. The District also conducts public education and outreach. The District is comprised of eight counties that share a common air district: Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare Counties. The following District regulations may directly or indirectly affect planning in the Giant Sequoia National Monument:

- Public Nuisance (Rule 4102) – Prohibits air discharge of material that causes nuisance or annoyance to any considerable number of people.
- Prescribed Burning and Hazard Reduction (Rule 4106) – This rule was adopted June 21, 2001, in response to California’s Title 17, and is designed to permit, regulate, and coordinate the use of prescribed burning and hazard reduction burning while minimizing smoke impacts on the public.
- Fugitive Dust (Regulation 8) – The existing Regulation 8 rules were developed to implement control strategies for major sources of dust. These include construction, demolition, excavation, extraction, handling/storage, landfills, paved/unpaved roads, and open areas. EPA has recently cited deficiencies in these existing rules and the District is evaluating a series of new rules aimed at further reductions in particulates.

Pollutants of Concern

Many of the pollutants that have damaged ecosystems and impaired visual conditions existed to some extent within natural systems. Thus, many native species and ecosystem processes evolved in the presence of these pollutants. For the protection of ecosystems in the Monument, it is critical to understand historic levels of these pollutants and to differentiate between anthropogenic and natural process contributions.

The primary air pollutants that impair visibility and cause detrimental effects to public health, and ecosystems include particulate matter, oxides of sulfur and nitrogen compounds, elemental carbon and oxides, ozone, and toxic air pollutants. Natural pollution may occur from volcanic activity, forest fires, decomposition of plants and animals, soil erosion, pollen and mold spores, volatile organic compounds emitted by vegetation, ocean spray, electrical storms, and photochemical reactions. Human pollution sources include industrial sources, prescribed burning, animal production, agricultural burning, residential and business development, and vehicle emissions.

The air pollutants of main concern in this area include particulate matter, ozone, and oxides of nitrogen.

Particulate Matter

Particulate matter in ambient air is composed of complex mixtures of inorganic and organic species. The mixture is made up of liquid or solid particles suspended in the air. These particles vary in origin, size, and composition. Major components of PM_{2.5} include nitrate, sulfate, ammonium, organic carbon, and elemental carbon (Chow et al. 1994).

PM_{2.5} is made up of combustion particles and re-condensed organic and metal vapors, and contains secondarily formed aerosols from gas to particle conversion (WHO 2003, Liu et al. 2003, Harrison et al. 2001). PM_{2.5} particles form mainly from high temperature sources or gas to particle conversion processes within the atmosphere (Harrison et al. 2001).

Particles formed from gases through nucleation originate mainly from anthropogenic sources such as combustion from motor vehicles, power generation, industry, and from residential fireplace and wood stoves (Liu, et al. 2003). Vehicular traffic has been shown to be an important source of fine particles, especially near busy roads (WHO, 2003, Gertler et al. 2000). Photochemical production of fine aerosols such as sulfate,

nitrate, and organic aerosols increases in the summer months in the presence of higher concentrations of ozone (Parkhurst, et al. 1999).

In the regulatory framework, PM is divided into fine and coarse particles. Fine particles are defined as particles with an aerodynamic diameter of less than 2.5 μm . Fine particles are made up of combustion particles and recondensed organic and metal vapors, and contain secondarily formed aerosols from gas to particle conversion (Liu et al. 2003, Harrison et al. 2001, WHO 2003). Coarse particles are defined as particles with an aerodynamic diameter between 2.5-10 μm . The coarse particles are mostly composed of crust materials and dust from roads and industries (Liu et al. 2003, WHO 2003). PM_{2.5} is defined as particles with an aerodynamic diameter less than 2.5 μm . PM₁₀ is defined as particles with an aerodynamic diameter of less than 10 μm .

Health Effects

Short term exposure to Particulate Matter has been associated with negative effects to human health. Long term exposure to Particulate Matter is believed to have a much greater impact on human health, but is less certain because less is known about it (Koelemeijer et al. 2006). It has been suggested that life expectancy is lower for people living in areas with high Particulate Matter levels (Houthuijs et al. 2001). Fine particle concentration (PM_{2.5}) are associated with adverse health effects on the general population; including increased mortality and morbidity, reduced lung function, increased respiratory symptoms (such as chronic cough or bronchitis), aggravated respiratory and cardiovascular disease, eye and throat irritation, coughing, breathlessness, blocked and runny noses, and skin rashes (Radojevic 1998, Houthuijs et al. 2001). Short exposure to PM₁₀ increases mortality, hospital admissions, respiratory symptoms, and reduces pulmonary function (Houthuijs et al. 2001). Long term exposure to PM₁₀ has adverse effects on respiratory health as well.

There is strong evidence to suggest that PM_{2.5} is more hazardous to human health than PM₁₀ in terms of cardio pulmonary disease, and mortality (WHO 2003). Thus epidemiological studies in the last decade have emphasized the negative health effects are mainly related to the increase in levels of fine particulate matter in the atmosphere of sizes of less than 2.5 μm (Querol et al. 2007). Fine particles measured as PM_{2.5} are strongly associated with mortality and hospitalization for cardio pulmonary diseases (WHO 2003). Smaller particles induce more inflammation than larger particles on a mass basis. The reduction in life expectancy is primarily due to increased cardio pulmonary disease and lung cancer mortality. The increases in cardio pulmonary disease are likely in lower respiratory symptoms and reduced function in children, and chronic obstructive pulmonary disease and reduced lung functions in adults (WHO 2003).

Effects on Forests and Ecosystems

Particulate matter (PM) from fire has been a part of the ecosystem in the Monument. PM has likely been reduced with the suppression of fire, particularly at higher elevations where impacts from anthropogenic emissions of PM are less. In the fire and smoke adapted Monument, PM is currently likely to be at or below historic levels.

Ozone

Ozone (O₃) is a powerful oxidant, causing irritation in human lungs and visible injury to plant leaves and needles. First discovered in the 1840s, O₃ was first shown to be toxic to animals in the 1870s and to cause crop damage in the 1940s (Carroll et al. 2003). Ozone is produced photochemically by oxides of nitrogen

(NO_x), volatile organic compound (VOC) emissions from combustion engines, and biogenic emissions of reactive VOC from plants in the Sierra Nevada coupled with strong sunlight and high temperatures (Murphy et al. 2007).

The most reactive VOCs in this area are isoprene and MBO (Biogenic 2-methyl-3-buten-1-ol). High isoprene emissions occur in the foothills of the western Sierra Nevada from a dense population of oak trees, while MBO is emitted from pines at a higher elevation (Steiner et al. 2007). Ozone exposure in the Sierra National Forest is higher than in the valley locations (Cisneros and Perez 2007).

NO_x condition upwind of the western Sierra Nevada and meteorology are the most important factors determining ozone production potential of isoprene and MBO emissions (Dreyfus et al. 2002). Increased temperatures in this region caused by climate change has the potential to create more ozone. Other factors that are important for local ozone production in the Central Valley includes large-scale meteorology, mixing depths, and transport of ozone formed in other areas such as San Francisco (Steiner et al. 2008).

NO_x concentration tends to decrease from west to east, with higher concentrations occurring in urban areas (Steiner et al. 2008). Thus NO_x concentration is slightly lower in the MBO-emitting pine region than in the isoprene-oak emitting regions. As a result production of O₃ is higher in the foothills where the plume of NO_x encounters these reactive VOCs.

Isoprene is the major factor enhancing O₃ production per unit of NO_x (Hirsch 1996). Oak forests and woodlands in the western Sierra Nevada foothills are the major source of isoprene emissions to the region (Dreyfus et al. 2002). The O₃ created in this area, and isoprene from oaks, is transported up to higher elevations in the western Sierra Nevada following the predominant wind patterns. Oxidation of isoprene is a major source of O₃ production on the western slope of the Sierra Nevada, and it is considered the dominant VOC ozone precursor (Dreyfus et al. 2002). The contribution to O₃ production by isoprene is compounded by the fact that hot and stable conditions associated with O₃ production are the same conditions that produce highest isoprene emission rates (Dreyfus et al. 2002).

Health Effects

According to Hayes (1993), a number of health effects have been documented or suspected due to ground level O₃ exposure. Some of the effects are lung function decrements, airway hyper-reactivity, epithelial cell damage, and bronchoalveolar inflammation. All are known to occur during the exposure of humans to low levels of ozone.

According to the EPA (1999), even at relatively low levels, O₃ may still cause inflammation and irritation of the respiratory tract, particularly during physical activity. The symptoms include coughing, throat irritation and breathing difficulty. Ozone can affect lung function and worsen asthma attacks. Ozone can increase the susceptibility of the lungs to infections, allergens, and other air pollutants. It damages lung tissue. Ozone may aggravate chronic lung diseases, such as emphysema and bronchitis; and reduce the immune system's ability to fight bacterial infection in the respiratory system (EPA 1999). Groups that are sensitive to O₃ include children and adults who are active outdoors, people with respiratory diseases, and people with unusual sensitivity to ozone. Roughly one out of three people in the United States are at higher risk of experiencing O₃ related health effects (EPA, 2000).

Effects on Forests and Ecosystems

Ozone can affect forest health and change biodiversity (Bytnerowicz et al. 2002). The diversity and population density of fungi growing on needles have decreased in locations with high ozone concentration. These organisms act as litter decomposers, and rates of decomposition may be affected. Fifty percent or more of the lichen species are missing due to high ozone levels. In the Sierra Nevada, atmospheric monitoring suggests that O₃ concentration occurs in doses sufficient to damage pines (Bytnerowicz et al. 2002). Most of the significant injuries continue to be evident in the Sierra and Sequoia National Forests. Ozone also affects the production of foliar chlorophyll. Ozone may be toxic to vegetation at concentrations greater than 30 to 40 ppb; the severity of plant damage depends on the characteristics and length of exposure as well as abiotic and biotic factors (Bytnerowicz et al. 2002).

Ponderosa and Jeffrey pines are particularly sensitive to this pollutant. Ozone damages trees and increases susceptibility to mortality from other factors such as drought, insects, fire, and extreme weather. The damage to ponderosa pine needles was first observed in the 1950s in southern California's San Bernardino Mountains. In the Sierra Nevada, ozone-affected forests on the western slopes began to be identified in the 1970s. Injury to the mixed conifer forest from tropospheric ozone has been occurring in southern California since the 1950s and in the Sierra Nevada since the 1970s (Arbaugh et al. 1998). Trees damaged by O₃ demonstrate decreased radial growth and reduced tolerance to western pine beetles and other stressors. Western pine beetles kill more trees and increase at a greater rate in places with higher O₃ levels. Ozone also affects shrubs and other understory vegetation which are less resilient to drought, more likely to be attacked by bark beetles and other insect pests, and generally less able to survive pathogen infection.

