Air Quality and Climate Change – Carbon Storage Errata Sheet

August 2022

1. **Air Quality, Affected Environment (pp. 11-22) the following sections were added to the document:**
    - Nuisance Smoke
    - Air Quality Health Standards
    - Smoke Emissions

Significance: These sections were inadvertently left out of the Air Quality Specialist Report Affected Environment. These sections are present within the Final Environmental Impact Statement (March 2022).

2. **Air Quality, Affected Environment (p. 25-27) the following section is added after the Smoke Emissions – Greenhouse Gas Emissions section:**

Radioactive Emissions

In northern Arizona, there are several types of radioactive elements. Most of these are naturally occurring, such as radon, potassium, and thorium. Northern Arizona also has rich deposits of uranium, which can and have been used for commercial purposes. In addition, northern Arizona, like much of the world, also has traces of man-made radioactive material, primarily from weapons testing conducted in the Cold War era. These radioactive elements include cesium and strontium. When a fire burns through an area, it may re-suspend radioactive particles present in forest surface fuels (Hejl et al., 2012). Some are naturally occurring chemicals that have always been present at some level in wildfire smoke and some have resulted from the weapons testing that occurred in the mid-20th century. Implementation of prescribed burning would comply with the Federal Clean Air Act and at the state level with the Arizona Department of Environmental Quality's regulations that require the project to not cause exceedances of the National and State Ambient Air Quality Standards. At the level of exposure the public is subjected to as a result of prescribed fire treatments, radionuclides do not pose as great a risk as wildfire. Radioactive material that may be carried in the smoke plume carries a risk of human health concerns of less than 1 chance in 10 million ((personal communication Graham 2012-2014) and Risk Assessment Corporation, (2002)) and the greatest health risk is from breathing high concentrations of particulate matter in the smoke.

Communication with the Environmental Protection Agency (personal communication Gerdes 2012 - 2014; Graham 2012-2014), and studies (see below) that addressed these emissions indicate that radioactive isotopes and other undesirable chemicals are present in wildfire emissions. Studies have shown that the levels of radioactive material that could be released in a prescribed burn or wildfire are very low and do not present a health risk. The following is a review of the literature discussing the public health concern related to radionuclide emissions from fires:

During the Cerro Grande fire of 2000, there was considerable public concern regarding the potential release of radionuclides from fires burning on lands managed by the Los Alamos National Laboratory (LANL). The following risk summary is from the 2002 Summary Report

Analysis of Exposure and Risks to the Public from Radionuclides and Chemicals Released by the Cerro Grande Fire at Los Alamos (Risk Assessment Corporation, 2002):

> "The primary health risks during the Cerro Grande fire were associated with breathing materials released into the air. It was estimated the risk of cancer from breathing any LANL-derived chemical or radioactive material that may have been carried in the smoke plume to be less than 1 chance in 10 million. Potential exposures in the surrounding communities to LANL-derived chemicals that are not carcinogenic were about 10 times lower than acceptable intakes established by the U.S. Environmental Protection Agency (EPA). The risk of cancer from breathing chemicals and radioactive materials in and on the natural vegetation that burned in the Cerro Grande Fire was greater than that from LANL-derived materials, but still less than 1 chance in 1 million. The vegetation that burned contained naturally occurring chemicals and radioactive materials and fallout produced during atmospheric tests of nuclear weapons. These materials and the risks they posed are present during any forest fire. The evidence suggests that some adverse health effects did result from breathing high concentrations of particulate matter in the smoke. Such exposures are associated with any forest fire. Deposition of LANL-derived chemicals and radioactive materials from the smoke plume to the soil was minimal."

Schollnberger et al., 2002 found that radiation doses from inhaled airborne radionuclides to individuals inside and outside the Los Alamos area from the Cerro Grande fire were likely very small, and health effects would be unlikely.

Following the Cerro Grande fire that burned through the city of Los Alamos and the Los Alamos National Laboratory (LANL) in New Mexico in 2000, the US Environmental Protection Agency (EPA), New Mexico Environment Department (NMED), and LANL partnered with Department of Energy to operate radiological monitoring systems as well as to initiate several studies to assess the impacts of the fire. The results of these efforts with regard to air quality and human health impact indicated that radionuclides originating from the LANL site during the Cerro Grande Fire were restricted to naturally occurring radionuclides.

LANL, the Department of Energy, and NMED-monitored radionuclide concentrations in smoke from the Las Conchas fire that burned through the Los Alamos area in the summer of 2011 and reported no significant detection levels (Michelotti et al., 2013).

A collaborative research effort was carried out between the U.S. Environmental Protection Agency and the U.S. Forest Service to simulate emissions in laboratory fires of pine needles and duff doped with nonradioactive cesium (Cs) (Hao et al., 2018). Following a radiological release event, nuclear power plant incident, improvised nuclear device, nuclear testing site, or hazardous waste site a wide area may be contaminated by radiological materials, including significant forest areas. There is a potential for emissions of radionuclides such as cesium-137 from a wildfire over a radionuclide-contaminated forest. The paper reports on a laboratory simulation study of a wildfire with two types of biomass doped with nonradioactive cesium. This simulation suggests that only 1 to 2.5 percent of the cesium in the biomass would be emitted from the wildfire, while the rest would reside in the residual ash. In the study, pine needles were the only contributor to the air emissions of cesium; duff was not a source of cesium emissions. In the study, cesium emitted from the simulated wildfire was concentrated in particle sizes larger than 10 micrometers (Hao et al. 2018). Laboratory testing of wildfire combustion suggests Cs fate is largely associated with ash (>99%) rather than air emissions. Hao (2018) confirms that cesium and other radionuclides that would be emitted by the Rim Country Project would not reach unsafe levels.

Baker et al., 2021 modeled emissions from a large hypothetical wildfire in a wildland-urban interface (WUI) impacted by a hypothetical radiological release event. "While ambient concentrations tended to be highest near the fire, the highest population committed effective dose

> equivalent by inhalation to an adult from ^{137}Cs over an hour was downwind where wind flows moved smoke to high population areas. Seasonal variations in meteorology (wind flows) can result in differential population impacts even in the same metropolitan area. Modeled post-incident ambient levels of ^{137}Cs both near these wildfires and further downwind in nearby urban areas were well below levels that would necessitate population evacuation or warrant other protective action recommendations such as shelter-in-place. These results suggest that 1) the modeling system captures local- to regional-scale transport and levels of PM2.5 from wildfire and 2) first responders and downwind population would not be expected to be at elevated risk from the initial inhalation exposure of ^{137}Cs re-emission and are more likely to have negative health impacts from other pollutants (e.g., carbon monoxide and total PM2.5 mass) emitted by wildfire (Adetona et al., 2013) rather than legacy radioactive ^{137}Cs emitted at levels similar to this assessment."
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> Evangeliou and Eckhardt, 2020 and Talerko et al., 2021 assessed the emissions from the unprecedented April 2020 wildfires in the Chernobyl Exclusion Zone and examined their dispersion and impact on the population. The assessment detailed that all doses of radionuclides are radiologically insignificant and no health impact on the European population is expected from the April 2020 fires.
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> A study that included Lockett Meadow, an area near Flagstaff, AZ, found levels of radioactive materials in the soil were no different than background levels, and would provide no added human health risk (Ketterer et al., 2004).

Significance: The additional literature review does not change the conclusions in the analysis that prescribed fire treatments would not result in health effects from the re-suspension of radioactive particles. A radioactive emissions analysis was present within the DEIS and was inadvertently deleted. Additional literature updates include the best available science.

Four Forest Restoration Initiative Rim Country Project Final Environmental Impact Statement

Air Quality Specialist Report

Carbon Storage

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For:
4FRI Rim Country EIS

Date: March, 2022, updated August 2022

Contents

Smoke/Air Quality

The proposed prescribed burning may have negative effects on air quality and human health. Some commenters are concerned that the smoke from prescribed burns would degrade air quality and the health of northern Arizona residents.

How Issue 6 is addressed:

Alternative 3 was partially developed to respond to this issue. It includes fewer acres of prescribed burning than the other action alternatives. This issue was also addressed in a considered and eliminated from detailed study alternative that proposed even less prescribed fire (see FEIS chapter 2). This issue will be addressed in the effect's analysis for all alternatives. Design features or mitigation measures will be included as needed where current law, rules, rules and policy would not adequately minimize the effects on air quality from the proposed project prescribed burning.

Indicators/Measures:

The potential for smoke emissions from proposed prescribed fire to affected communities will be evaluated qualitatively and quantitatively. Four main smoke effects will be evaluated: (1) nuisance smoke; (2) unhealthy smoke effects that would result from exceedances of the National Ambient Air Quality Standards (NAAQS) caused by project implementation burning. (It should be noted that uncontrolled smoke emissions from the project could cause NAAQS exceedances on clean air days or add to background air pollutant levels and increase air pollution to unhealthy amounts. Project smoke emissions from prescribed burning would be regulated by the Arizona Department of Environmental Quality in order to prevent exceedances of NAAQS); (3) effects to visibility or regional haze; and (4) greenhouse gas emissions.

A quantitative analysis of criteria air pollutant emissions to be modeled include the following: carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 10 microns in size (PM10), particulate matter less than 2.5 microns in size (PM2.5), and sulfur dioxide (SO2). The project's potential annual smoke emissions will be compared to annual emissions shown in the EPA's National Emissions Inventory in order to provide readers with comparisons of the amounts of smoke the project could produce compared to county, state wide and national prescribed fire and wildfire smoke emissions.

Greenhouse gas (CO2 equivalent) emissions estimates will also be completed for comparison purposes to the National Emissions Inventory.

Methodology

Nuisance smoke is analyzed qualitatively and discussed in terms of the regulatory framework used by the State of Arizona for dealing with smoke complaints.

National Ambient Air Quality Standards are analyzed qualitatively and discussed in terms of the regulatory framework used by the State of Arizona for preventing exceedances of the health standards.[1]

Project smoke emissions are analyzed quantitatively to show comparisons of potential prescribed fire smoke emissions to county, statewide and national level prescribed fire and wildfire emissions (NEI, 2017). The DEIS First Order Fire Effects Model data (FOFEM) were expanded on for the FEIS (Air Quality report Appendices B, C, D). The DEIS Table 44, Comparison of Percent Changes in Total Surface Fuel Loadings from existing conditions (DEIS p 258) was removed because the table showed a set of values that are not used to estimate emissions in the FEIS air quality section.

Visibility or regional haze is analyzed qualitatively and discussed in terms of the regional haze planning framework used by the State of Arizona for moving current visibility conditions towards meeting visibility goals.

Prescribed fire greenhouse gas emissions are analyzed quantitatively in order to show comparisons of potential CO2 equivalent (CO2e) emissions to county, statewide and national level prescribed fire and wildfire emissions (NEI 2017).

For detailed information about methodology see Appendix A.

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[1] Compared to the other current and planned prescribed burning projects in Arizona the Rim Country project would produce large amounts of smoke emissions over twenty years. This analysis shows the approximate amounts of emissions using several burning scenarios. While this information can be useful for comparing the project's emissions to other emissions sources the amounts of emissions does not easily equate into knowing what the smoke concentrations would be in populated or smoke sensitive areas. Estimating smoke concentrations would require smoke dispersion modeling that generally is available for up to a 72-hour forecast period based on weather forecast models. The ADEQ uses such modeling for forecasting the capacity of the atmosphere to disperse smoke emissions. The department bases burn day authorizations on the amounts of burning the land management agencies have requested to complete, weather forecasts and smoke dispersion modeling.