Nitrogen Oxides (NO_x)

Nitrogen oxides form when fuel is burned at high temperatures, principally generated from motor vehicles and stationary sources such as electric utilities and industrial boilers. Nitrogen oxides can negatively affect aquatic systems, visibility, and are a precursor compound to ozone and PM_{2.5}. The primary releases of nitrogen compounds (oxides, ammonium, and nitrates) to the air in natural ecosystems are from microbial activity, lightning and wildfires. Historic levels have almost doubled globally as a result of fossil fuel combustion, animal husbandry practices, and fertilization.

Nitrogen Dioxide (NO₂)

Nitrogen dioxide (NO₂) belongs to the family of nitrogen oxides (NO_x). It is recognized to cause negative effects on human health (WHO, 2003). A suffocating, brownish gas, nitrogen dioxide is a strong oxidizing agent that reacts in the air to form corrosive nitric acid, as well as toxic organic nitrates. It also plays a major role in the atmospheric reactions that produce ground level ozone.

Nitrogen Dioxide (NO₂) Health Effects

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. The effects of short-term exposure are still unclear, but continued or frequent exposure to concentrations that are typically much higher than those normally found in ambient air may cause increased incidence of acute respiratory illness in children. EPA's health-based national air quality standard for NO₂ is 0.053 ppm (measured as an annual average) (Table 1).

Effects on Forests and Ecosystems

Nitrogen oxides in the air are a significant contributor to nitrogen deposition, which causes a number of environmental effects, such as acid rain and eutrophication. Eutrophication occurs when a body of water has an increase in nutrients, which reduces oxygen in the water, creating an environment that is destructive to aquatic life. Even moderate concentrations of NO_x and other nitrogen compounds can contribute substantial amounts of deposited nitrogen to the forests affecting growth, species composition, and surface and ground water quality (Fenn et al. 2003, Bytnerowicz and Fenn 1996, Tarnay et al. 2001).

Current Air Quality Conditions

District Designations. The District is considered to be in non-attainment (not meeting standards) federally for ozone and Particulate Matter (PM). Smoke from various sources is a contributor to PM and ozone.

Visibility Conditions. Visibility in the Sierra Nevada improves from south to north and from low to high elevation. Sequoia and Kings Canyon National Parks, the southernmost and lowest elevation Class I monitoring sites, experience some of the worst visibility conditions among western Class I Areas. Smoke can contribute to visibility impairment. The Interagency Monitoring of Protected Visual Environments (IMPROVE) site at Sequoia National Park is considered representative of visibility conditions in the Monument. This site shows high nitrate concentrations, indicating an urban influence.

Ozone Impacts to Vegetation. Amounts of ozone have increased in the San Joaquin Valley as a result of increased levels of nitrogen compounds and volatile organic compounds. The Forest Service and National Park Service have tracked injury to conifers in the southern Sierra Nevada since 1991. Some of the earliest plots have been evaluated for a period of over 20 years. The data confirms injury in Jeffrey and Ponderosa pines with the bulk of injury occurring in stressed trees. There is inadequate monitoring data to fully understand the physiological effects.

Sulfur and Nitrogen Compounds. Nitrogen compounds in the air have shown an overall increase compared to preindustrial levels, although the total amount has not been quantified. Deposition of nitrogenous and sulfurous pollutants is highest on the western slopes of the Sierra Nevada closest to the valley. Deposition from urban and agricultural sources may be approaching saturation in southern parts of the Sierra.

Environmental Effects

— Air Quality

Emissions From National Monument Activities

Smoke from prescribed burning and wildland fire affect air quality and are a concern for potential adverse effects on human health and visibility. Smoke can affect visitors to the Monument and residents in surrounding communities.

Prescribed Burning

When considering the use of prescribed burning to reduce fuels and restore the natural role of fire in ecosystems, the effects of smoke must be evaluated.

The use of prescribed burning to restore natural processes to the fire-adapted landscape of the Monument must weigh both the potential benefits and the potential impacts on air quality, both within the Monument and the air district. In spite of their ecological benefits, prescribed fires, as well as natural fires, produce gases and aerosols that have instantaneous and long-term effects on air quality (Fang et al. 1999). The extent of these effects depends on fire size, fuel composition, and the physical and chemical characteristics of the events (Kasischke and Penner 2004). Before 1800, 1.8 million hectares burned annually in California (Stephens et al. 2007). High severity, stand-replacing fires have been increasing in frequency since that time (Miller et al. 2008). Keeping the Sierra Nevada frequent, low-intensity fire regime functioning can reduce emissions and fire severity (Collins et al. 2007, Hurteau et al. 2008). A healthy, functioning natural ecosystem will accomplish long-term air quality goals for the Monument and help buffer anthropogenic emissions from the region.

Fires emit large amounts of particulate matter (PM₁₀ and PM_{2.5}) and carbon monoxide, as well as the precursors to ozone: nitrous oxides (NO_x) and volatile organic compounds (VOCs). Other chemical constituents of smoke such as polycyclic aromatic hydrocarbons (PAHs) may also enter the lungs. Some carcinogenic components in smoke are benzo-pyrene and aldehydes.

Wildfires result in greater emissions per acre when compared to prescribed burns. They also typically occur under conditions of high temperature and low humidity, when high concentrations of ozone are most likely. Prescribed burning mitigates impacts to air quality by reducing existing fuels and decreasing fire hazard and the risk of high intensity wildfire. Prescribed burning allows for better control and timing of emissions and a decrease in the quantity of fuels available for consumption in a wildfire. Infrequent large wildfires will still occur naturally in some vegetation types. Prescribed fire will help to reduce the frequency and extent of large-scale high intensity wildfire events and the corresponding negative effects on air quality.

The composition and quantity of smoke emissions from fires and the impact of those emissions on local and regional air quality vary dramatically with the chemistry and condition of the fuel, the amount and arrangement of fuel layers, the behavior of the fire and weather conditions, and the size and type of fire that occurs (Ward and Hardy 1991). The phase of combustion also affects fire emissions. For instance, smoldering combustion produces more CO, NH₃ and particulates than flaming combustion (Griffith et al. 1991, Ward 1999). With higher fuel moisture, a greater proportion of consumption occurs in the smoldering phase of the fire. This phase typically has lower combustion efficiency. The smoldering phase is the least efficient due to incomplete combustion and yields the highest pollutant to consumed fuel ratio.

The number of acres burned is the single most important factor in determining total emissions within an airshed. Large fires, whether originating as wildland fires or prescribed fires, produce more total emissions than small fires. Therefore, reducing the total acreage burned, regardless of the type of fire, is the most effective way to reduce the total emissions within an airshed for a short time interval (less than 100 years). In the monument, fire acres burned per year will likely remain similar over longer time periods (thousands of years).

Fire type also influences emissions. Prescribed fires typically produce lower per-acre emissions than wildland fires. Heading fires (a fire that burns with the wind) typically produce lower per-acre emissions than backing fires, and surface fires typically produce lower per-acre emissions than crown fires. The differences in emissions among the different fire types may be attributed to differences in meteorological conditions, fuel properties, and resultant fire behavior and fuel consumption. Because prescribed fire generally produces

lower per-acre emissions than wildland fire, it is possible to burn more acres with prescribed fire than would normally occur with wildland fire and produce the same total emissions within an airshed.

The primary benefit of a prescribed fire program is in modifying the timing, size, and type of fire that occurs within a particular geographic region. With prescribed fire, it is possible to replace large, high-intensity wildland fires characterized by high fuel consumption and high total emissions with smaller, lower-intensity prescribed fires characterized by lower fuel consumption and lower total emissions. This decrease in wildland fire emissions typically comes with increased prescribed fire emissions. Prescribed fire allows for some control of emissions by allowing air regulators to help time emissions to minimize human health impacts.

Tian et al. (2008) investigated air quality impacts of prescribed fires under different management practices and fire return intervals in the Southern Pine Forests of Georgia. They found that night-time air quality impacts from prescribed fire during the smoldering phase are greater than in the flaming phase. This is because at night, when smoldering is the highest, dispersion is the lowest. They also showed that the frequency of prescribed fire is inversely proportional to the amount of emissions. When the burn frequency is low, more biofuel is burnt in each fire, leading to larger emissions and air quality impacts per fire. In addition, more fuels of larger size, which usually cannot be consumed completely during flaming, contribute significantly to smoldering emissions when the time between fires increases.

Air quality impacts are measured in terms of pollutant concentrations in ambient air, not in terms of total emissions. Emissions do not equate to concentrations. Higher emissions do not necessarily mean higher concentrations. Air concentrations are a function not only of the total emissions within the airshed, but also of the timing of the emissions, the locations of emission sources relative to sensitive receptors, the meteorology of the area, and the physical characteristics of the plume. Prescribed fire generally produces lower total emissions, lower fire intensity, lower total heat production, and lower plume rise than wildfires. A wildfire can often lead to higher smoke concentrations at locations farther from the source than a similar size prescribed fire. This difference can often lead to higher smoke concentrations at locations far from the source than a prescribed fire of the same size. Type of fire, distance from the source, and acres burned per day are likely the main factors determining human health impacts from smoke.

Effect of Prescribed Burning on CO₂ Emissions and the Carbon Budget

An issue of significance concerning prescribed burning emissions is their effects on the carbon budget. Western and Southeastern US needle leaf forests were estimated to be dominant contributors to total yearly US fire CO₂ emissions which amounted to 293 Tg CO₂ yr⁻¹ for the period 2002-2006 (1Tg or teragram = 10¹² g) (Wiedinmyer and Neff 2007). California contributed a significant annual average emission of CO₂ from fires, 24 Tg yr⁻¹, equivalent to 6% of fossil fuel combustion estimates. Prescribed fires were observed to constitute an insignificant percentage of this emission. A 2002 study by the CARB (2006) estimated CO₂ emissions from prescribed fires in California to be 123,480 Mg yr⁻¹ (1 Mg or megagram = 10⁶ g). Although current prescribed fire emissions are an insignificant percentage of the total fire emissions, different scenarios which increase prescribed fire acreage and frequency need to be analyzed for their effect on the forests of the monument as a carbon sink or source. Fluxes of other carbon forms such as black carbon and dissolved organic carbon, in addition to CO₂, will also have to be included in these carbon budget equations. Black carbon, an air pollutant and residue of incomplete combustion, is persistent in the environment and may constitute a significant portion of the total carbon emissions from forest fires in California and the San Joaquin Valley basin.