Resource Indicators and Measures

Table 1. Resource condition indicators and measures for assessing effects

Issue	Indicator or Measure	Source
Issue 6	Nuisance Smoke (*Qualitative*) Exceedances of NAAQS (*Qualitative*) Smoke Emissions – Criteria Air Pollutants (*Quantitative*)	"Nuisance Smoke" is defined in the Arizona State Implementation Plan as "Amounts of smoke in the ambient air which interfere with a right or privilege common to members of the public, including the use or enjoyment of public or private resources" (Appendix A-10, pg. 35 of the Arizona State Implementation Plan) Forest Service Manual 2500 – Watershed and Air Management – Air Resource Management Apache-Sitgreaves, Coconino, and Tonto National Forests Land and Resource Management Plans Arizona Administrative Code Title 18. Environmental Quality Chapter 2. Department of Environmental Quality - Air Pollution Control (includes) Article 15. Forest and Range Management Burns Arizona Department of Environmental Quality Smoke Management Program
Not identified as a	Smoke Emissions – Greenhouse Gases[2] (Quantitative)	USDA Forest Service, Climate Change Considerations in Project Level NEPA Analysis, January 13, 2009

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[2] The primary GHGs that enter the atmosphere as a result of anthropogenic activities include carbon dioxide (CO2), methane (CH4), nitrous oxide (N20), and fluorinated gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. GHGs are often presented using the unit of metric tons of CO2 equivalent (mt CO2e) or Million Metric Tons (MMT CO2e), a metric to express the impact of each different greenhouse gas in terms of the amount of CO2 making it possible to express greenhouse gases as a single number. For example, 1 ton of methane would be equal to 28 tons of CO2 equivalent, because it has a Global Warming Potential (GWP) 28 times that of CO2. As defined by EPA, the GWP provides "ratio of the time-integrated radiative forcing from the instantaneous release of one kilogram of a trace substance relative to that of one kilogram of CO2." The GWP of greenhouse gas is used to compare global impacts of different gases and used specifically to measure how much energy the emissions of one ton of gas would absorb over a given period of time (e.g. 100 years), relative to the emissions of one ton of CO2. The GWP accounts for the intensity of each GHGs heat trapping effect and its longevity in the atmosphere. The GWP provides a method to quantify the cumulative effects of multiple GHGs released into the atmosphere by calculating carbon dioxide equivalent for the GHGs (SEA_WegVZinke 2019).

- Carbon dioxide, by definition, has a GWP of 1 regardless of the time period used because it is the gas being used as the reference. CO2 remains in the climate system for a very long time; CO2 emissions cause increases in the atmospheric concentrations of CO2 that would last thousands of years (EPA 2016).
- Methane is estimated to have a GWP of 28-36 times that of CO2 over 100 years depending upon the source. CH4 emitted today lasts about a decade on average, which is much less time than CO2. But CH4 also absorbs much more energy than CO2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The methane GWP also accounts for some indirect effects, such as the fact that methane is a precursor to ozone, and ozone is in itself a greenhouse gas (EPA 2016).
- Nitrous Oxide has a GWP of 298 times that of CO2 for a 100-year timescale. N2O emitted today remains in the atmosphere for more than 100 years, on average (EPA 2016).

Issue	Indicator or Measure	Source
significant issue.		
Issue 6	Visibility or Regional Haze (Qualitative)	Arizona Regional Haze Plan

Affected Environment

Nuisance Smoke

"Nuisance Smoke" is defined in the Arizona State Implementation Plan as "Amounts of smoke in the ambient air which interfere with a right or privilege common to members of the public, including the use or enjoyment of public or private resources" (Arizona State Implementation Plan, Appendix A-10, page 35).

Nuisance smoke often results in public reports or complaints about smoke. Nuisance smoke can range from people seeing smoke on the horizon to persons who are concerned about possibly being exposed to smoke to people being affected by smoke exposure and breathing smoke. The State of Arizona's Smoke Management Program is tasked with overseeing the documentation and investigation of smoke complaints and with verifying the severity of smoke impacts and the potential for or actual occurrence of exceedances of the health standards.

Public tolerance for smoke, in addition to law, regulation, or policy, effectively sets a social limit to how many acres are treated with wildland fire. The ADEQ and other agencies respond to public inputs by trying to minimize impacts, even when they're well within legal limits. Community public relations and education coupled with pre-burn notification greatly improve public acceptance of fire management programs. The general public will tolerate several days in a row, and several weeks a year, but even the most supportive and educated have tolerance limits (Kleindienst 2012). To maintain public support for prescribed burns and the beneficial use of wildfires, land managers must be responsive to the public's tolerance thresholds.

Public acceptance of smoke varies greatly from year to year. Acceptance of smoke from prescribed fires and beneficial wildfires is high following seasons with high profile, high severity wildfire events, and during extremely dry years when the threat of large, high severity incidents is elevated. Conversely, acceptance wanes during wetter year when the threat of uncharacteristic fires is low, despite climatology in milder years being more favorable for achieving desired fire effects, especially in areas highly departed from natural or reference conditions (Kleindienst 2012).

Air Quality Health Standards

National Ambient Air Quality Standards

The Clean Air Act, which was last amended in 1990, requires the EPA to set National Ambient Air Quality Standards (40 CFR part 50) for pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards. Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

The EPA has set National Ambient Air Quality Standards (NAAQS) for six principal pollutants, which are called "criteria" air pollutants and they include carbon monoxide (CO), lead, nitrogen dioxide, ozone, particulate matter less than 10 microns in size (PM10), particulate matter less than 2.5 microns in size (PM2.5), and sulfur dioxide.

Periodically, the standards are reviewed and may be revised.[3] The current standards are listed below in Table 1. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air (µg/m3) (EPA 2021a).

Table 1. National Ambient Air Quality Standards (40 CFR part 50) for pollutants considered harmful to public health and the environment

Criteria Air Pollutant	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)	primary	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	
Lead (Pb)	primary and secondary	Rolling 3-month average	0.15 $\mu g/m^3$ (1)	Not to be exceeded
Nitrogen Dioxide (NO_2)	primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	primary and secondary	1 year	53 ppb (2)	Annual Mean

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[3] (1) In areas designated nonattainment for the Pb standards prior to the promulgation of the current (2008) standards, and for which implementation plans to attain or maintain the current (2008) standards have not been submitted and approved, the previous standards (1.5 µg/m3 as a calendar quarter average) also remain in effect.
(2) The level of the annual NO2 standard is 0.053 ppm. It is shown here in terms of ppb for the purposes of clearer comparison to the 1-hour standard level.
(3) Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) O3 standards additionally remain in effect in some areas. Revocation of the previous (2008) O3 standards and transitioning to the current (2015) standards will be addressed in the implementation rule for the current standards.
(4) The previous SO2 standards (0.14 ppm 24-hour and 0.03 ppm annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet 1 year since the effective date of designation under the current (2010) standards, and (2)any area for which an implementation plan providing for attainment of the current (2010) standard has not been submitted and approved and which is designated nonattainment under the previous SO2 standards or is not meeting the requirements of a SIP call under the previous SO2 standards (40 CFR 50.4(3)). A SIP call is an EPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required NAAQS.

Criteria Air Pollutant		Primary/ Secondary	Averaging Time	Level	Form
Ozone (O_3)		primary and secondary	8 hours	0.070 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 µg/m^3	annual mean, averaged over 3 years
		secondary	1 year	15.0 µg/m^3	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 µg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

The project is in a NAAQS non-attainment area.[4] The Payson area in Gila County is in moderate non-attainment for particulate air pollution (PM10 1987). In addition, there are several non-attainment areas to the south and southwest outside of the project area (EPA 2021d).

Pollution from distant, large population centers in Arizona and California affects the air quality in the area. Large dust storms that occur in the Phoenix valley can produce large amounts fugitive dust that have also been known to affect air quality in Northern Arizona, but these events are generally limited to a few days a year. Ozone levels are increasing, and are trending up in northern Arizona (Kleindienst 2012).

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[4] Nonattainment Areas are designated by EPA based upon air quality monitoring data or modeling studies that indicate an area violates, or contributes to violations of the NAAQS. States are required to submit a State Implement Plan (SIP), which defines the strategies used to control air pollution in order to bring air quality into attainment. After air quality improves and no longer violates the NAAQS, EPA may re-designate the area as attainment and these areas are known as maintenance areas. The CAA and EPA regulations impose requirements for Federal agencies to work with State and local governments in nonattainment and maintenance areas to ensure that federal actions conform to the initiatives established in the applicable SIP. These regulations are defined under the CAA General Conformity Rule.

Natural background ozone concentrations are naturally high in the West; transport from industry and large urban areas in Arizona and California and other non-local sources also contributes significantly (Tong and Mauzerall 2008; Koo et al. 2010). Under certain weather conditions, smoke from wildfires fires has the potential to contribute to the formation of ozone. Yet, data on how much ozone is created from the precursor pollutants emitted in wildland fire smoke, or prescriptive criteria to deter ozone creation are not available.

Wildland fires produce Carbon Monoxide, PM2.5, PM10, Nitrogen Oxides, and Sulfur Dioxide criteria air pollutants. The U.S. Air Quality Index is the EPA’s index for reporting air quality to the public. Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below represents good air quality, while an AQI value over 300 represents hazardous air quality (Table 2) (EPA 2021b)

For each pollutant an AQI value of 100 generally corresponds to an ambient air concentration that equals the level of the short-term national ambient air quality standard for protection of public health. AQI values at or below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is unhealthy: at first for certain sensitive groups of people, then for everyone as AQI values get higher.

The AQI is divided into six categories. Each category corresponds to a different level of health concern. Each category also has a specific color. The color makes it easy for people to quickly determine whether air quality is reaching unhealthy levels in their communities. EPA establishes an AQI for five major air pollutants regulated by the Clean Air Act. Each of these pollutants has a national air quality standard set by EPA to protect public health:

- ground-level ozone
- particle pollution (also known as particulate matter, including PM2.5 and PM10)
- carbon monoxide
- sulfur dioxide
- nitrogen dioxide

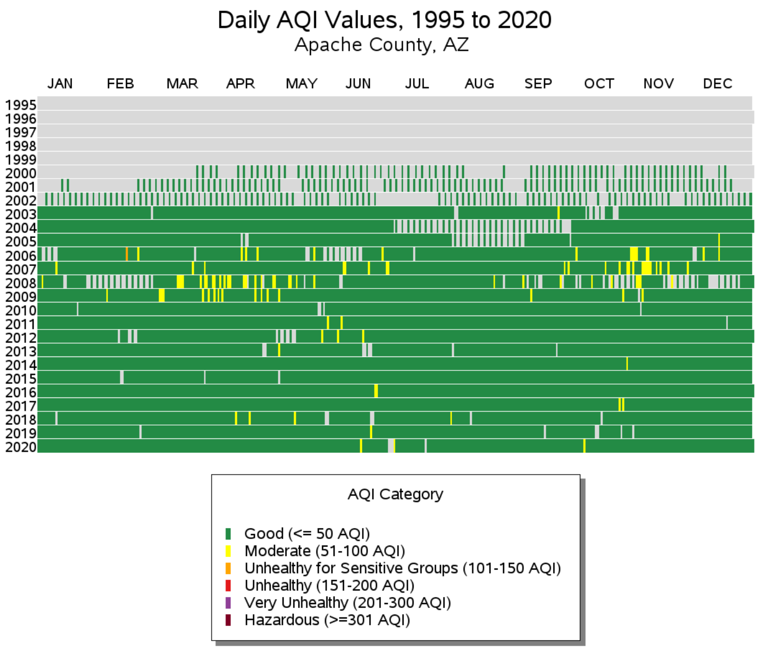
The ADEQ displays real time particulate monitoring data for monitoring stations near the Rim Country project at this website: https://www.phoenixvis.net/PPMmain.aspx

Table 2. AQI basics table for ozone and particulate pollution

AQI Basics for Ozone and Particle Pollution			
Daily AQI Color	**Levels of Concern**	**Values of Index**	**Description of Air Quality**
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.