Cumulative Effects

Air pollution is one of the most serious threats to Sequoia National Monument. The Monument is in a region that has some of the worst air quality in the nation. Air quality is typically worse than in other national forests. Air pollution threatens the health and welfare of the public, natural resources, and staff.

Most of the Sequoia National Monument air pollution originates in the San Joaquin Valley and is transported into the Monument by prevailing winds (Blumental, et al. 1985, Lehrman et al. 1994, Shair 1987, Tracer Technologies 1992, Roberts et al. 1991, Zabik and Seiber 1993). Unlike many other states, California has few large stationary sources of air pollution. mobile, area, and small stationary sources emit the majority of the state's pollutants.

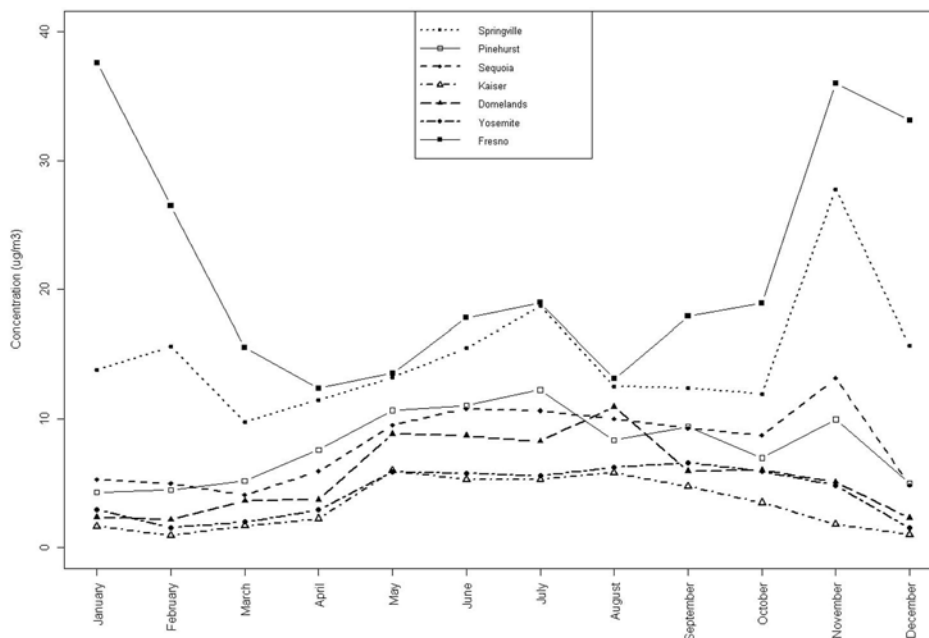
NO_x is a key ingredient in PM_{2.5} and ozone formation. About 75 percent of the NO_x in this area come from mobile sources (SJVAPCD, 2009). With the population in the San Joaquin Valley expected to grow by 60 percent between 2000 and 2020 (SJVAPCD 2009), the problem is likely to get worse. Population growth leads to an increase in vehicle activity. The current spread out, car dependent society combined with the highest population growth in the state will likely lead to more driving which will lead to more air pollution problems.

Significant amounts of the Asian aerosols have been observed at high elevation mountain sites in the western United States (VanCuren and Cahill 2002, VanCuren 2003, Liu et al. 2003). Pollutants from Asia are a regular component of the troposphere over the western North America. They are more pronounced during the spring and to a lesser extent during the summer. Pollutants from intercontinental transport contribute to some of the PM and ozone problems in Sequoia National Monument during the spring and summer.

Particulate Matter in the Southern Sierra Nevada

Figure 1 depicts seasonal patterns for PM_{2.5} in the southern Sierra Nevada and the city of Fresno.

Figure 1



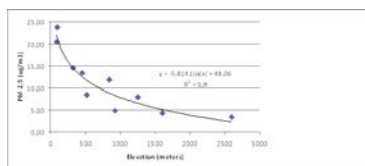
PM_{2.5} data for Fresno follow a trend of increased PM_{2.5} during the winter months (November to February). This seasonal pattern contrasts with the most remote site at Pinehurst where monthly averages are lower in the winter and higher in the summer. Winter PM_{2.5} concentrations in the Monument appear to be disconnected from the Central Valley in the winter months.

Overall, PM_{2.5} concentrations diverge during the winter months, and trend together during the summer months. Urban contributions to PM_{2.5} are limited in more remote areas during the winter months. Beginning in April and continuing to August, PM_{2.5} equilibrates between lower and higher elevation areas on the western slope of the Sierra Nevada.

Sites situated between urban and undisturbed areas show a seasonal pattern that is influenced by elevation and proximity to urban areas. This is potentially driven by winter inversions that set up over the central valley. These inversions may slow the transport of PM_{2.5} from urban areas by inhibiting the mixing and venting of air masses from the Central Valley.

Figure 2 is a regression plot of elevation and PM_{2.5}. The data used were obtained from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network from 2002 to 2008, the Air Resources Board (ARB) network from 2006 to 2008, and the Forest Service network from 2006 to 2008. Sites in the IMPROVE network include Yosemite National Park, Sequoia and Kings Canyon National Parks (SEKI), Kaiser, and the Domelands Wilderness. Sites in the Forest Service network include North Fork, Pinehurst, Springville, and Trimmer. Visalia and Fresno are sites in the ARB network.

Figure 2



Site elevation may be the main factor in the Sierra Nevada for PM_{2.5} concentrations. Lower elevations and sites located near urban areas have seasonal high PM_{2.5} during the winter months (November to February). Higher elevation sites such as Pinehurst and Kernville see a decrease in PM_{2.5} during this period. The site at Springville has a slight increase in PM_{2.5} during the winter. In November, Springville was mixing well with Fresno, but was isolated from the higher elevation sites.

Sites at elevations higher than 400 meters are currently below national air quality standards. These findings indicate that locations in the Sequoia National Monument, which form part of the San Joaquin Air Basin, are under attainment or are cleaner than urban locations.

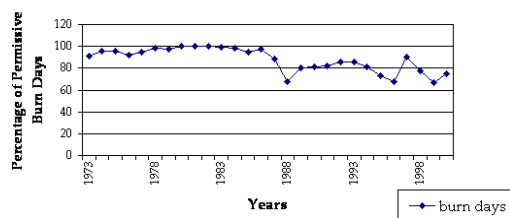
Late summer to early fall, PM_{2.5} concentrations in sites located between urban areas and wilderness are lower than what would be expected if PM concentrations were being driven primarily by fire. Further, the data suggest that elevation (including location) and time of year are helpful management considerations for fire. This information, coupled with the small size of prescribed fires, may prevent hazardous impacts to air quality.

Retrospective Analysis of Burn Days

Burn day designations within the Monument are currently designated by the San Joaquin Valley Air Pollution Control District (District). Until recently the California Air Resources Board (CARB) has provided this service. The data used for the retrospective analyses were based on burn day designations historically provided by CARB. Annual summaries were used to establish trends and daily records from 1998 to 2001 were used to look at monthly variations.

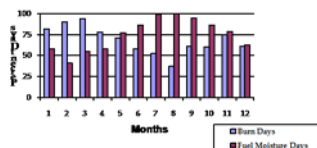
An examination of CARB burn day records from 1973 to 2000 suggests that designated burn days have declined in the Monument since 1973 (Figure IV-1). Up to about 1988, over 95% of the days each year were permissive burn days. From 1988 to 2000, the number of permissive days has been just under 80 percent. Even though burn days have declined since 1973 a fairly high percentage of days remain available. The District is planning to develop a burn day designation process that will involve dividing the District up into zones. More refined meteorological data is expected to provide better forecasting and the ability to differentiate “burn” and “no burn” designations at a zone scale. This process could provide more burn day designations in the Monument.

Figure IV-1: Burn Days 1973 to 2000

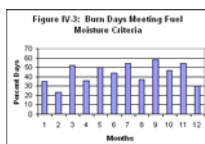


Available burn days only provide the information needed to minimize the potential for smoke impacts. The Forest Service has many other criteria that must be met prior to ignition of a prescribed burn. One of the principal criteria is fuel moisture. Days meeting fuel moisture criteria and designated burn days for 1998 to 2001 were examined to better understand how they might constrain prescribed fire in the Monument (Figure IV-2). The number of designated burn days tends to start high in January and peak in March. There is a considerable drop from April to August, and then a slight increase from September to December. The number of days when fuel moisture criteria is suitable for prescribed burning is at its lowest in January and February and picks up in the spring months. Conditions are normally too dry for burning after May and remain that way until about September. Generally the data suggest that, in early spring, fuel moisture is more constraining than permissive burn days and, in the fall, permissive burn days are more constraining than fuel moisture.

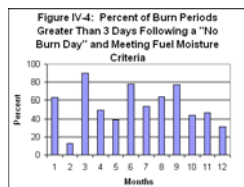
Figure IV-2: Burn Days vs. Days Meeting Fuel Moisture Criteria



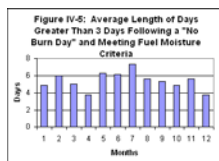
Both fuel moisture records and burn day designations for the 1998 to 2001 period were used to examine monthly variation in permissive burn days that met fuel moisture criteria (Figure IV-3). The data suggest slightly more days meeting both criteria in the fall burn period than in the spring period. The traditional burning period in the spring (March, April, May) averages about 45 percent of the days meeting criteria. The traditional burning period in the fall (September, October, November) averages over 50 percent of the days meeting criteria.



Another factor that could limit prescribed fire application is the availability of consecutive burn days meeting a prescription for larger projects that might take multiple days to complete. The 1998 to 2001 data was examined to better understand the opportunities for multiple day projects. The frequency (percent) of burn periods following a no burn period that would extend at least 3 days is displayed in Figure IV-4. Fuel moisture criteria are integrated as well. Coordination with the San Joaquin Valley Air Pollution Control District staff might allow better predictions of these periods.



Of those periods that exceeded 3 days, the average length was 4½ days. The monthly variation in the average length of days exceeding 3 days is shown in Figure IV-5. These data tend to indicate that sufficient opportunity exists to allow the varying amounts of prescribed fire considered in each alternative. The more complex issue may be one of public acceptance of smoke, which is discussed in more detail in the section on Smoke and Public Nuisance below.



Methodology

PM_{2.5} and CO₂ emissions were calculated using the methods outlined by the General Conformity State Implementation Plan Handbook (USDA Forest Service 1995). The emissions calculations used the total number of acres to be treated, vegetation type, estimated fuel loading, and an emissions factor. The projected number of acres of prescribed and wildfire were predicted with the SPECTRUM model.