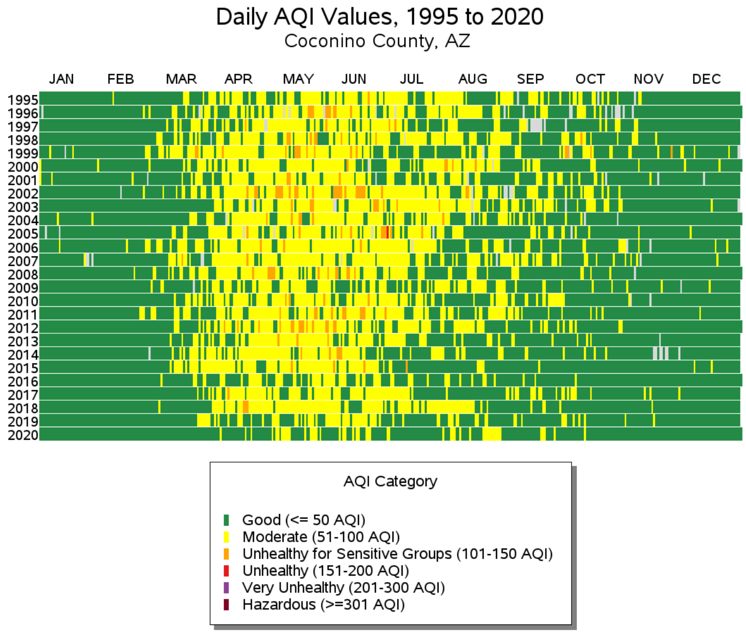
AQI Basics for Ozone and Particle Pollution			
Daily AQI Color	**Levels of Concern**	**Values of Index**	**Description of Air Quality**
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.

Figures 1-5 show AQI information for all monitored criteria air pollutants from 1995-2020 in Apache, Coconino, Gila, Navajo, and Yavapai Counties. The figures show general over all improving air quality conditions in the counties except for Gila County that is impacted by emissions from copper mining operations and transport pollutants from the Phoenix metropolitan area. In addition, except for Gila County, most of the air pollution impacts occur from approximately March-September when ground level ozone levels are highest (EPA 2021c).



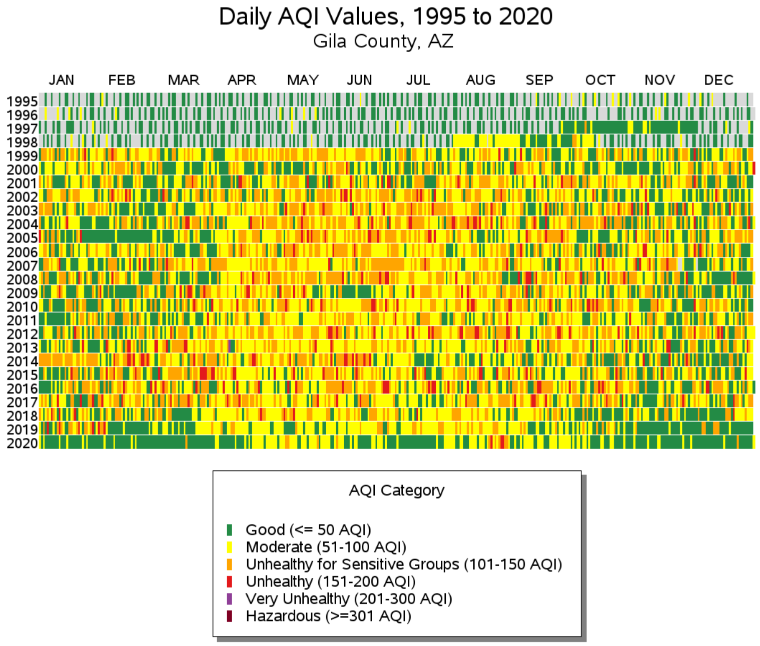
Source: U.S. EPA AirData <https://www.epa.gov/air-data>
Generated: June 21, 2021
Note: The PM2.5 monitoring network was phased in between 1999 and 2001 in most areas. Earlier years in this plot do not include PM2.5 data.

Figure1. Apache county AQI values 1995-2020



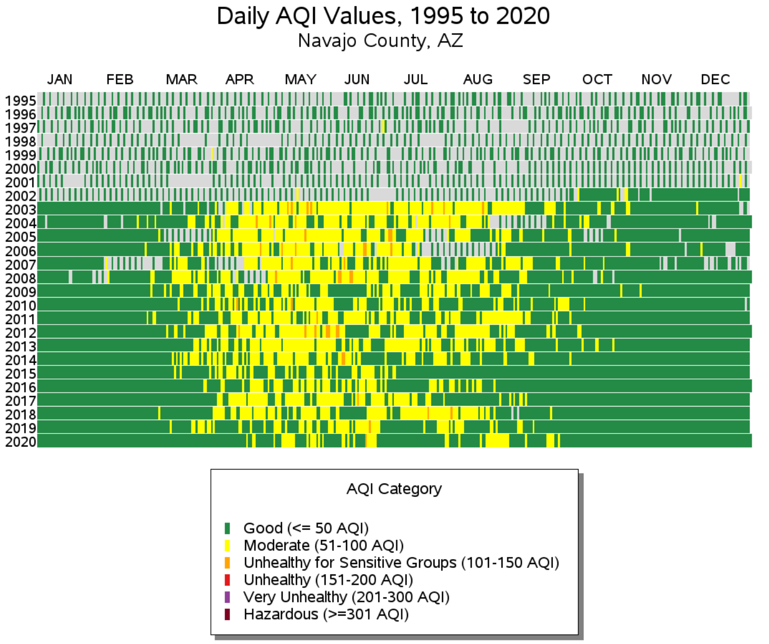
Source: U.S. EPA AirData <https://www.epa.gov/air-data>
Generated: January 29, 2021
Note: The PM2.5 monitoring network was phased in between 1999 and 2001 in most areas. Earlier years in this plot do not include PM2.5 data.

Figure2. Coconino county AQI values 1995-2020



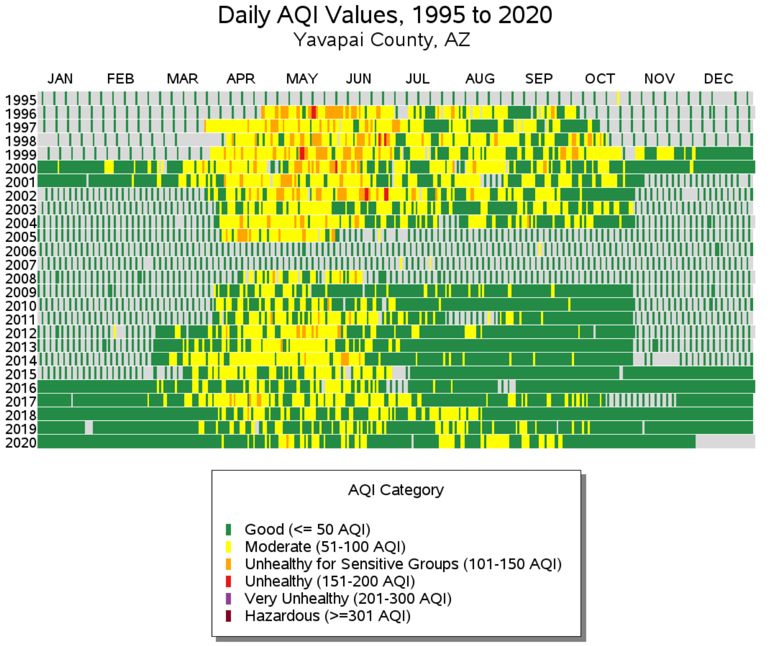
Source: U.S. EPA AirData <https://www.epa.gov/air-data>
Generated: January 29, 2021
Note: The PM2.5 monitoring network was phased in between 1999 and 2001 in most areas. Earlier years in this plot do not include PM2.5 data.

Figure 3. Gila county AQI values 1995-2020



Source: U.S. EPA AirData <https://www.epa.gov/air-data>
Generated: January 29, 2021
Note: The PM2.5 monitoring network was phased in between 1999 and 2001 in most areas. Earlier years in this plot do not include PM2.5 data.

Figure 4. Navajo county AQI values 1995-2020



Source: U.S. EPA AirData <https://www.epa.gov/air-data>
Generated: January 29, 2021
Note: The PM2.5 monitoring network was phased in between 1999 and 2001 in most areas. Earlier years in this plot do not include PM2.5 data.

Figure 5. Yavapai county AQI values 1995-2020

Smoke Sensitive Areas

The Regional Haze State Implementation Plan for Arizona defines ‘sensitive receptors’ as “population centers such as towns and villages, camp grounds and trails, hospitals, nursing homes, schools, roads, airports, mandatory Class I Federal areas, where smoke and air pollutants can adversely affect public health, safety, and welfare” (Arizona State Implementation Plan, Appendix A-10 page 36). Several smoke sensitive areas, or sensitive receptors lay within the airsheds of the areas proposed for treatment (Table 3). These areas may have smoke sensitive receptors including hospitals, long term care facilities, schools, young children, and elders. The list is not inclusive, and we recognize that there are several communities within, adjacent, or sometimes downwind of the project that are likely to have some effects of smoke from Rim Country activities and are not listed.

Table 3. Smoke sensitive areas

Area	Proximity to Implementation Area
Apache County	Down-wind east/northeast of the project area
Verde Valley	Less than 10 miles downslope south and southwest of project area
The Navajo Reservation	Northeast and east of the project area
Fort Apache Reservation	Adjacent to project area to the south and east
The Hopi Reservation	Northeast and east of the project area
Snowflake / Taylor	About 15 miles north of the project area
Tonto Basin /Roosevelt	About 10 miles south southwest of the project area
Show Low	Project area to the east and west of Show Low
Heber Overgaard	Project area is adjacent to town in multiple directions
Strawberry / Pine	Project area is on all sides of the both towns
Blue Ridge	Project area is on all sides of the developed areas
Pinetop/Lakeside	Project area is on all sides of the project area
Payson	Project area is on all sides of the project area

Meteorological and Topographical Effects on Air Quality

Topography and weather patterns determine the extent to which airborne particulate matter accumulates within local airsheds and the capacity of the atmosphere to disperse pollutants. Diurnal temperature changes affect how pollutants in the region are dispersed. Meteorological conditions limit how much smoke an airshed can absorb at any point in time without exceeding NAAQS. During the warmest days and seasons of the year, air is heated at the surface, and rises, lifting smoke up to heights where transport winds carry it away and disperse it during the daily burn periods. Winds in the project area are predominantly from the south and southwest (Figure 6) and, as such, during daytime hours, fire activities within the Rim Country treatment area are most likely to affect smoke sensitive receptors to the north and northeast of fire locations (DRI 2021).

The best windows for smoke dispersal are when the atmosphere is unstable, allowing smoke to rise up high and disperse. These conditions, when combined with low fuel moistures and high fuel loading, can also lead to undesirable fire behavior and effects. The best dispersal days are often too extreme for prescribed fire. Overnight, winds often become calm, allowing topographic effects to dominate smoke movement. As the temperature decreases, air flows downhill, carrying smoke from fires and which often pools in low lying areas until the air warms again the next day. Because most communities are located in valley or canyon bottoms nighttime settling of smoke from fires generally generates more concerns and complaints of nuisance smoke compared to daytime smoke (NWCG 2018).

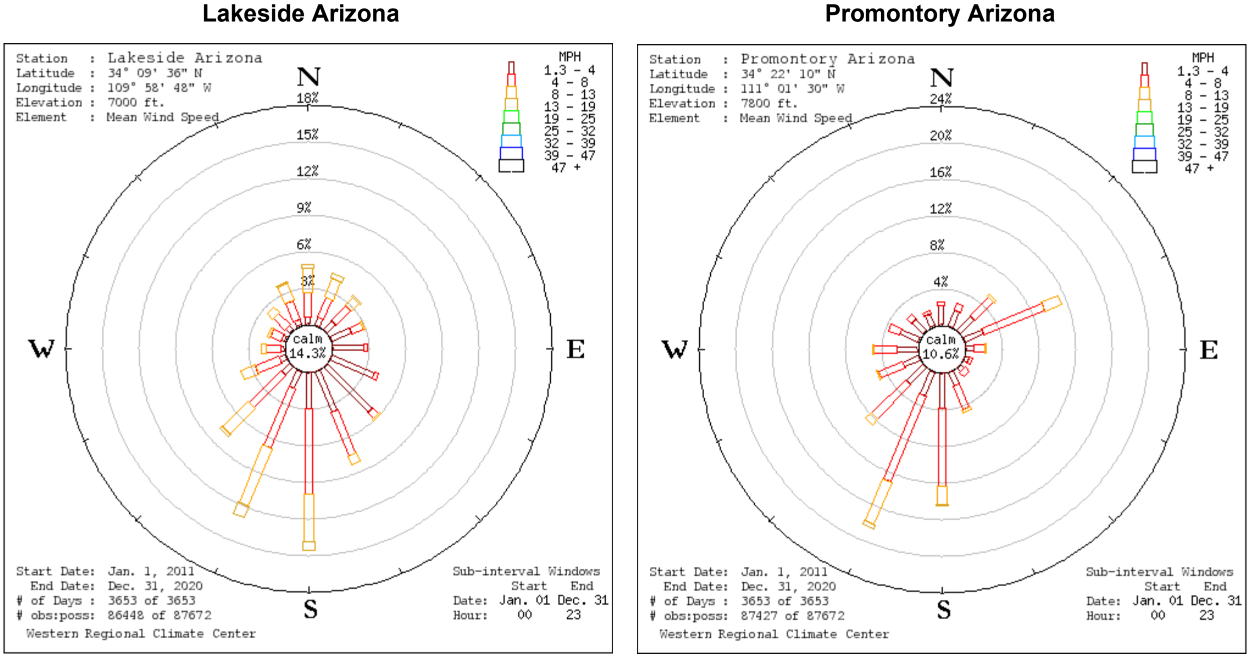


Figure 6. Lakeside and Promontory weather stations wind roses showing 24 hour or daily wind direction and speed over ten years from 2011-2020. The bars show the direction the wind is blowing from.

During the winter, weather conditions can trap emissions in a layer of cold surface air or inversions. Under these conditions, particulates can be trapped close the surface in local airsheds, including the communities of Flagstaff, Young, Payson, Pumpkin Center, Roosevelt, St. John, and the Verde Valley.

Smoke Emissions – Criteria Air Pollutants

Sources of Air Pollution

Forest Service management activities with the largest direct effects on air quality are prescribed fires and wildland fire use. From 1995-2018 the acreages of prescribed fire have increased across all three National Forests, though the actual amount fluctuates from year to year (Figure 8).

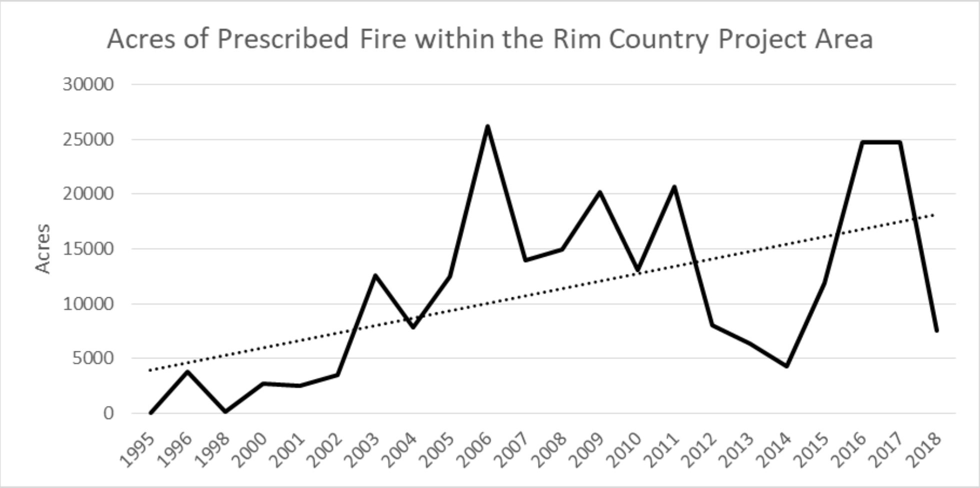


Figure9. Acres of prescribed fire and trends for Rim County project area from 1995-2018

Table 4 shows data from the 2017 National Emissions Inventory for annual criteria air pollutant emissions from various sources at the county, state and national levels for comparing to Rim Country annual emissions. The data includes emissions from wildfires, prescribed fires and agricultural field burning and total emissions from all polluting sources. The information is useful for comparing the potential project emissions with other sources in and around the Rim Country area (NEI 2017).

Table 4. Data from the 2017 National Emissions Inventory showing annual air pollutant emissions from various sources at the county, state and national levels for comparing to Rim Country annual emissions

Source - Geographic Area	Carbon Monoxide (tons per year)	PM2.5 (tons per year)	PM10 (tons per year)	Nitrogen Oxides (tons per year)	Sulfur Dioxide (tons per year)	Volatile Organic Compounds (tons per year)
Apache County – All Sources	64,060.00	5,985	14,642.00	16,241.00	6,434.00	63,716.00
Coconino County – All Sources	217,728.53	16,310.23	27,990.80	16,352.10	1,193.37	135,338.30
Gila County – All Sources	51,468.82	4,450.64	10,961.87	3,428.56	24,736.79	53,066.83
Navajo County – All Sources	40,838.15	3,443.68	14,348.08	10,951.96	1,860.50	49,465.40
Yavapai County – All Sources	70,904.32	4,724.40	18,222.75	11,521.70	1,927.88	62,638.80
Arizona – All Sources	1,423,957.51	84,891.20	253,704.86	187,586.89	52,185.17	1,095,958.31
National – All Sources	70,995,207.70	5,708,145.22	17,064,238.92	11,855,303.54	2,725,449.36	43,105,760.80
Apache County – Prescribed Fires	37,870.19	3,144.05	3,709.98	357	235.80	8,890.19
Apache County – Wildfires	917.31	81.05	95.64	15.12	7.69	217.15
Apache County – Agricultural Field Burning	-	-	-	-	-	-
Coconino County – Prescribed Fires	87,038.59	7,261.73	8,568.84	867.93	556.33	20,445.83
Coconino County – Wildfires	84,468.20	7,182.56	8,475.42	1,021.05	594.57	19,891.94
Coconino County - Agricultural Field Burning	-	-	-	-	-	-
Gila County - Prescribed Fires	6,731.31	565.53	667.33	72.32	44.61	1,582.67
Gila County – Wildfires	26,798.07	2,449.48	2,890.39	549.57	257.63	6,373.85
Gila County - Agricultural Field Burning	11.80	1.50	2.04	0.28	0.05	1.19
Navajo County – Prescribed Fires	12,840.55	1,056.77	1,246.99	108.85	76.20	3,010.95
Navajo County – Wildfires	1,520.97	129.57	152.89	18.70	10.80	358.27
Navajo County - Agricultural Field Burning	-	-	-	-	-	-
Yavapai County – Prescribed Fires	2,164.79	189.51	223.62	33.34	17.43	511.80
Yavapai County – Wildfires	18,658.90	1,738.28	2,051.17	425.94	192.62	4,450.05
Yavapai County - Agricultural Field Burning	7.12	0.52	0.91	0.31	0.06	1.21
Arizona – Prescribed Fires	154,560.64	12,936.68	15,265.28	1,596.09	1,004.69	36,322.43
Arizona – Wildfires	369,187.82	32,221.86	38,021.79	5,557.86	2,933.56	87,248.11

Source - Geographic Area	**Carbon Monoxide (tons per year)**	**PM2.5 (tons per year)**	**PM10 (tons per year)**	**Nitrogen Oxides (tons per year)**	**Sulfur Dioxide (tons per year)**	**Volatile Organic Compounds (tons per year)**
Arizona - Agricultural Field Burning	1,772.13	201.19	282.71	57.11	18.44	214.60
National – Prescribed Fires	8,870,309.36	805,307.13	948,309.47	164,697.23	78,190.63	2,042,074.79
National – Wildfires	19,487,071.80	1,655,210.73	1,952,987.64	230,541.00	135,352.57	4,577,921.78
National - Agricultural Field Burning	301,034.72	30,776.12	42,932.75	12,705.85	4,236.92	38,061.10

Comparing Wildfire to Prescribed Fire and Wildland Fire Use

Smoke is inevitable in the airsheds of fire adapted ecosystems, such as those of Northern Arizona. Federal land managers have the role of protecting and meeting air quality standards while simultaneously allowing fire, as nearly as possible, to function in its natural role in the ecosystem (USDA and USDOI 1995). Smoke and visibility impairment from wildland fire that closely mimics what would occur naturally is generally viewed as acceptable (Peterson 2001).

Currently, controlled prescribed burns and wildland fire use are regulated and their emissions are monitored and regulated in the same manner as emissions sources that are more controllable (such fugitive dust, vehicle emissions, smoke from wood-burning stoves, and industrial emissions), and included in air quality assessments used to approve burn plans. Smoke impacts from uncontrolled wildfire can be more difficult or impossible to mitigate compared to prescribed fire and wildland fire use, whether the expected effects of the fire are desirable or not. Among the many factors the federal land management agencies should weigh when deciding how to manage a wildfire, or whether to ignite a prescribed fire is whether the potential benefits of the fire outweigh the smoke affects or impacts. Prescribed fires and wildfires both produce smoke, but differ in the amount, timing, and predictability of these events (Table 5). Most wildfires in the southwest occur between late April and mid-September. Currently, most prescribed fires are implemented in the early spring or late fall.

Fire managers are able to manage smoke impacts to some degree by implementing prescribed fire and managing wildland fire use when metrological conditions are favorable. It may be possible to minimize burning and/or hold a fire in check on days when reduced emissions are needed. It can be advantageous to blackline a prescribed burn unit well in advance of burning the entire unit to take advantage of burn windows with good ventilation. Various Emissions Reductions Techniques and Smoke Management Techniques are utilized and documented as a standard part of implementing prescribed fires and wildland fire use as required by ADEQ rules (ADEQ 2004).

Table 5. Generalized comparison of options for managing prescribed burn and wildland fire use

Emission Characteristics	Planned Ignitions	Unplanned Ignitions
Predictability of when smoke events occur	Predictable	Somewhat predictable to unpredictable
Predictability of the **severity** (concentration) of smoke impacts	Predictable	Somewhat predictable to unpredictable
Predictability of **where** there will be smoke impacts	Mostly predictable	Somewhat predictable to unpredictable (knowing where a fire will start)
Controllability of smoke	Mostly controllable	Mostly controllable to uncontrollable
Duration of smoke events	Days or weeks	Days, weeks, or months
Frequency of smoke events	Intermittent to frequent and increasing	Intermittent to frequent during the fire season, likely to increase
Severity/desirability of the effects of the fire	Mostly desirable	Mostly desirable to mostly undesirable
Longevity of negative effects	Short to moderate	Short to permanent
Extent of negative effects	Small, unlikely to be more than a few contiguous acres if it occurs	Variable, ranging from less than an acre to hundreds of thousands of acres
Potential for significant negative effects (other than smoke), such as downstream flooding or damage to infrastructure outside the fire perimeter	Low, but present	Low to very high
Threat to human life and property	Low, but present	Low to very high

Activities on prescribed fires and wildfires in an airshed are coordinated between fire managers, working with the Arizona Department of Air Quality, to either spread high emission producing events from multiple wildland fires over several days to reduce the concentration of pollutants, or facilitate these events to occur simultaneously on days with favorable ventilation to move the pollutants up and out of the airshed all at once to reduce the concentration and duration of smoke impacts.

Actual smoke effects are dependent on numerous factors, some predictable, some less so. Air quality effects are more closely related to ventilation parameters, live and dead fuel moisture, wind direction and speed, fuel chemistry, firing techniques, timing and duration of ignition, fuel arrangements and loading, atmospheric stability, than the Rim Country Alternatives.

Smoke can travel great distances and affect communities far away from the burn unit, often persisting for a time after the burn has been completed. Fires burning under historic conditions in the vegetation types targeted for restoration treatments in this analysis produce behavior and effects that are mostly low to moderate. Large, uncharacteristically high severity fires usually create more emissions over a longer time that prescribed fires, because of differences in the size and duration of the fires (Hardy et al. 2001) and the amount of fuel consumed.