The emission calculation formula is as follows:

$$E = S (A \times L \times EF \times \%C) / 2000 \text{ (tons)}$$

L= Fuel Loading for ith species (tons)

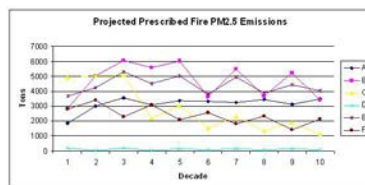
EF= Emission factor for ith species (lbs/ton)

%C= Percent Combustion

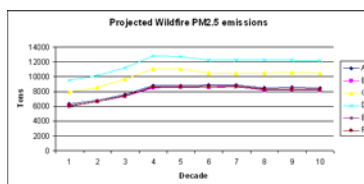
Air Quality Impact Assessment

Prescribed burns produce ozone precursors. Ozone problems in the Monument occur mainly during the summer (May through September) and are primarily driven by urban influence. Prescribed burns are typically not conducted during this time period. This evaluation will only analyze the possible effects of prescribed burns on PM_{2.5} levels. Wildfires occur during this time, but it is impossible to predict when they will happen. It is assumed that if a wildfire occurs in the Monument, the concentrations of particulate matter will be the most impacted. Ozone concentrations are assumed to be less impacted, and PM_{2.5} is a better representative of overall air quality impacts.

The following graph presents, by alternative, the predicted PM_{2.5} emissions from prescribed fire by decade. Prescribed fires were predicted with the SPECTRUM Model.



The graph below presents, by alternative, the predicted PM_{2.5} emissions from wildfire by decade. Wildfires were predicted with the SPECTRUM Model.



Prescribed fire and wildfire are separated to better analyze overall impacts to air quality. Differences in total PM_{2.5} emissions generated by the model are not significant between scenarios. All model scenarios would have virtually the same overall impact on air quality. Tradeoffs between levels of control between emissions are the primary factors in overall impacts to air quality.

Prescribed fire primarily burns during the spring or fall. This can prevent the occurrence of destructive summer fires, thus decreasing emissions and minimizing air quality impacts. Destructive fires have the greatest impacts on air quality. Land management agencies have no control over when these fires start and very little control after they start. Wildfire can burn large areas quickly. Wildfires that are not controlled can have very high emissions that lead to the high production of air pollutants and degradation of local and regional air quality.

Impacts on air quality are likely to be most affected with a change in fire return intervals in the Monument that increase fuel consumption. This could be the effect of temperatures above the historic normal, changes in precipitation that cause conditions that are drier than normal, and forest type conversion.

The following table ranks the overall impacts on air quality, with specific rationale for each alternative. Because of the removal of fuels, Alternative E would likely have the least impact on air quality. Alternatives B and F, similar to Alternative E, would maximize emission control and minimize wildfire emissions. Alternative A would reduce wildfire emissions, but not allow as much control of emissions as Alternatives B, E, and F. Alternative C would increase short-term emissions by maximizing wildfire re-introduction and limiting mechanical fuels reduction. Alternative D would have the greatest impacts on air quality because emissions would be dominated by wildfires with the greatest potential to change the fire system.

Table 1 Air Quality Ranking by Alternative

Alternatives	Overall Impacts to Air Quality	Rationale
A	3 ⁽¹⁾	Moderate wildfire emissions, with the priority of fuel reduction tools allowing for some control of emissions impacts on air quality.
B	2	Low wildfire emissions, with the priority of fuel reduction tools allowing for greater control of timing of emissions release and minimizing air quality impacts.
C	4	Moderately high wildfire emissions, with less use of mechanical treatments and moderate prescribed fire emissions. Restoring the natural process of wildfire without managing stand structure results in short-term (3 decades) increase in emissions.
D	5	High wildfire emissions, with much less use of prescribed fire and mechanical treatments. Reduces overall control of emissions while maximizing total emissions released through uncontrolled fires.

Alternatives	Overall Impacts to Air Quality	Rationale
E	1	Low wildfire emissions, with greater use of mechanical treatments and prescribed fire. Allows maximum control of emissions while minimizing total emissions from fire.
F	2	Low wildfire emissions, with flexibility of management tools allowing for greater control of timing of emissions release and minimizing air quality impacts.

1. Qualitative Scale: 1 lowest impact, 2 low impact, 3 moderate impact, 4 moderately high impact, and 5 high impact.

Climate Change

The climate system is often defined as average weather. The climate system is complex and interactive. Climate is usually described in terms of mean and variability of temperature, precipitation and wind over a period of time. The periods of time, range from months to millions of years. The classical period is 30 years. The climate system evolves under its own internal dynamics and external factors that affect climate. External factors include human caused changes in atmospheric composition through the increase of GHGs (green house gases), as well as natural events such as solar variations and volcanic eruptions.

The most important GHGs are CO₂ (carbon dioxide), CH₄ (methane), N₂O (nitrous oxide), several synthetic halocarbons (chlorofluorocarbons (CFCs), hydrofluorocarbons, perfluorocarbons, halons and sulphurhexafluoride), H₂O (water), O₃ (ozone), and aerosols.

The most important GHG related to prescribed fire in the Giant Sequoia National Monument is CO₂.

The Environmental Protection Agency (EPA) (2007) developed a “State of Knowledge” paper that outlines what is known, what is very likely and what is uncertain about global climate change.

The following elements are known about climate change: human activities are increasing the levels of GHGs since pre-industrial times thus changing the composition of Earth’s atmosphere; the build up of CO₂ and other GHGs are largely due to the burning of fossil fuels; an unequivocal global warming trend of about 1 to 1.7 degrees Fahrenheit occurred from 1906-2005. Green house gases emitted by human activities remain in the atmosphere for periods ranging from decades to centuries, therefore atmospheric concentrations of GHGs will continue to rise over the next few decades; and increasing GHGs concentrations tend to warm the planet.

The following is very likely about climate change: The increase of anthropogenic GHG concentrations have resulted in most of the observed increase in global average temperatures since the mid-20th century; the average global temperatures and sea levels will continue to rise and precipitation patterns will change as GHGs in the atmosphere continue to rise.

The following is uncertain about climate change: how much and how fast warming will occur; and how warming will affect precipitation patterns and the rest of the climate system.

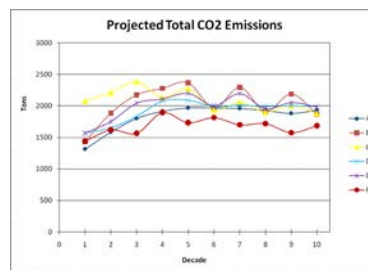
Given what is and is not known about global climate change, the following discussion outlines the cumulative effects of this project on CO₂ emissions and effects of climate change on forest resources.

Projected climate change impacts include air temperature increases, sea level rise, changes in the timing, location, and quantity of precipitation, and increased frequency of extreme weather events such as heat waves, droughts, and floods. The intensity and severity of these effects are expected to vary regionally and even locally, making any discussion of potential site-specific effects of global climate change on forest resources speculative.

Because CO₂ from prescribed fire mixes readily into the global CO₂ pool, it is not currently possible to discern the effects of this plan from the effects of all other greenhouse gas sources worldwide, nor is it expected that attempting to do so would provide a practical or meaningful analysis of effects. Potential regional and local variability in climate change effects add to the uncertainty regarding the actual intensity of this plan's effects on global climate change. Further, any emissions associated with the implementation of any of these alternatives would be extremely small in the global atmospheric CO₂ context, making it impossible to measure the incremental cumulative impact on global climate.

Scrutiny of the overall carbon budget for specific ecosystems may reveal that reduction or exclusion of fires to promote forests carbon sink properties may not necessarily be effective. A recent study by Fellows and Goulden (2008) showed that due to fire exclusion between the 1930s and the 1990s, US mid-montane conifer forests underwent pest and disease induced net loss of big trees while forest stem density (small tree numbers) increased. This effect caused a noteworthy net decline of above ground carbon biomass (storage). Such findings indicate prescribed burning may be a potent method for forest carbon sequestration in California and the Sequoia National Monument.

The potential for cumulative effects is considered negligible for all alternatives because none of the alternatives would result in measurable direct and indirect effects on air quality or global climatic patterns due to the size of the monument. Nevertheless, different execution of alternatives would have different CO₂ emission and carbon sequestration potentials. Alternative F will emit the least amount of CO₂. For further discussion on carbon sequestration potential of alternatives please see the effects on vegetation conditions section in chapter 4 of this DEIS.



Smoke and Public Nuisance

The regulatory environment for smoke has shown an overall emphasis on accommodating prescribed fire out of recognition of the severe fire risk in the western United States. In California, the public nuisance rule provides an important protection measure for property, safety, and health. However, this rule can have an unpredictable impact on prescribed burning programs.

In response to the California Code of Regulations, the SJVAPCD enacted Rule 4102. This is the Nuisance Rule, which was adopted May 21, 1992 and amended December 17, 1992. This rule essentially requires the SJVAPCD to investigate and take action to remedy any air discharge that is causing injury, detriment, nuisance, or annoyance to any considerable number of persons.

Good smoke management techniques, improved burn day forecasts, and public communication can mitigate some complaints. Public nuisance issues are more commonly associated with changing or unforeseen conditions in the burn day forecast, or lower elevation projects where the smoke is not fully dispersed during daytime hours. Although difficult to predict, it is probably safe to assume that the impact of public nuisance calls on prescribed fire projects would increase, given growing populations in the foothill areas on the west side of the Monument.

Current Air Quality Monitoring Program

Sequoia National Forest currently incorporates a robust smoke monitoring program into forest management practices. The current program is specifically designed to focus on the monitoring of particulate matter less than 2.5 microns in diameter (PM_{2.5}), meteorology, and ozone. This allows fire managers at Sequoia National Forest to disseminate critical air quality issues in a timely manner.

The monitoring program is a cooperative effort that shares information and expertise with the public, other National Forests, the National Park System, public health officials, the California Air Resources Board, and local air districts particularly during fire events.

Currently, the goals of the monitoring program are to:

- Provide expertise on air quality science, policy, and regulations.
- Provide a quick monitoring response.
- Provide quality long term monitoring data.
- Produce accurate near real time data.
- Provide technical expertise on air quality monitoring equipment.
- Use monitoring data to inform future policy decisions to enhance resource protection.
- Collect long-term air monitoring data to evaluate trends and patterns in air quality.

This monitoring is used to verify the assumptions used in planning and compliance documents, assess potential human health effects, inform of potential impacts that would significantly deteriorate air quality and visibility in Class I Wilderness areas, and provide scientific evidence to help prevent future state and national ambient air quality standard violations.

To facilitate access to the monitoring data, Iridium and ORBCOMM satellite networks are used to relay hourly data and provide web-based data access. Near real-time data of non-validated (raw) data is available at <http://www.satguard.com/USFS/default.asp>. Making data available to the public and other agencies ensures transparency and allows for quick access and interpretation of all data.

Since 2005, the Forest Service has operated three permanent air quality monitoring sites to monitor air quality in the Sierra Nevada, which includes the Monument. Each site uses a Met One Instruments, Inc. Model BAM-1020, Beta Attenuation Mass Monitor (BAM), to collect hourly PM_{2.5} data, and a 2B Technologies, Inc. Model 202 Ozone Monitor (2B) to collect hourly ozone data. A Met One Instruments, Inc. Model

E-BAM, Environmental Beta Attenuation Monitor (EBAM), is used to monitor hourly $PM_{2.5}$ at three additional sites surrounding the Monument, from late spring to early winter to coincide with the fire season in the Sierra Nevada. A cache of monitoring equipment currently consists of an additional eight EBAMs and two 2Bs. This cache is used to supplement the local, regional, and national monitoring programs during smoke events.

All prescribed burns are conducted in accordance with federal, state, and SJVAPCD regulations. Prescribed burns are conducted during SJVAPCD-determined burn days. Monitoring is customized using cache equipment, when appropriate, to monitor individual prescribed fires and assist fire management and air regulating officials in determining smoke impacts. Permanent and seasonally-placed monitoring equipment is used as initial monitoring coverage during wildfires, with cache equipment used as needed at temporary sites.

Monitoring Equipment Description

The BAM and EBAM use a vacuum pump to draw a measured sample of ambient air that deposits particulates on to filter paper. A Carbon 14 source emits beta particles that pass through the tape and are counted on a detector. A beta count is taken prior to the sample, and after the sample to determine the particulate mass. The measured air flow through the filter tape is used to calculate the concentration.

The BAM is a Federal Equivalent Method (FEM) for measuring $PM_{2.5}$ as of March 12, 2008. BAM hourly readings have a resolution of $\pm 1 \text{ ug/m}^3$. The BAM hourly lower detection limit is less than 4.8 ug/m^3 . The BAM 24 hour average lower detection limit is less than 1.0 ug/m^3 (Met One 2008).

The EBAM is designed by Met One Instruments Inc. for temporary and quick deployment. The EBAM has not been designated by the EPA as a FEM. When compared to an FEM in laboratory conditions, an EBAM was found to overestimate smoke particulate concentration by 1 percent (USFS 2006). EBAM hourly readings have an accuracy of $\pm 10\%$. The hourly lower detection limit is less than 6.0 ug/m^3 . The 24 hour average lower detection limit is less than 1.2 ug/m^3 (Met One 2, 2008).

The 2B ozone monitor uses absorption of ultraviolet light at 254 nm to calculate ozone in ambient air. A small pump is used to draw ambient air between a mercury lamp and a detector. The light absorbed is used to determine ozone concentration in the sample. One minute lower detection limit is less than 1.3 ppb with a precision of 1.5 ppb or 2 percent of the reading.

Monitoring Sites

Monitoring sites are chosen strategically to provide data for smoke from wildfires and prescribed fires, to understand pollutant fluxes into and out of Forest Service managed land, and to establish yearly air quality patterns. Data collected are used to understand air quality in the Monument including the effects of emissions from the Monument and the effects of emissions on the Monument from outside sources. Data collected during an incident are analyzed to help understand fire effects on public health, the transport of smoke, and the relation of emissions estimates, fire intensity, and size to $PM_{2.5}$ and ozone concentrations.

The air quality monitoring program keeps fire managers, the public, and appropriate authorities informed of current air quality where there are potential impacts from smoke.

Standards for Air Quality

The following table shows the standards that the public can use to determine which concentrations of $PM_{2.5}$ are harmful, the effects of each concentration, and the precautionary actions that the public should take.

Air Quality Report

Standard Index Category	PM _{2.5} 24-hr Concentration (µg/m ³)	Health Effects	Cautionary Statements
Good	0-15.4	None	None
Moderate	15.5-40.4	None	None
Unhealthy for Sensitive Groups	40.5-65.4	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
Unhealthy	65.5-150.4	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion/
Very unhealthy	150.5-250.4	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion
Hazardous	>250.4	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

The table below can be used by the public to determine the visibility range and assess the air quality in their area.

Category	PM 2.5 1-hr Avg. Concentration (µg/m ³)	Visibility Range (miles)
Good	0-40	10 miles and up
Moderate	41-80	6 to 9 miles
Unhealthy for Sensitive Groups	81-175	3 to 5 miles
Unhealthy	176-300	1½ to 2½ miles
Very Unhealthy	301-500	1 to 1¼ mile

Category	PM 2.5 1-hr Avg. Concentration ($\mu\text{g}/\text{m}^3$)	Visibility Range (miles)
Hazardous	Over 500	$\frac{3}{4}$ mile or less

The procedure for using personal observations to determine the approximate PM_{2.5} concentration for local areas is as follows:

1. Face away from the sun.
2. Determine the limit of your visible range by looking for targets at known distance (miles). Visible range is that point at which even high contrast objects totally disappear.
3. Use the values above to determine the local forest fire smoke category.

Conclusions and Recommendations

Air quality in Sequoia National Monument is primarily driven by anthropogenic emissions. Proximity to California’s Central Valley suggests that air quality in the Monument will continue to degrade without significant changes in anthropogenic emissions. Fire is the primary source of emissions from the Monument. Whereas an increase in prescribed burning has been observed in the rest of the country since the late 1990s, prescribed burning in SJV and California has been essentially constant. During the same period, a sharp rise in wildfires has also been observed in California and nationwide. The risks of Wildfire in the Western US (Westerling et al. 2006) will increase with an increase of temperature. This will lead to an increase of acute bad air quality episodes during the summer at the Monument. We will have to conduct prescribed burns of higher frequency and spatial coverage to mitigate future poor air quality episodes; and to enhance the storage of carbon by the prevention of the release of carbon to the atmosphere. Alternative E is the alternative with the lowest potential to impact to air quality followed by Alternatives B and F.

Legal and Regulatory Compliance

DRAFT Air Quality Giant Sequoia National Monument Laws and Policies

Draft Laws and Policies for All Action Alternatives (B, C, D, E, F) and No Action Alternative (A)	
General Use:	<p>Continue visibility monitoring program and determine sensitive indicators for each air quality related value in national forest class I Areas. Protect air quality related values by reviewing all projects and management activities that may impact those values. Review external PSD (prevention of significant deterioration) source applications and make recommendations to permitting authorities.</p> <hr/> <p>Minimize resource and air quality impacts from air pollutants generated by management activities through use of the following control measures:</p> <ol style="list-style-type: none"> 1. Follow dust abatement procedures.

Draft Laws and Policies for All Action Alternatives (B, C, D, E, F) and No Action Alternative (A)

	<ol style="list-style-type: none"> 2. Conduct an air quality analysis for all projects that may impair Air quality to determine impacts, mitigations, and/or controls. 3. Respond to local planning and regulatory authorities when development outside Forest jurisdiction may impact forest resources. 4. Conduct prescribed burning activities in accordance with air pollution control district regulations and with proper prescriptions to assure good smoke management: <ul style="list-style-type: none"> Avoid burning on high visitor days. Notify the public before burning.
	<p>Use the following documents for guidance and direction for smoke management and air quality protection:</p> <ol style="list-style-type: none"> 1. Interim Air Quality Policy on Wildland and Prescribed Fires, announced by the Environmental Protection Agency (EPA) in 1998. 2. Memorandum of Understanding between the California Air Resources Board (CARB) and the Forest Service, signed on July 13, 1999. 3. Smoke Management Guidelines for Agricultural and Prescribed Burning under Title 17. 4. The Nevada Smoke Management Plan.
	<p>Coordinate and cooperate with other agencies and the public to manage air quality. Conduct prescribed burns when conditions for smoke dispersal are favorable, especially away from sensitive or Class I Areas. Use smoke modeling tools to predict smoke dispersion.</p>

Assumptions and Methodology

Methodology

PM_{2.5} and CO₂ emissions were calculated using the methods outlined by the General Conformity State Implementation Plan Handbook (USDA Forest Service 1995). The emissions calculations used the total number of acres to be treated, vegetation type, estimated fuel loading, and an emissions factor. The projected number of acres of prescribed and wildfire were predicted with the SPECTRUM model.

The emission calculation formula is as follows:

$$E = S (A \times L \times EF \times \%C) / 2000 \text{ (tons)}$$

L= Fuel Loading for ith species (tons)

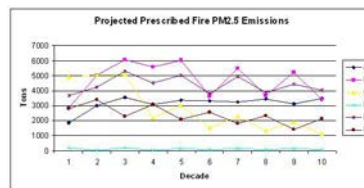
EF= Emission factor for ith species (lbs/ton)

%C= Percent Combustion

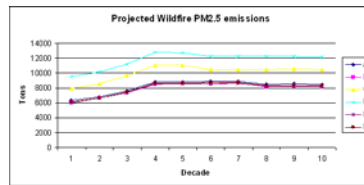
Air Quality Impact Assessment

Prescribed burns produce ozone precursors. Ozone problems in the Monument occur mainly during the summer (May through September) and are primarily driven by urban influence. Prescribed burns are typically not conducted during this time period. This evaluation will only analyze the possible effects of prescribed burns on PM_{2.5} levels. Wildfires occur during this time, but it is impossible to predict when they will happen. It is assumed that if a wildfire occurs in the Monument, the concentrations of particulate matter will be the most impacted. Ozone concentrations are assumed to be less impacted, and PM_{2.5} is a better representative of overall air quality impacts.

The following graph presents, by alternative, the predicted PM_{2.5} emissions from prescribed fire by decade. Prescribed fires were predicted with the SPECTRUM Model.



The graph below presents, by alternative, the predicted PM_{2.5} emissions from wildfire by decade. Wildfires were predicted with the SPECTRUM Model.



Prescribed fire and wildfire are separated to better analyze overall impacts to air quality. Differences in total PM_{2.5} emissions generated by the model are not significant between scenarios. All model scenarios would have virtually the same overall impact on air quality. Tradeoffs between levels of control between emissions are the primary factors in overall impacts to air quality.

Prescribed fire primarily burns during the spring or fall. This can prevent the occurrence of destructive summer fires, thus decreasing emissions and minimizing air quality impacts. Destructive fires have the greatest impacts on air quality. Land management agencies have no control over when these fires start and very little control after they start. Wildfire can burn large areas quickly. Wildfires that are not controlled can have very high emissions that lead to the high production of air pollutants and degradation of local and regional air quality.