Prescribed burning is implemented only with approved site-specific burn plans and with smoke management mitigation and approvals. All burning is conducted according to ADEQ rules, including the legal limits to smoke emissions from prescribed burns as imposed by Federal and State Law. The ADEQ enforces these rules by regulating acres that are treated based on expected air effects. These rules ensure that effects from all burning within the area are mitigated and that Clean Air Act requirements are met. Prescribed fires are initiated under conditions that allow managers to meet both control objectives (fire behavior), and resource objectives (fire effects, including air quality effects).

Smoke Emissions – Greenhouse Gas Emissions

Table 6 shows data from the 2017 National Emissions Inventory for annual greenhouse gas emissions from various sources at the county, state, and national levels for comparing to Rim Country annual emissions. The data includes emissions from wildfires and prescribed fires and total emissions from all polluting sources. The information is useful for comparing the potential project emissions with other sources in and around the Rim Country area (NEI 2017).

Table 6. Data from the 2017 National Emissions Inventory showing greenhouse gas emissions from various sources at the county, state, and national levels for comparing to Rim Country annual emissions[5]

Source - Geographic Area	Carbon Dioxide (tons per year)	Methane (tons per year)	Nitrous Oxide (tons per year)	CO2e (tons per year)
Apache County – All Sources	15,150,672	3,547	251	15,353,162
Coconino County – All Sources	3,538,513	12,007	33	3,980,562
Gila County – All Sources	970,517	1,727	14	1,036,949
Navajo County – All Sources	6,121,739	5,881	115	6,367,851
Yavapai County – All Sources	4,414,659	4,253	63	4,586,517
Arizona – All Sources	85,815,904	81,357	2,381	89,454,179
National – All Sources	5,381,953,222	6,247,460	142,348	5,649,281,475
Apache County – Prescribed Fires	358,725	1,820		424,231
Apache County – Wildfires	12,287	45		13,907
Coconino County – Prescribed Fires	850,657	4,192		1,001,572
Coconino County – Wildfires	924,980	4,106		1,072,805
Gila County – Prescribed Fires	68,677	325		80,388
Gila County – Wildfires	418,981	1,351		467,604
Navajo County – Prescribed Fires	114,815	614		136,932
Navajo County – Wildfires	16,831	74		19,495
Yavapai County – Prescribed Fires	27,696	107		31,539
Yavapai County – Wildfires	315,809	950		349,996
Arizona – Prescribed Fires	1,541,085	7,456		1,809,495
Arizona – Wildfires	4,652,066	18,180		5,306,541
National – Prescribed Fires	120,709,651	437,280		136,451,741
National – Wildfires	208,941,083	945,704		242,986,414

Radioactive Emissions

In northern Arizona, there are several types of radioactive elements. Most of these are naturally occurring, such as radon, potassium, and thorium. Northern Arizona also has rich deposits of uranium, which can and have been used for commercial purposes. In addition, northern Arizona, like much of the world, also has traces of man-made radioactive material, primarily from weapons testing conducted in the Cold War

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[5] The 2017 NEI does not have data for Nitrous Oxide emissions available for prescribed and wildfire sources.

era. These radioactive elements include cesium and strontium. When a fire burns through an area, it may re-suspend radioactive particles present in forest surface fuels (Hejl et al., 2012). Some are naturally occurring chemicals that have always been present at some level in wildfire smoke and some have resulted from the weapons testing that occurred in the mid-20th century. Implementation of prescribed burning would comply with the Federal Clean Air Act and at the state level with the Arizona Department of Environmental Quality's regulations that require the project to not cause exceedances of the National and State Ambient Air Quality Standards. At the level of exposure the public is subjected to as a result of prescribed fire treatments, radionuclides do not pose as great a risk as wildfire. Radioactive material that may be carried in the smoke plume carries a risk of human health concerns of less than 1 chance in 10 million ((personal communication Graham 2012-2014) and Risk Assessment Corporation, (2002)) and the greatest health risk is from breathing high concentrations of particulate matter in the smoke.

Communication with the Environmental Protection Agency (personal communication Gerdes 2012 - 2014; Graham 2012-2014), and studies (see below) that addressed these emissions indicate that radioactive isotopes and other undesirable chemicals are present in wildfire emissions. Studies have shown that the levels of radioactive material that could be released in a prescribed burn or wildfire are very low and do not present a health risk. The following is a review of the literature discussing the public health concern related to radionuclide emissions from fires:

During the Cerro Grande fire of 2000, there was considerable public concern regarding the potential release of radionuclides from fires burning on lands managed by the Los Alamos National Laboratory (LANL). The following risk summary is from the 2002 Summary Report Analysis of Exposure and Risks to the Public from Radionuclides and Chemicals Released by the Cerro Grande Fire at Los Alamos (Risk Assessment Corporation, 2002):

> "The primary health risks during the Cerro Grande fire were associated with breathing materials released into the air. It was estimated the risk of cancer from breathing any LANL-derived chemical or radioactive material that may have been carried in the smoke plume to be less than 1 chance in 10 million. Potential exposures in the surrounding communities to LANL-derived chemicals that are not carcinogenic were about 10 times lower than acceptable intakes established by the U.S. Environmental Protection Agency (EPA). The risk of cancer from breathing chemicals and radioactive materials in and on the natural vegetation that burned in the Cerro Grande Fire was greater than that from LANL-derived materials, but still less than 1 chance in 1 million. The vegetation that burned contained naturally occurring chemicals and radioactive materials and fallout produced during atmospheric tests of nuclear weapons. These materials and the risks they posed are present during any forest fire. The evidence suggests that some adverse health effects did result from breathing high concentrations of particulate matter in the smoke. Such exposures are associated with any forest fire. Deposition of LANL-derived chemicals and radioactive materials from the smoke plume to the soil was minimal."

Schollnberger et al., 2002 found that radiation doses from inhaled airborne radionuclides to individuals inside and outside the Los Alamos area from the Cerro Grande fire were likely very small, and health effects would be unlikely.

Following the Cerro Grande fire that burned through the city of Los Alamos and the Los Alamos National Laboratory (LANL) in New Mexico in 2000, the US Environmental Protection Agency (EPA), New Mexico Environment Department (NMED), and LANL partnered with Department of Energy to operate radiological monitoring systems as well as to initiate several studies to assess the impacts of the fire. The results of these efforts with regard to air quality and human health impact indicated that radionuclides originating from the LANL site during the Cerro Grande Fire were restricted to naturally occurring radionuclides.

LANL, the Department of Energy, and NMED-monitored radionuclide concentrations in smoke from the Las Conchas fire that burned through the Los Alamos area in the summer of 2011 and reported no significant detection levels (Michelotti et al., 2013).

A collaborative research effort was carried out between the U.S. Environmental Protection Agency and the U.S. Forest Service to simulate emissions in laboratory fires of pine needles and duff doped with nonradioactive cesium (Cs) (Hao et al., 2018). Following a radiological release event, nuclear power plant incident, improvised nuclear device, nuclear testing site, or hazardous waste site a wide area may be contaminated by radiological materials, including significant forest areas. There is a potential for emissions of radionuclides such as cesium-137 from a wildfire over a radionuclide-contaminated forest. The paper reports on a laboratory simulation study of a wildfire with two types of biomass doped with nonradioactive cesium. This simulation suggests that only 1 to 2.5 percent of the cesium in the biomass would be emitted from the wildfire, while the rest would reside in the residual ash. In the study, pine needles were the only contributor to the air emissions of cesium; duff was not a source of cesium emissions. In the study, cesium emitted from the simulated wildfire was concentrated in particle sizes larger than 10 micrometers (Hao et al. 2018). Laboratory testing of wildfire combustion suggests Cs fate is largely associated with ash (>99%) rather than air emissions. Hao (2018) confirms that cesium and other radionuclides that would be emitted by the Rim Country Project would not reach unsafe levels.

Baker et al., 2021 modeled emissions from a large hypothetical wildfire in a wildland-urban interface (WUI) impacted by a hypothetical radiological release event. “While ambient concentrations tended to be highest near the fire, the highest population committed effective dose equivalent by inhalation to an adult from ^{137}Cs over an hour was downwind where wind flows moved smoke to high population areas. Seasonal variations in meteorology (wind flows) can result in differential population impacts even in the same metropolitan area. Modeled post-incident ambient levels of ^{137}Cs both near these wildfires and further downwind in nearby urban areas were well below levels that would necessitate population evacuation or warrant other protective action recommendations such as shelter-in-place. These results suggest that 1) the modeling system captures local- to regional-scale transport and levels of PM2.5 from wildfire and 2) first responders and downwind population would not be expected to be at elevated risk from the initial inhalation exposure of ^{137}Cs re-emission and are more likely to have negative health impacts from other pollutants (e.g., carbon monoxide and total PM2.5 mass) emitted by wildfire (Adetona et al., 2013) rather than legacy radioactive ^{137}Cs emitted at levels similar to this assessment.”

Evangeliou and Eckhardt, 2020 and Talerko et al., 2021 assessed the emissions from the unprecedented April 2020 wildfires in the Chernobyl Exclusion Zone and examined their dispersion and impact on the population. The assessment detailed that all doses of radionuclides are radiologically insignificant and no health impact on the European population is expected from the April 2020 fires.

A study that included Lockett Meadow, an area near Flagstaff, AZ, found levels of radioactive materials in the soil were no different than background levels, and would provide no added human health risk (Ketterer et al., 2004).

Visibility or Regional Haze

Under the CAA the 1999 Regional Haze Rule (RHR) (40 CFR Parts 51 and 52) mandates that states address control of man-made air pollution that impacts visibility in designated Class I areas. Class I areas include wilderness, national parks and monuments greater than 5000 acres which existed as of August 7, 1977 (Figure 9).