Indirect Effects

Air Quality

Emissions From National Monument Activities

Smoke from prescribed burning and wildland fire affect air quality and are a concern for potential adverse effects on human health and visibility. Smoke can affect visitors to the Monument and residents in surrounding communities.

Prescribed Burning

When considering the use of prescribed burning to reduce fuels and restore the natural role of fire in ecosystems, the effects of smoke must be evaluated.

The use of prescribed burning to restore natural processes to the fire-adapted landscape of the Monument must weigh both the potential benefits and the potential impacts on air quality, both within the Monument and the air district. In spite of their ecological benefits, prescribed fires, as well as natural fires, produce gases and aerosols that have instantaneous and long-term effects on air quality (Fang et al. 1999). The extent of these effects depends on fire size, fuel composition, and the physical and chemical characteristics of the events (Kasischke and Penner 2004). Before 1800, 1.8 million hectares burned annually in California (Stephens et al. 2007). High severity, stand-replacing fires have been increasing in frequency since that time (Miller et al. 2008). Keeping the Sierra Nevada frequent, low-intensity fire regime functioning can reduce emissions and fire severity (Collins et al. 2007, Hurteau et al. 2008). A healthy, functioning natural ecosystem will accomplish long-term air quality goals for the Monument and help buffer anthropogenic emissions from the region.

Fires emit large amounts of particulate matter (PM₁₀ and PM_{2.5}) and carbon monoxide, as well as the precursors to ozone: nitrous oxides (NO_x) and volatile organic compounds (VOCs). Other chemical constituents of smoke such as polycyclic aromatic hydrocarbons (PAHs) may also enter the lungs. Some carcinogenic components in smoke are benzo-pyrene and aldehydes.

Wildfires result in greater emissions per acre when compared to prescribed burns. They also typically occur under conditions of high temperature and low humidity, when high concentrations of ozone are most likely. Prescribed burning mitigates impacts to air quality by reducing existing fuels and decreasing fire hazard and the risk of high intensity wildfire. Prescribed burning allows for better control and timing of emissions and a decrease in the quantity of fuels available for consumption in a wildfire. Infrequent large wildfires will still occur naturally in some vegetation types. Prescribed fire will help to reduce the frequency and extent of large-scale high intensity wildfire events and the corresponding negative effects on air quality.

The composition and quantity of smoke emissions from fires and the impact of those emissions on local and regional air quality vary dramatically with the chemistry and condition of the fuel, the amount and arrangement of fuel layers, the behavior of the fire and weather conditions, and the size and type of fire that occurs (Ward and Hardy 1991). The phase of combustion also affects fire emissions. For instance, smoldering combustion produces more CO, NH₃, and particulates than flaming combustion (Griffith et al. 1991, Ward 1999). With higher fuel moisture, a greater proportion of consumption occurs in the smoldering phase of the fire. This phase typically has lower combustion efficiency. The smoldering phase is the least efficient due to incomplete combustion and yields the highest pollutant to consumed fuel ratio.

The number of acres burned is the single most important factor in determining total emissions within an airshed. Large fires, whether originating as wildland fires or prescribed fires, produce more total emissions than small fires. Therefore, reducing the total acreage burned, regardless of the type of fire, is the most effective way to reduce the total emissions within an airshed for a short time interval (less than 100 years). In the monument, fire acres burned per year will likely remain similar over longer time periods (thousands of years).

Fire type also influences emissions. Prescribed fires typically produce lower per-acre emissions than wildland fires. Heading fires (a fire that burns with the wind) typically produce lower per-acre emissions than backing fires, and surface fires typically produce lower per-acre emissions than crown fires. The differences in emissions among the different fire types may be attributed to differences in meteorological conditions, fuel properties, and resultant fire behavior and fuel consumption. Because prescribed fire generally produces lower per-acre emissions than wildland fire, it is possible to burn more acres with prescribed fire than would normally occur with wildland fire and produce the same total emissions within an airshed.

The primary benefit of a prescribed fire program is in modifying the timing, size, and type of fire that occurs within a particular geographic region. With prescribed fire, it is possible to replace large, high-intensity wildland fires characterized by high fuel consumption and high total emissions with smaller, lower-intensity prescribed fires characterized by lower fuel consumption and lower total emissions. This decrease in wildland fire emissions typically comes with increased prescribed fire emissions. Prescribed fire allows for some control of emissions by allowing air regulators to help time emissions to minimize human health impacts.

Tian et al. (2008) investigated air quality impacts of prescribed fires under different management practices and fire return intervals in the Southern Pine Forests of Georgia. They found that night-time air quality impacts from prescribed fire during the smoldering phase are greater than in the flaming phase. This is because at night, when smoldering is the highest, dispersion is the lowest. They also showed that the frequency of prescribed fire is inversely proportional to the amount of emissions. When the burn frequency is low, more biofuel is burnt in each fire, leading to larger emissions and air quality impacts per fire. In addition, more fuels of larger size, which usually cannot be consumed completely during flaming, contribute significantly to smoldering emissions when the time between fires increases.

Air quality impacts are measured in terms of pollutant concentrations in ambient air, not in terms of total emissions. Emissions do not equate to concentrations. Higher emissions do not necessarily mean higher concentrations. Air concentrations are a function not only of the total emissions within the airshed, but also of the timing of the emissions, the locations of emission sources relative to sensitive receptors, the meteorology of the area, and the physical characteristics of the plume. Prescribed fire generally produces lower total emissions, lower fire intensity, lower total heat production, and lower plume rise than wildfires. A wildfire can often lead to higher smoke concentrations at locations farther from the source than a similar size prescribed fire. This difference can often lead to higher smoke concentrations at locations far from the source than a prescribed fire of the same size. Type of fire, distance from the source, and acres burned per day are likely the main factors determining human health impacts from smoke.

Effect of Prescribed Burning on CO₂ Emissions and the Carbon Budget

An issue of significance concerning prescribed burning emissions is their effects on the carbon budget. Western and Southeastern US needle leaf forests were estimated to be dominant contributors to total yearly US fire CO₂ emissions which amounted to 293 Tg CO₂ yr⁻¹ for the period 2002-2006 (1Tg or teragram = 10¹² g) (Wiedinmyer and Neff 2007). California contributed a significant annual average emission of CO₂ from fires, 24 Tg yr⁻¹, equivalent to 6% of fossil fuel combustion estimates. Prescribed fires were observed

to constitute an insignificant percentage of this emission. A 2002 study by the CARB (2006) estimated CO₂ emissions from prescribed fires in California to be 123,480 Mg yr⁻¹ (1 Mg or megagram = 106 g). Although current prescribed fire emissions are an insignificant percentage of the total fire emissions, different scenarios which increase prescribed fire acreage and frequency need to be analyzed for their effect on the forests of the monument as a carbon sink or source. Fluxes of other carbon forms such as black carbon and dissolved organic carbon, in addition to CO₂, will also have to be included in these carbon budget equations. Black carbon, an air pollutant and residue of incomplete combustion, is persistent in the environment and may constitute a significant portion of the total carbon emissions from forest fires in California and the San Joaquin Valley basin.

Impacts on air quality are likely to be most affected with a change in fire return intervals in the Monument that increase fuel consumption. This could be the effect of temperatures above the historic normal, changes in precipitation that cause conditions that are drier than normal, and forest type conversion.

The following table ranks the overall impacts on air quality, with specific rationale for each alternative. Because of the removal of fuels, Alternative E would likely have the least impact on air quality. Alternatives B and F, similar to Alternative E, would maximize emission control and minimize wildfire emissions. Alternative A would reduce wildfire emissions, but not allow as much control of emissions as Alternatives B, E, and F. Alternative C would increase short-term emissions by maximizing wildfire re-introduction and limiting mechanical fuels reduction. Alternative D would have the greatest impacts on air quality because emissions would be dominated by wildfires with the greatest potential to change the fire system.

Table 2 Air Quality Ranking by Alternative

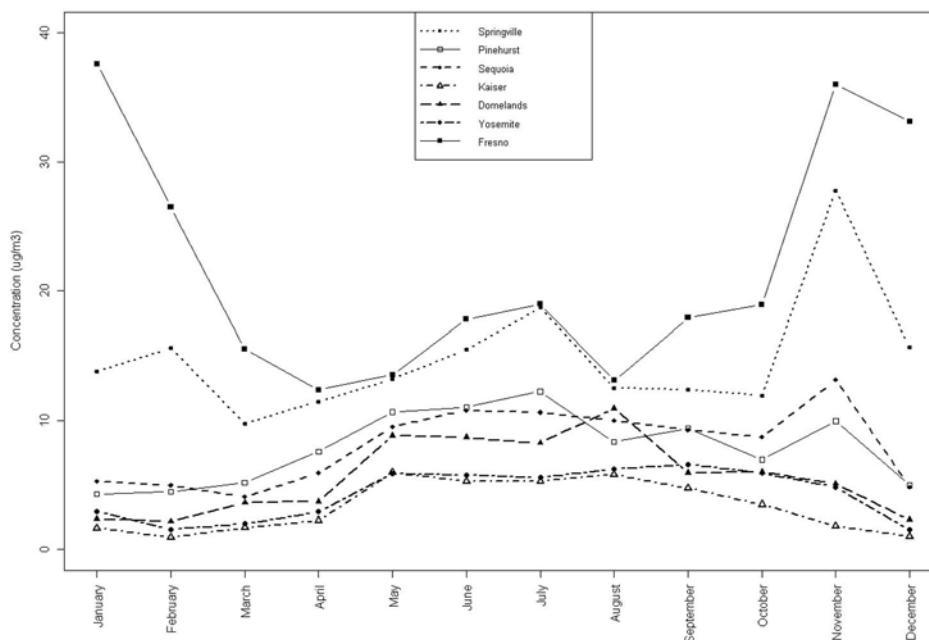
Alternatives	Overall Impacts to Air Quality	Rationale
A	3 ⁽¹⁾	Moderate wildfire emissions, with the priority of fuel reduction tools allowing for some control of emissions impacts on air quality.
B	2	Low wildfire emissions, with the priority of fuel reduction tools allowing for greater control of timing of emissions release and minimizing air quality impacts.
C	4	Moderately high wildfire emissions, with less use of mechanical treatments and moderate prescribed fire emissions. Restoring the natural process of wildfire without managing stand structure results in short-term (3 decades) increase in emissions.
D	5	High wildfire emissions, with much less use of prescribed fire and mechanical treatments. Reduces overall control of emissions while maximizing total emissions released through uncontrolled fires.
E	1	Low wildfire emissions, with greater use of mechanical treatments and prescribed fire. Allows maximum control of emissions while minimizing total emissions from fire.
F	2	Low wildfire emissions, with flexibility of management tools allowing for greater control of timing of emissions release and minimizing air quality impacts.