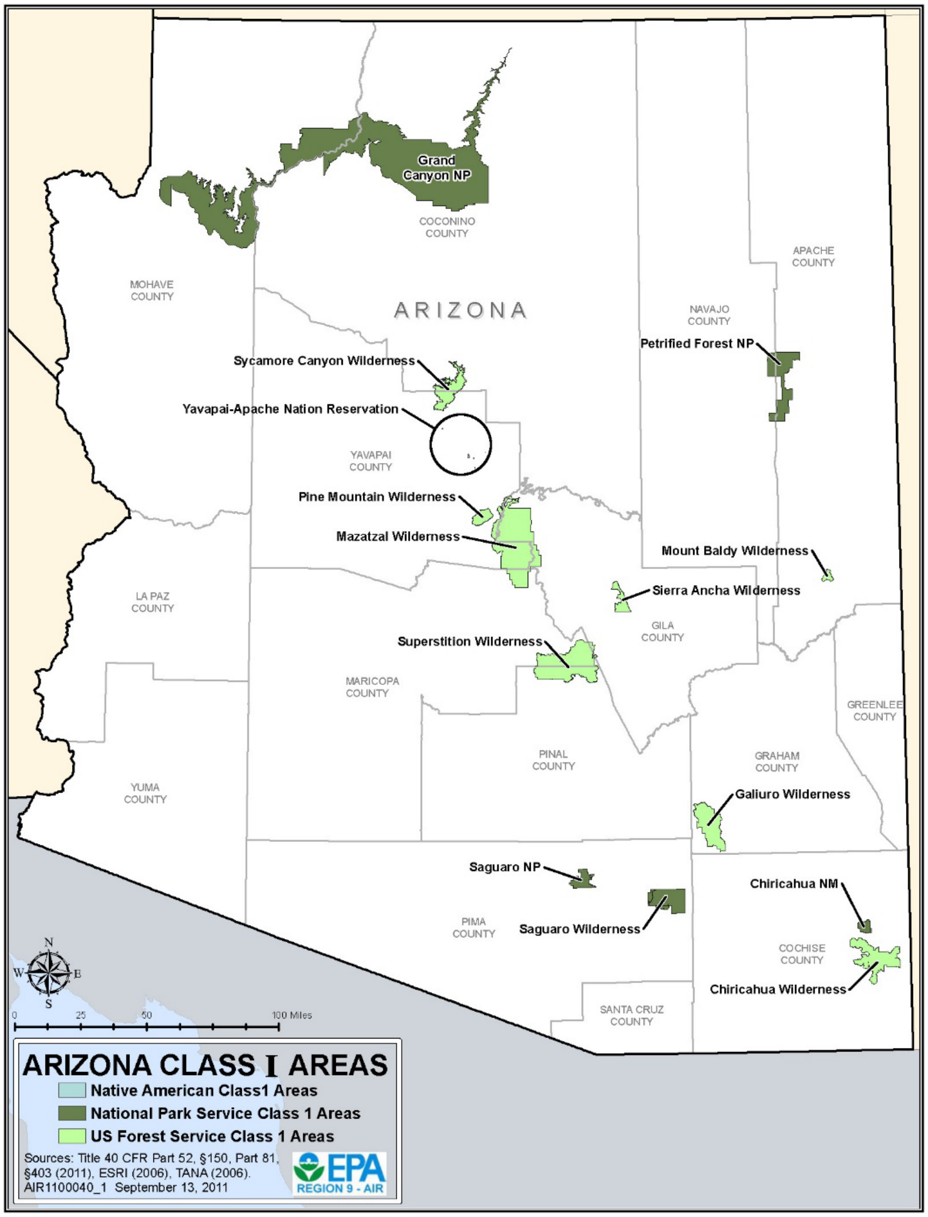
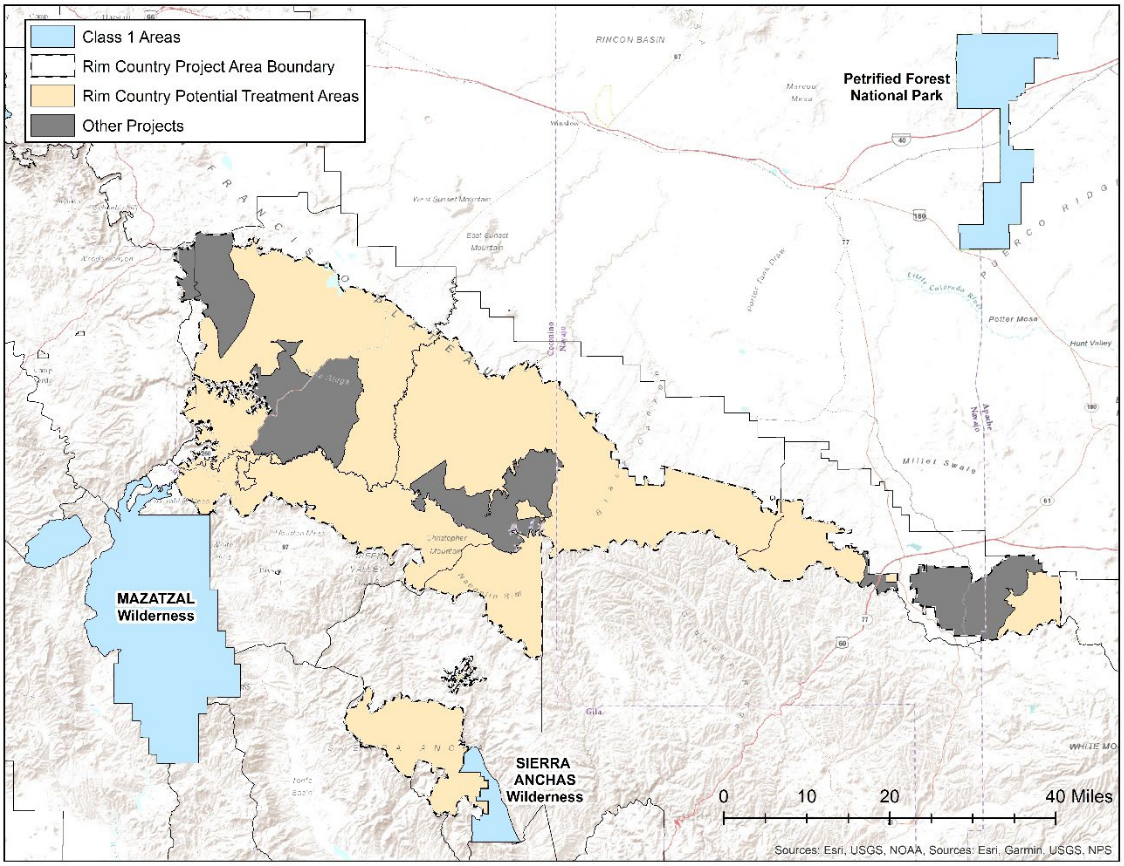


Figure 9. Arizona Class I Areas

The Class I areas most likely to be affected by smoke emissions from the Rim Country project area are Petrified Forest National Park, Mazatzal Wilderness, and Sierra Anchas Wilderness (Figure 10).



Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS

Figure 10: Class 1 areas with greatest potential to be affected by Rim Country smoke emissions

The goal of the RHR is to return visibility conditions in Class I areas to natural background conditions by the year 2064. EPA defines "regional haze" as visibility impairment produced by sources and activities that emit fine particles and their precursor emissions across a broad geographic area, which can interfere with the scenic vistas integral to our national parks, forests, and wilderness areas.

Under the RHR each area or state is given a reasonable progress goal (RPG) for the 20 percent best or clearest days and 20 percent most impaired days[6], which is reevaluated during each SIP revision. The RPGs incrementally reduce the amount of pollutants to ultimately reach a physical state termed "natural conditions" by 2064. Visibility values are expressed in deciviews, or a measurement based on perceptible change to the human eye. The RHR also includes requirements for periodic plan revisions and progress reports. Table 7 lists the Federal Class I areas in Arizona and their associated visibility values in deciviews (dv) (ADEQ 2015).

The federal land management agencies responsibility with regard to visibility involves coordination with the EPA, and State, county, and tribal air regulatory agencies in managing and mitigating the emissions of

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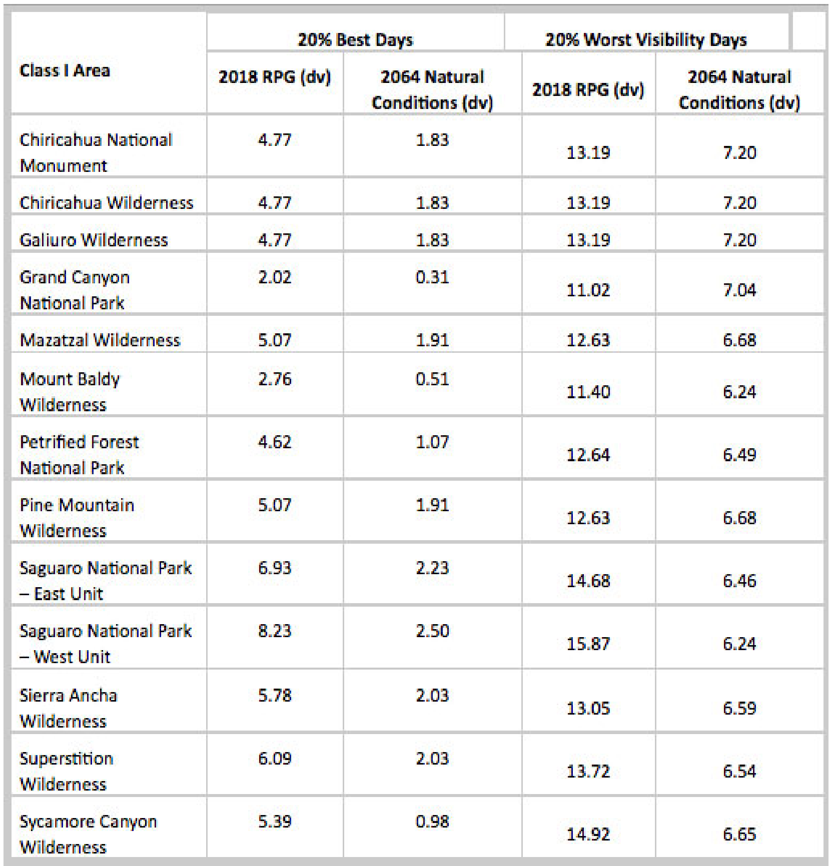
[6] Haziest, or worst visibility days include smoke from uncontrolled wildfires – something we cannot control. The new SIP revisions are being based upon "most impaired days" and the new terminology replaces "worst visibility days".

air pollutants resulting from agency activities, such as the application of prescribed burning and wildland fire use. If conditions prescribed by the RHR and the Arizona regional haze state implementation plan are met, visibility is expected to improve over time in and outside of the of the Rim Country area.



Class I Area	20% Best Days		20% Worst Visibility Days	
	2018 RPG (dv)	2064 Natural Conditions (dv)	2018 RPG (dv)	2064 Natural Conditions (dv)
Chiricahua National Monument	4.77	1.83	13.19	7.20
Chiricahua Wilderness	4.77	1.83	13.19	7.20
Galiuro Wilderness	4.77	1.83	13.19	7.20
Grand Canyon National Park	2.02	0.31	11.02	7.04
Mazatzal Wilderness	5.07	1.91	12.63	6.68
Mount Baldy Wilderness	2.76	0.51	11.40	6.24
Petrified Forest National Park	4.62	1.07	12.64	6.49
Pine Mountain Wilderness	5.07	1.91	12.63	6.68
Saguaro National Park – East Unit	6.93	2.23	14.68	6.46
Saguaro National Park – West Unit	8.23	2.50	15.87	6.24
Sierra Ancha Wilderness	5.78	2.03	13.05	6.59
Superstition Wilderness	6.09	2.03	13.72	6.54
Sycamore Canyon Wilderness	5.39	0.98	14.92	6.65

Table 7. List of the Federal Class I areas in Arizona and their associated visibility values in deciviews (dv)

According to the Interagency Monitoring of Protected Visual Environments (IMPROVE) data, the primary contributor to visibility impairment on the most impaired days for the Class I areas in and around the Rim County area is organic matter, which is often due to wildfire sources that are difficult to predict or control, but regulatory efforts can still have a positive impact on visibility by reducing other pollution sources.

Based on data from several years of data from the IMPROVE monitoring sites nearest to the Rim Country area the data is showing a gradual improvement in visibility (Figure 11-14). Many emission reductions that are required as part of the Regional Haze SIP process will occur over the next several years, so significant improvements in visibility should be seen in the next decade (IMPROVE 2021; ADEQ 2015).

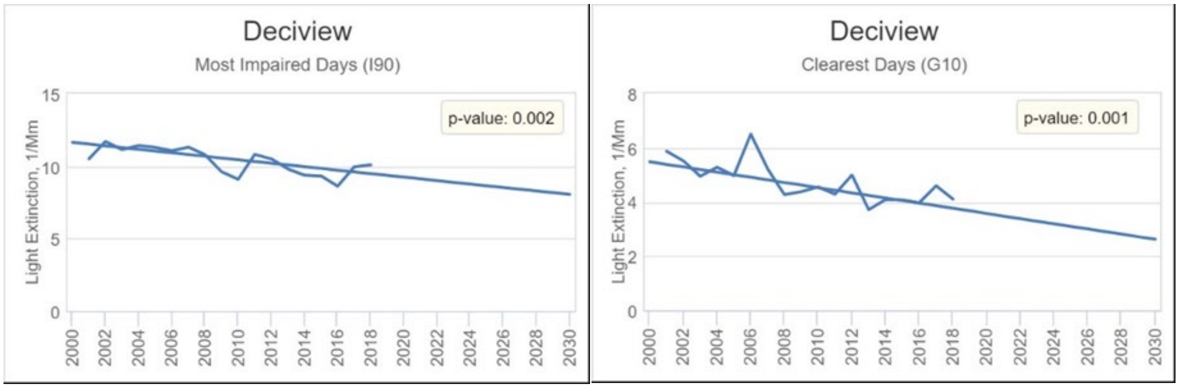


Figure 11. Ike’s Backbone visibility on the most impaired and clearest days 2001-2018