1. Qualitative Scale: 1 lowest impact, 2 low impact, 3 moderate impact, 4 moderately high impact, and 5 high impact.

Particulate Matter in the Southern Sierra Nevada

Figure 1 depicts seasonal patterns for $PM_{2.5}$ in the southern Sierra Nevada and the city of Fresno.

Figure 3



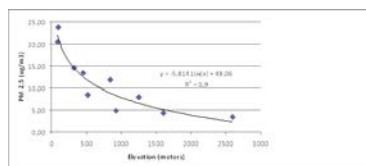
$PM_{2.5}$ data for Fresno follow a trend of increased $PM_{2.5}$ during the winter months (November to February). This seasonal pattern contrasts with the most remote site at Pinehurst where monthly averages are lower in the winter and higher in the summer. Winter $PM_{2.5}$ concentrations in the Monument appear to be disconnected from the Central Valley in the winter months.

Overall, $PM_{2.5}$ concentrations diverge during the winter months, and trend together during the summer months. Urban contributions to $PM_{2.5}$ are limited in more remote areas during the winter months. Beginning in April and continuing to August, $PM_{2.5}$ equilibrates between lower and higher elevation areas on the western slope of the Sierra Nevada.

Sites situated between urban and undisturbed areas show a seasonal pattern that is influenced by elevation and proximity to urban areas. This is potentially driven by winter inversions that set up over the central valley. These inversions may slow the transport of $PM_{2.5}$ from urban areas by inhibiting the mixing and venting of air masses from the Central Valley.

Figure 2 is a regression plot of elevation and $PM_{2.5}$. The data used were obtained from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network from 2002 to 2008, the Air Resources Board (ARB) network from 2006 to 2008, and the Forest Service network from 2006 to 2008. Sites in the IMPROVE network include Yosemite National Park, Sequoia and Kings Canyon National Parks (SEKI), Kaiser, and the Domelands Wilderness. Sites in the Forest Service network include North Fork, Pinehurst, Springville, and Trimmer. Visalia and Fresno are sites in the ARB network.

Figure 4



Site elevation may be the main factor in the Sierra Nevada for PM_{2.5} concentrations. Lower elevations and sites located near urban areas have seasonal high PM_{2.5} during the winter months (November to February). Higher elevation sites such as Pinehurst and Kernville see a decrease in PM_{2.5} during this period. The site at Springville has a slight increase in PM_{2.5} during the winter. In November, Springville was mixing well with Fresno, but was isolated from the higher elevation sites.

Sites at elevations higher than 400 meters are currently below national air quality standards. These findings indicate that locations in the Sequoia National Monument, which form part of the San Joaquin Air Basin, are under attainment or are cleaner than urban locations.

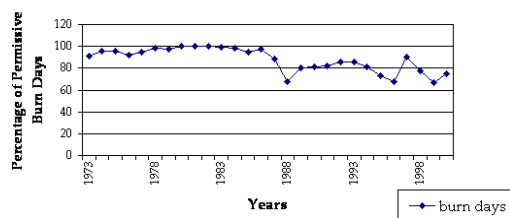
Late summer to early fall, PM_{2.5} concentrations in sites located between urban areas and wilderness are lower than what would be expected if PM concentrations were being driven primarily by fire. Further, the data suggest that elevation (including location) and time of year are helpful management considerations for fire. This information, coupled with the small size of prescribed fires, may prevent hazardous impacts to air quality.

Retrospective Analysis of Burn Days

Burn day designations within the Monument are currently designated by the San Joaquin Valley Air Pollution Control District (District). Until recently the California Air Resources Board (CARB) has provided this service. The data used for the retrospective analyses were based on burn day designations historically provided by CARB. Annual summaries were used to establish trends and daily records from 1998 to 2001 were used to look at monthly variations.

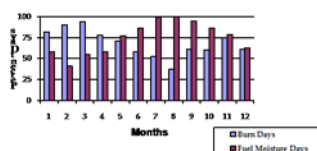
An examination of CARB burn day records from 1973 to 2000 suggests that designated burn days have declined in the Monument since 1973 (Figure IV-1). Up to about 1988, over 95% of the days each year were permissive burn days. From 1988 to 2000, the number of permissive days has been just under 80 percent. Even though burn days have declined since 1973 a fairly high percentage of days remain available. The District is planning to develop a burn day designation process that will involve dividing the District up into zones. More refined meteorological data is expected to provide better forecasting and the ability to differentiate “burn” and “no burn” designations at a zone scale. This process could provide more burn day designations in the Monument.

Figure IV-1: Burn Days 1973 to 2000

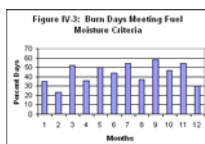


Available burn days only provide the information needed to minimize the potential for smoke impacts. The Forest Service has many other criteria that must be met prior to ignition of a prescribed burn. One of the principal criteria is fuel moisture. Days meeting fuel moisture criteria and designated burn days for 1998 to 2001 were examined to better understand how they might constrain prescribed fire in the Monument (Figure IV-2). The number of designated burn days tends to start high in January and peak in March. There is a considerable drop from April to August, and then a slight increase from September to December. The number of days when fuel moisture criteria is suitable for prescribed burning is at its lowest in January and February and picks up in the spring months. Conditions are normally too dry for burning after May and remain that way until about September. Generally the data suggest that, in early spring, fuel moisture is more constraining than permissive burn days and, in the fall, permissive burn days are more constraining than fuel moisture.

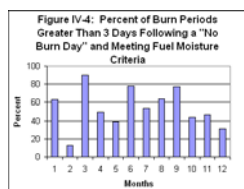
Figure IV-2: Burn Days vs. Days Meeting Fuel Moisture Criteria



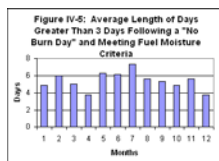
Both fuel moisture records and burn day designations for the 1998 to 2001 period were used to examine monthly variation in permissive burn days that met fuel moisture criteria (Figure IV-3). The data suggest slightly more days meeting both criteria in the fall burn period than in the spring period. The traditional burning period in the spring (March, April, May) averages about 45 percent of the days meeting criteria. The traditional burning period in the fall (September, October, November) averages over 50 percent of the days meeting criteria.



Another factor that could limit prescribed fire application is the availability of consecutive burn days meeting a prescription for larger projects that might take multiple days to complete. The 1998 to 2001 data was examined to better understand the opportunities for multiple day projects. The frequency (percent) of burn periods following a no burn period that would extend at least 3 days is displayed in Figure IV-4. Fuel moisture criteria are integrated as well. Coordination with the San Joaquin Valley Air Pollution Control District staff might allow better predictions of these periods.



Of those periods that exceeded 3 days, the average length was 4½ days. The monthly variation in the average length of days exceeding 3 days is shown in Figure IV-5. These data tend to indicate that sufficient opportunity exists to allow the varying amounts of prescribed fire considered in each alternative. The more complex issue may be one of public acceptance of smoke, which is discussed in more detail in the section on Smoke and Public Nuisance below.



Climate Change

The climate system is often defined as average weather. The climate system is complex and interactive. Climate is usually described in terms of mean and variability of temperature, precipitation and wind over a period of time. The periods of time, range from months to millions of years. The classical period is 30 years. The climate system evolves under its own internal dynamics and external factors that affect climate. External factors include human caused changes in atmospheric composition through the increase of GHGs (green house gases), as well as natural events such as solar variations and volcanic eruptions.

The most important GHGs are CO₂ (carbon dioxide), CH₄ (methane), N₂O (nitrous oxide), several synthetic halocarbons (chlorofluorocarbons (CFCs), hydrofluorocarbons, perfluorocarbons, halons and sulphurhexafluoride), H₂O (water), O₃ (ozone), and aerosols.

The most important GHG related to prescribed fire in the Giant Sequoia National Monument is CO₂.

The Environmental Protection Agency (EPA) (2007) developed a "State of Knowledge" paper that outlines what is known, what is very likely and what is uncertain about global climate change.

The following elements are known about climate change: human activities are increasing the levels of GHGs since pre-industrial times thus changing the composition of Earth's atmosphere; the build up of CO₂ and other GHGs are largely due to the burning of fossil fuels; an unequivocal global warming trend of about 1 to 1.7 degrees Fahrenheit occurred from 1906-2005. Green house gases emitted by human activities remain in the atmosphere for periods ranging from decades to centuries, therefore atmospheric concentrations of GHGs will continue to rise over the next few decades; and increasing GHGs concentrations tend to warm the planet.

The following is very likely about climate change: The increase of anthropogenic GHG concentrations have resulted in most of the observed increase in global average temperatures since the mid-20th century; the average global temperatures and sea levels will continue to rise and precipitation patterns will change as GHGs in the atmosphere continue to rise.

The following is uncertain about climate change: how much and how fast warming will occur; and how warming will affect precipitation patterns and the rest of the climate system.

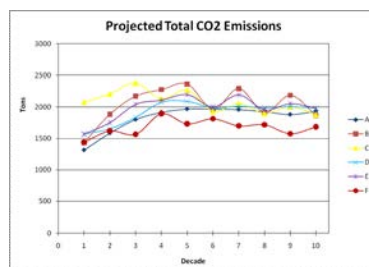
Given what is and is not known about global climate change, the following discussion outlines the cumulative effects of this project on CO₂ emissions and effects of climate change on forest resources.

Projected climate change impacts include air temperature increases, sea level rise, changes in the timing, location, and quantity of precipitation, and increased frequency of extreme weather events such as heat waves, droughts, and floods. The intensity and severity of these effects are expected to vary regionally and even locally, making any discussion of potential site-specific effects of global climate change on forest resources speculative.

Because CO₂ from prescribed fire mixes readily into the global CO₂ pool, it is not currently possible to discern the effects of this plan from the effects of all other greenhouse gas sources worldwide, nor is it expected that attempting to do so would provide a practical or meaningful analysis of effects. Potential regional and local variability in climate change effects add to the uncertainty regarding the actual intensity of this plan's effects on global climate change. Further, any emissions associated with the implementation of any of these alternatives would be extremely small in the global atmospheric CO₂ context, making it impossible to measure the incremental cumulative impact on global climate.

Scrutiny of the overall carbon budget for specific ecosystems may reveal that reduction or exclusion of fires to promote forests carbon sink properties may not necessarily be effective. A recent study by Fellows and Goulden (2008) showed that due to fire exclusion between the 1930s and the 1990s, US mid-montane conifer forests underwent pest and disease induced net loss of big trees while forest stem density (small tree numbers) increased. This effect caused a noteworthy net decline of above ground carbon biomass (storage). Such findings indicate prescribed burning may be a potent method for forest carbon sequestration in California and the Sequoia National Monument.

The potential for cumulative effects is considered negligible for all alternatives because none of the alternatives would result in measurable direct and indirect effects on air quality or global climatic patterns due to the size of the monument. Nevertheless, different execution of alternatives would have different CO₂ emission and carbon sequestration potentials. Alternative F will emit the least amount of CO₂. For further discussion on carbon sequestration potential of alternatives please see the effects on vegetation conditions section in chapter 4 of this DEIS.



Smoke and Public Nuisance

The regulatory environment for smoke has shown an overall emphasis on accommodating prescribed fire out of recognition of the severe fire risk in the western United States. In California, the public nuisance rule provides an important protection measure for property, safety, and health. However, this rule can have an unpredictable impact on prescribed burning programs.

In response to the California Code of Regulations, the SJVAPCD enacted Rule 4102. This is the Nuisance Rule, which was adopted May 21, 1992 and amended December 17, 1992. This rule essentially requires the SJVAPCD to investigate and take action to remedy any air discharge that is causing injury, detriment, nuisance, or annoyance to any considerable number of persons.

Good smoke management techniques, improved burn day forecasts, and public communication can mitigate some complaints. Public nuisance issues are more commonly associated with changing or unforeseen conditions in the burn day forecast, or lower elevation projects where the smoke is not fully dispersed during daytime hours. Although difficult to predict, it is probably safe to assume that the impact of public nuisance

calls on prescribed fire projects would increase, given growing populations in the foothill areas on the west side of the Monument.

Current Air Quality Monitoring Program

Sequoia National Forest currently incorporates a robust smoke monitoring program into forest management practices. The current program is specifically designed to focus on the monitoring of particulate matter less than 2.5 microns in diameter (PM_{2.5}), meteorology, and ozone. This allows fire managers at Sequoia National Forest to disseminate critical air quality issues in a timely manner.

The monitoring program is a cooperative effort that shares information and expertise with the public, other National Forests, the National Park System, public health officials, the California Air Resources Board, and local air districts particularly during fire events.

Currently, the goals of the monitoring program are to:

- Provide expertise on air quality science, policy, and regulations.
- Provide a quick monitoring response.
- Provide quality long term monitoring data.
- Produce accurate near real time data.
- Provide technical expertise on air quality monitoring equipment.
- Use monitoring data to inform future policy decisions to enhance resource protection.
- Collect long-term air monitoring data to evaluate trends and patterns in air quality.

This monitoring is used to verify the assumptions used in planning and compliance documents, assess potential human health effects, inform of potential impacts that would significantly deteriorate air quality and visibility in Class I Wilderness areas, and provide scientific evidence to help prevent future state and national ambient air quality standard violations.

To facilitate access to the monitoring data, Iridium and ORBCOMM satellite networks are used to relay hourly data and provide web-based data access. Near real-time data of non-validated (raw) data is available at <http://www.satguard.com/USFS/default.asp>. Making data available to the public and other agencies ensures transparency and allows for quick access and interpretation of all data.

Since 2005, the Forest Service has operated three permanent air quality monitoring sites to monitor air quality in the Sierra Nevada, which includes the Monument. Each site uses a Met One Instruments, Inc. Model BAM-1020, Beta Attenuation Mass Monitor (BAM), to collect hourly PM_{2.5} data, and a 2B Technologies, Inc. Model 202 Ozone Monitor (2B) to collect hourly ozone data. A Met One Instruments, Inc. Model E-BAM, Environmental Beta Attenuation Monitor (EBAM), is used to monitor hourly PM_{2.5} at three additional sites surrounding the Monument, from late spring to early winter to coincide with the fire season in the Sierra Nevada. A cache of monitoring equipment currently consists of an additional eight EBAMs and two 2Bs. This cache is used to supplement the local, regional, and national monitoring programs during smoke events.

All prescribed burns are conducted in accordance with federal, state, and SJVAPCD regulations. Prescribed burns are conducted during SJVAPCD-determined burn days. Monitoring is customized using cache equipment, when appropriate, to monitor individual prescribed fires and assist fire management and air regulating officials in determining smoke impacts. Permanent and seasonally-placed monitoring equipment is used as initial monitoring coverage during wildfires, with cache equipment used as needed at temporary sites.

Monitoring Equipment Description

The BAM and EBAM use a vacuum pump to draw a measured sample of ambient air that deposits particulates on to filter paper. A Carbon 14 source emits beta particles that pass through the tape and are counted on a detector. A beta count is taken prior to the sample, and after the sample to determine the particulate mass. The measured air flow through the filter tape is used to calculate the concentration.

The BAM is a Federal Equivalent Method (FEM) for measuring $PM_{2.5}$ as of March 12, 2008. BAM hourly readings have a resolution of $\pm 1 \text{ ug/m}^3$. The BAM hourly lower detection limit is less than 4.8 ug/m^3 . The BAM 24 hour average lower detection limit is less than 1.0 ug/m^3 (Met One 2008).

The EBAM is designed by Met One Instruments Inc. for temporary and quick deployment. The EBAM has not been designated by the EPA as a FEM. When compared to an FEM in laboratory conditions, an EBAM was found to overestimate smoke particulate concentration by 1 percent (USFS 2006). EBAM hourly readings have an accuracy of $\pm 10\%$. The hourly lower detection limit is less than 6.0 ug/m^3 . The 24 hour average lower detection limit is less than 1.2 ug/m^3 (Met One 2, 2008).

The 2B ozone monitor uses absorption of ultraviolet light at 254 nm to calculate ozone in ambient air. A small pump is used to draw ambient air between a mercury lamp and a detector. The light absorbed is used to determine ozone concentration in the sample. One minute lower detection limit is less than 1.3 ppb with a precision of 1.5 ppb or 2 percent of the reading.

Monitoring Sites

Monitoring sites are chosen strategically to provide data for smoke from wildfires and prescribed fires, to understand pollutant fluxes into and out of Forest Service managed land, and to establish yearly air quality patterns. Data collected are used to understand air quality in the Monument including the effects of emissions from the Monument and the effects of emissions on the Monument from outside sources. Data collected during an incident are analyzed to help understand fire effects on public health, the transport of smoke, and the relation of emissions estimates, fire intensity, and size to $PM_{2.5}$ and ozone concentrations.

The air quality monitoring program keeps fire managers, the public, and appropriate authorities informed of current air quality where there are potential impacts from smoke.

Standards for Air Quality

The following table shows the standards that the public can use to determine which concentrations of $PM_{2.5}$ are harmful, the effects of each concentration, and the precautionary actions that the public should take.

Standard Index Category	PM_{2.5} 24-hr Concentration (µg/m³)	Health Effects	Cautionary Statements
Good	0-15.4	None	None
Moderate	15.5-40.4	None	None
Unhealthy for Sensitive Groups	40.5-65.4	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
Unhealthy	65.5-150.4	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion/
Very unhealthy	150.5-250.4	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion
Hazardous	>250.4	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

The table below can be used by the public to determine the visibility range and assess the air quality in their area.

Category	PM 2.5 1-hr Avg. Concentration ($\mu\text{g}/\text{m}^3$)	Visibility Range (miles)
Good	0-40	10 miles and up
Moderate	41-80	6 to 9 miles
Unhealthy for Sensitive Groups	81-175	3 to 5 miles
Unhealthy	176-300	1½ to 2½ miles
Very Unhealthy	301-500	1 to 1¼ mile
Hazardous	Over 500	¾ mile or less

The procedure for using personal observations to determine the approximate $\text{PM}_{2.5}$ concentration for local areas is as follows:

1. Face away from the sun.
2. Determine the limit of your visible range by looking for targets at known distance (miles). Visible range is that point at which even high contrast objects totally disappear.
3. Use the values above to determine the local forest fire smoke category.

Conclusions and Recommendations

Air quality in Sequoia National Monument is primarily driven by anthropogenic emissions. Proximity to California's Central Valley suggests that air quality in the Monument will continue to degrade without significant changes in anthropogenic emissions. Fire is the primary source of emissions from the Monument. Whereas an increase in prescribed burning has been observed in the rest of the country since the late 1990s, prescribed burning in SJV and California has been essentially constant. During the same period, a sharp rise in wildfires has also been observed in California and nationwide. The risks of Wildfire in the Western US (Westerling et al. 2006) will increase with an increase of temperature. This will lead to an increase of acute bad air quality episodes during the summer at the Monument. We will have to conduct prescribed burns of higher frequency and spatial coverage to mitigate future poor air quality episodes; and to enhance the storage of carbon by the prevention of the release of carbon to the atmosphere. Alternative E is the alternative with the lowest potential to impact to air quality followed by Alternatives B and F.

Cumulative Effects

Air pollution is one of the most serious threats to Sequoia National Monument. The Monument is in a region that has some of the worst air quality in the nation. Air quality is typically worse than in other national forests. Air pollution threatens the health and welfare of the public, natural resources, and staff.

Most of the Sequoia National Monument air pollution originates in the San Joaquin Valley and is transported into the Monument by prevailing winds (Blumental, et al. 1985, Lehrman et al. 1994, Shair 1987, Tracer

Technologies 1992, Roberts et al. 1991, Zabik and Seiber 1993). Unlike many other states, California has few large stationary sources of air pollution. mobile, area, and small stationary sources emit the majority of the state's pollutants.

NO_x is a key ingredient in PM_{2.5} and ozone formation. About 75 percent of the NO_x in this area come from mobile sources (SJVAPCD, 2009). With the population in the San Joaquin Valley expected to grow by 60 percent between 2000 and 2020 (SJVAPCD 2009), the problem is likely to get worse. Population growth leads to an increase in vehicle activity. The current spread out, car dependent society combined with the highest population growth in the state will likely lead to more driving which will lead to more air pollution problems.

Significant amounts of the Asian aerosols have been observed at high elevation mountain sites in the western United States (VanCuren and Cahill 2002, VanCuren 2003, Liu et al. 2003). Pollutants from Asia are a regular component of the troposphere over the western North America. They are more pronounced during the spring and to a lesser extent during the summer. Pollutants from intercontinental transport contribute to some of the PM and ozone problems in Sequoia National Monument during the spring and summer.

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