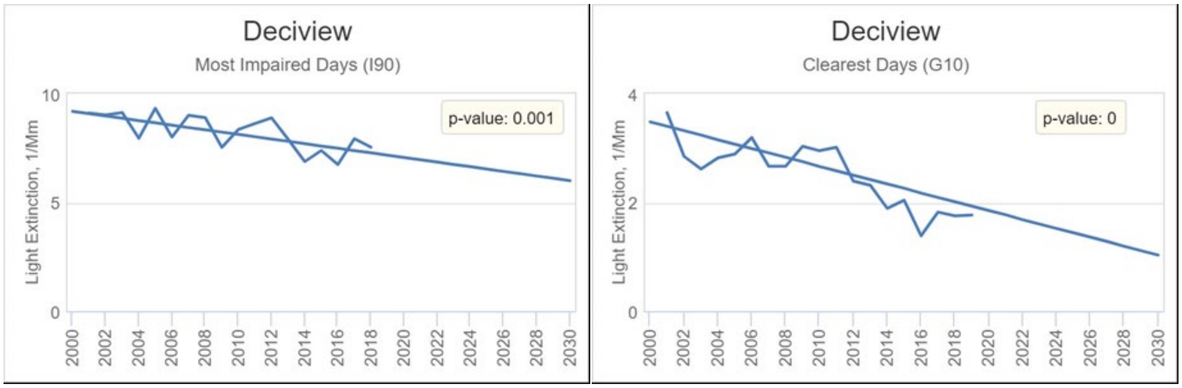


Figure 12. Mount Baldy visibility on the most impaired and clearest days 2001-2019

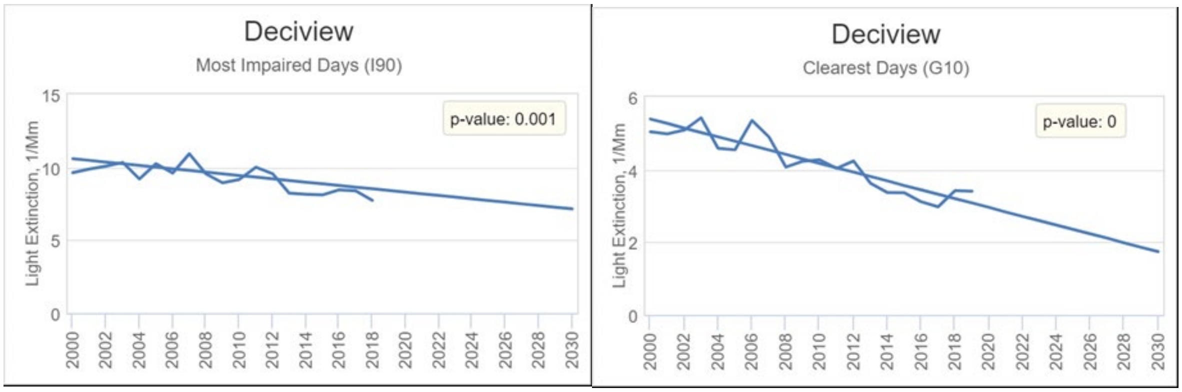


Figure 13. Petrified Forest National Park visibility on the most impaired and clearest days 1991-2019

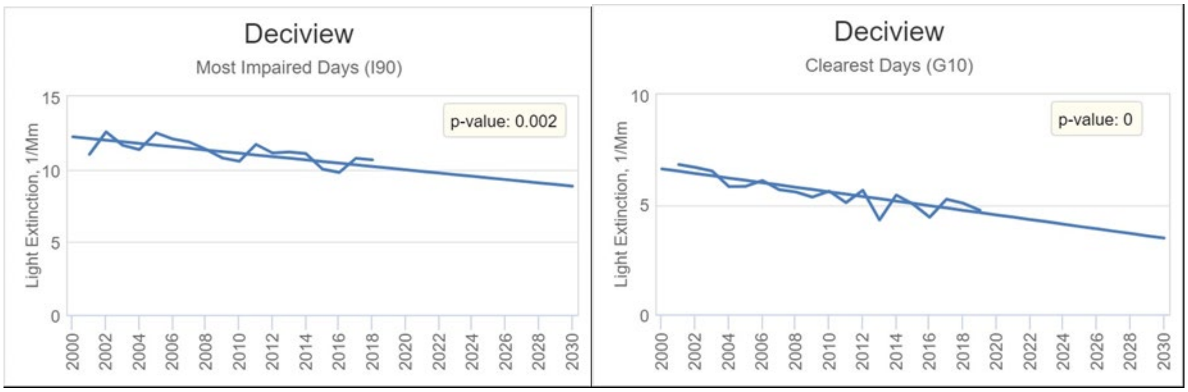


Figure 14. Tonto National Monument visibility on the most impaired and clearest days 1992-2019

Wilderness Areas Air Quality Related Values

Air pollution affects the natural quality of Forest lands, particularly wilderness areas or Air Quality Related Values (AQRV). High ozone concentrations can injure sensitive vegetation. Fossil fuel burning emits sulfur dioxide (SO2) and nitrogen oxides (NOx) into the atmosphere. Certain types of agricultural activities, such as livestock grazing and dairy production, emit ammonia (NH3) to the atmosphere. Such emissions can lead to atmospheric deposition of sulfuric acids, nitric acids, and ammonium to national forest ecosystems above critical load (CL) thresholds. Atmospheric deposition can cause lake body acidification, eutrophication, and hypoxia, soil nutrient changes, and vegetation impacts. Deposition of toxic metals such as mercury and lead can be harmful to both aquatic and terrestrial ecosystems. Visibility in most national forests is obscured some portion of the year by anthropogenic haze of fine pollutant particles.. In addition, the Clean Air Act requires Forest Service operations, visitor use, and permitted operations such as prescribed burning, fossil fuels development and production, and mining to comply with NAAQS and protection of AQRV (CASTNET 2021).

Ecological Effects of Smoke

Fire has historically played an important role in defining the character of ecosystems in Northern Arizona. The cover types in the Rim Country analysis that are targeted for restoration treatments are adapted to frequent fire, often area-wide fires (Cooper 1960; Covington et al. 1997b; Kaib 2001; Fulé et al. 2003; Huffman 2017), indicating an even more frequent smoke regime. Research in Northern Arizona has shown that the emergence of many species is enhanced by exposure to smoke from ponderosa pine needle litter (Abella 2006; Abella et al. 2007; Lata 2015).

From an ecological perspective, smoke effects are important to the germination of many native plants and, in some cases, appear to be more important than heat (Abella 2006; Abella et al. 2007; Schwilk and Zavala 2012; Lata 2015; Keeley and Pausas 2016). The composition of surface vegetative communities has shifted with fire suppression and changes to forest structure (Laughlin et al. 2011), and some of the changes may be attributable to the lack of smoke, or changes in the timing of smoke exposure (Abella 2006; Abella et al. 2007; Lata 2015). Many species with adaptations to smoke occur in the Rim Country project area, including, but not limited to, Nama dichotomum, Heliomersis longifolia, Penstemon barbatus, Penstemon virgatum, Artemisia ludoviciana, Erigeron speciosus, Linum lewisii, and Symphyotrichum falcatum. Pine needle smoke may also be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1974; Alexander and Hawksworth 1976; Zimmerman and Laven 1987).

Environmental Consequences

No-Action Alternative 1

This section discloses the environmental effects of the no-action alternative 1.

Direct and Indirect Effects of the No-Action Alternative 1

Under this alternative, smoke emissions from the proposed treatment area and effects would come from wildfires. The impacts would be infrequent perhaps a few times a year, and with unpredictable temporal and spatial scale and health effects.

Nuisance Smoke

Under Alternative 1, nuisance smoke from wildfires would continue to occur at current levels and would probably increase over time as increases to forest fuels accumulations and stand densities causes potentially greater fire behavior intensity and fire size, or extent (Figure 1). Climate change, is forecast to also cause an increase in the occurrence and severity of droughts and drier and warmer fire seasons resulting in increasing wildfire intensity and extent. Nuisance smoke complaints from prescribed burning would be managed under the State's smoke management program described under Consistency with Relevant Laws, Rules, and Policy below (Personal communication with Ronald Sherman, Arizona State Smoke Management Program, December 9, 2020).

Exceedances of NAAQS

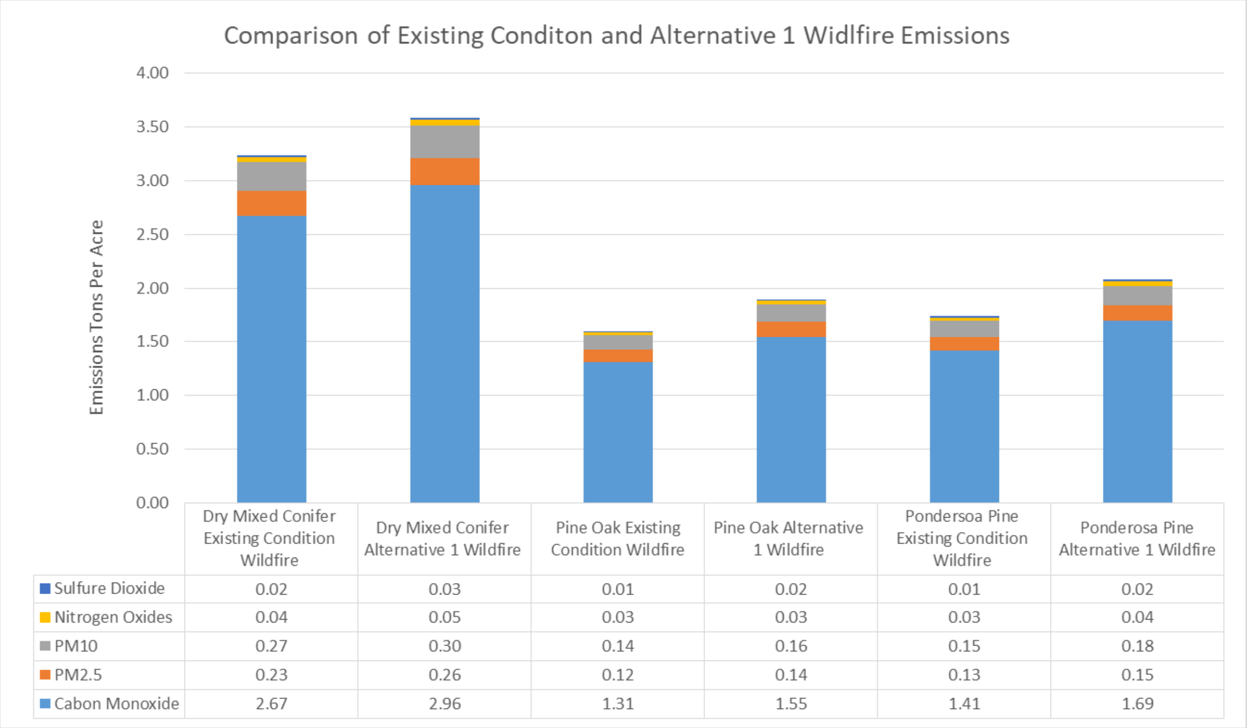
Under Alternative 1, exceedances of air quality human health standards would follow the same path as nuisance smoke.

Smoke Emissions – Criteria Air Pollutants

If the current average annual acres burned by wildfire remained the same, about 27,426 acres, it is likely that the entire proposed treatment area would burn by 2057, along with the associated air quality effects (Rim Country FEIS Fire Ecology Report). Due to increasing surface fuel loadings, and forests moving towards denser stands, the potential for increasing high fire intensity fire behavior and crown fire from wildfires burning under Alternative 1 conditions in 2029 would produce more emissions than one burning under current existing conditions (Figure 1). Wildfires would produce the most emissions from the treatment area under this alternative. On a per acre basis, potential emissions increase by 10-20%, due to the increase in surface fuel loadings and lingering smoke, stand densities, fire behavior intensity. Much of the lingering smoke comes from high amounts of duff, litter, coarse woody debris, stumps, and other fuels that can smolder more than fuels burned in a fire's flaming front or flaming zone. This in combination with the expected increase in annual acres burned would lead to an increase in overall emissions from wildfires. The timing and type of smoke effects would change little initially, but as the likelihood of large fires increase so does the potential for air pollution levels that exceed the NAAQS and causes nuisance smoke.

Alternative 1 would not increase potential smoke impacts during the times of the year when smoke impacts are largely from prescribed fire and wood heating burning (wood stoves), generally, mid to late fall, winter, and early spring.

Figure 1 shows a comparison of current condition potential wildfire emissions and potential Alternative 1 wildfire emissions in 2029. The graph and table show the average per acre emissions for dry mixed conifer, pine oak and ponderosa pine ecological response units. Dry mixed conifer has the highest fuel loading and consequently produces the greatest amounts of smoke on a per acre basis followed by pine oak and ponderosa pine that show similar, lesser amounts (Appendix D – Fuel Loadings and Emissions Calculations).



	Dry Mixed Conifer Existing Condition Wildfire	Dry Mixed Conifer Alternative 1 Wildfire	Pine Oak Existing Condition Wildfire	Pine Oak Alternative 1 Wildfire	Pondersoa Pine Existing Condition Wildfire	Ponderosa Pine Alternative 1 Wildfire
■ Sulfure Dioxide	0.02	0.03	0.01	0.02	0.01	0.02
■ Nitrogen Oxides	0.04	0.05	0.03	0.03	0.03	0.04
■ PM10	0.27	0.30	0.14	0.16	0.15	0.18
■ PM2.5	0.23	0.26	0.12	0.14	0.13	0.15
■ Cabon Monoxide	2.67	2.96	1.31	1.55	1.41	1.69

Figure 8. Existing condition (2018) wildfire smoke criteria air pollutant emissions and Alternative 1 (2029) wildfire emissions for dry mixed conifer, pine oak and ponderosa pine ecological response units (tons per acre)

Table 2 shows data from the 2017 National Emissions Inventory for annual criteria air pollutant emissions from various sources at the county, state, and national levels for comparing to Rim Country annual emissions. The data includes emissions from wildfires, prescribed fires and agricultural field burning and total emissions from all polluting sources. The information is useful for comparing the potential project emissions with other sources in and around the Rim Country area (NEI 2017).

Table 2. Data from the 2017 National Emissions Inventory showing annual air pollutant emissions from various sources at the county, state and national levels for comparing to Rim Country annual emissions

Source - Geographic Area	Carbon Monoxide (tons per year)	PM2.5 (tons per year)	PM10 (tons per year)	Nitrogen Oxides (tons per year)	Sulfur Dioxide (tons per year)	Volatile Organic Compounds (tons per year)
Apache County – All Sources	64,060.00	5,985	14,642.00	16,241.00	6,434.00	63,716.00
Coconino County – All Sources	217,728.53	16,310.23	27,990.80	16,352.10	1,193.37	135,338.30
Gila County – All Sources	51,468.82	4,450.64	10,961.87	3,428.56	24,736.79	53,066.83
Navajo County – All Sources	40,838.15	3,443.68	14,348.08	10,951.96	1,860.50	49,465.40
Yavapai County – All Sources	70,904.32	4,724.40	18,222.75	11,521.70	1,927.88	62,638.80
Arizona – All Sources	1,423,957.51	84,891.20	253,704.86	187,586.89	52,185.17	1,095,958.31
National – All Sources	70,995,207.70	5,708,145.22	17,064,238.92	11,855,303.54	2,725,449.36	43,105,760.80
Apache County – Prescribed Fires	37,870.19	3,144.05	3,709.98	357	235.80	8,890.19
Apache County – Wildfires	917.31	81.05	95.64	15.12	7.69	217.15
Apache County – Agricultural Field Burning	-	-	-	-	-	-
Coconino County – Prescribed Fires	87,038.59	7,261.73	8,568.84	867.93	556.33	20,445.83
Coconino County – Wildfires	84,468.20	7,182.56	8,475.42	1,021.05	594.57	19,891.94
Coconino County - Agricultural Field Burning	-	-	-	-	-	-
Gila County - Prescribed Fires	6,731.31	565.53	667.33	72.32	44.61	1,582.67
Gila County – Wildfires	26,798.07	2,449.48	2,890.39	549.57	257.63	6,373.85
Gila County - Agricultural Field Burning	11.80	1.50	2.04	0.28	0.05	1.19
Navajo County – Prescribed Fires	12,840.55	1,056.77	1,246.99	108.85	76.20	3,010.95
Navajo County – Wildfires	1,520.97	129.57	152.89	18.70	10.80	358.27
Navajo County - Agricultural Field Burning	-	-	-	-	-	-
Yavapai County – Prescribed Fires	2,164.79	189.51	223.62	33.34	17.43	511.80
Yavapai County – Wildfires	18,658.90	1,738.28	2,051.17	425.94	192.62	4,450.05
Yavapai County - Agricultural Field Burning	7.12	0.52	0.91	0.31	0.06	1.21
Arizona – Prescribed Fires	154,560.64	12,936.68	15,265.28	1,596.09	1,004.69	36,322.43
Arizona – Wildfires	369,187.82	32,221.86	38,021.79	5,557.86	2,933.56	87,248.11
Arizona - Agricultural Field Burning	1,772.13	201.19	282.71	57.11	18.44	214.60

Source - Geographic Area	Carbon Monoxide (tons per year)	PM2.5 (tons per year)	PM10 (tons per year)	Nitrogen Oxides (tons per year)	Sulfur Dioxide (tons per year)	Volatile Organic Compounds (tons per year)
National – Prescribed Fires	8,870,309.36	805,307.13	948,309.47	164,697.23	78,190.63	2,042,074.79
National – Wildfires	19,487,071.80	1,655,210.73	1,952,987.64	230,541.00	135,352.57	4,577,921.78
National - Agricultural Field Burning	301,034.72	30,776.12	42,932.75	12,705.85	4,236.92	38,061.10

Table 3 shows the amount of smoke emissions that would be produced if an Alternative 1 wildfire scenario were to burn the three major project area ecological response units that are proposed for restoration treatments under the action alternatives. A comparison of the emissions to Arizona's annual total wildfire emissions is shown. If a wildfire were to burn the entire 974,440-acre area the criteria air pollutant emissions would range approximately from 461-684 percent greater than the total Arizona annual wildfire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 3. Comparison of Alternative 1 wildfire scenario smoke emissions to the action alternatives major project area ecological response units that are proposed for restoration treatments and Arizona annual emissions[7]

RIM Country FEIS Alternative 1 Ecological Response Units	Burned Acres	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)
Dry Mixed Conifer	59,858	177,180	15,563	17,957	2,993	1,796
Pine Oak	149,440	231,632	20,922	23,910	4,483	2,989
Ponderosa Pine	765,142	1,293,090	114,771	137,726	30,605	15,303
Total	**974,440**	**1,701,902**	**151,256**	**179,593**	**38,081**	**20,088**
Arizona Annual Wildfire Emissions		369,188	32,222	38,022	5,558	2,934
Percent Increase of Alternative 1 Wildfire Emission Compared to Arizona Annual Wildfire Emissions		461%	469%	472%	685%	684%

Smoke Emissions – Greenhouse Gas Emissions

Under Alternative 1, the potential greenhouse gas emissions would follow the same path as smoke emissions – above. In about year 2029 potential emissions would increase to above current condition emissions due to increasing accumulations of fuels over time. Figure 2 shows the burned acre CO2e[8] emissions based on the amount of CO2 and CH4 that would be produced (Appendix D – Fuel Loadings and Emissions Calculations). (For this analysis the conservative CH4 Global Warming Potential value of 36 is used, Table 1 above.)

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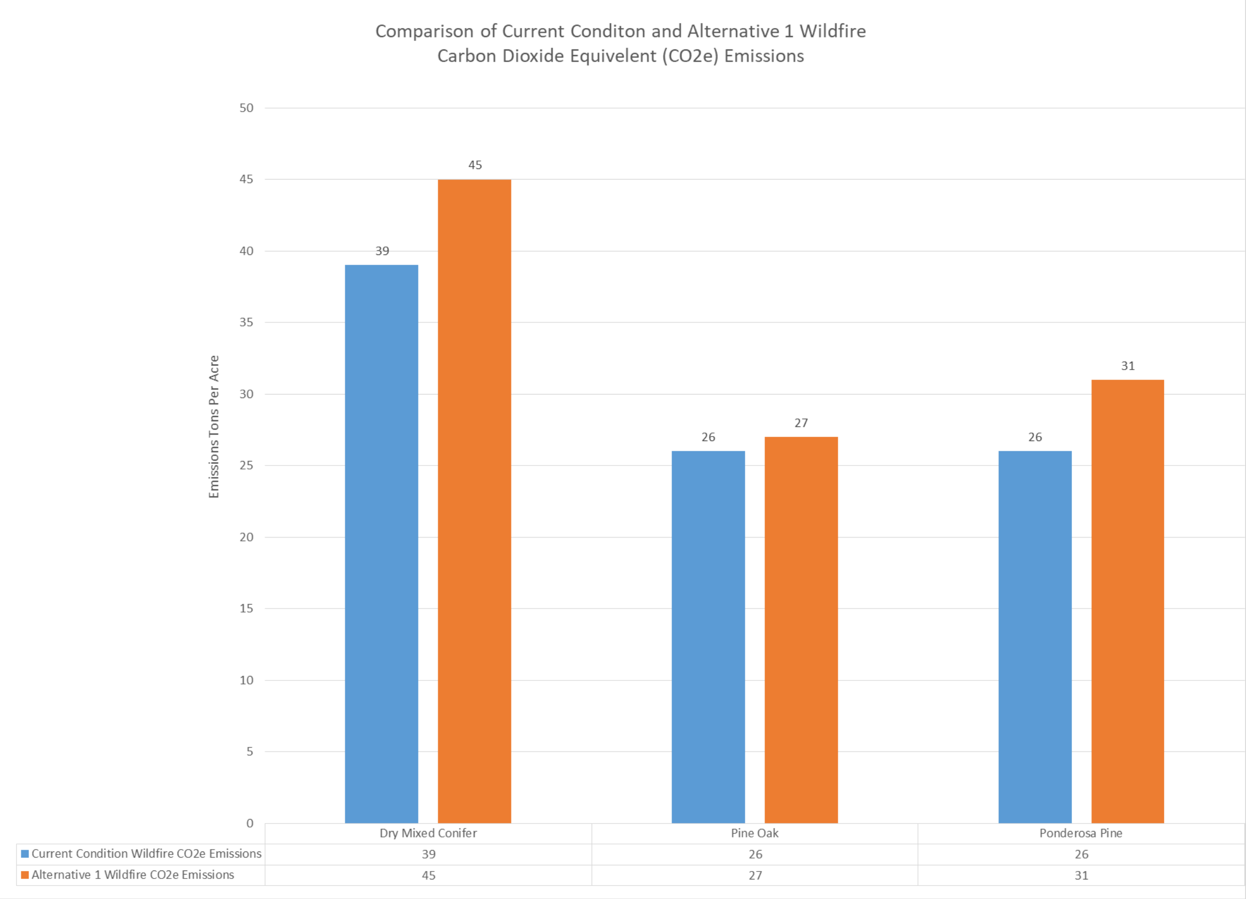
[7] The project smoke emissions modeling does not include volatile organic compounds (VOC) outputs.

[8] Carbon Dioxide equivalent emission or CO2e are based on the amount of CO2 and CH4 that would be produced. For this analysis the conservative CH4 Global Warming Potential value of 36 is used.



	Dry Mixed Conifer	Pine Oak	Ponderosa Pine
🟦 Current Condition Wildfire CO2e Emissions	39	26	26
🟧 Alternative 1 Wildfire CO2e Emissions	45	27	31

Figure 9. Comparison of current condition and Alternative 1 carbon dioxide equivalent (CO2e) emissions for dry mixed conifer, pine oak, and ponderosa pine ecological response units (tons per acre)

Table 4 shows data from the 2017 National Emissions Inventory for annual greenhouse gas emissions from various sources at the county, state, and national levels for comparing to Rim Country annual emissions. The data includes emissions from wildfires and prescribed fires and total emissions from all polluting sources. The information is useful for comparing the potential project emissions with other sources in and around the Rim Country area (NEI 2017).

Table 4. Data from the 2017 National Emissions Inventory showing greenhouse gas emissions from various sources at the county, state and national levels for comparing to Rim Country annual emissions[9]

Source - Geographic Area	Carbon Dioxide (tons per year)	Methane (tons per year)	Nitrous Oxide (tons per year)	CO2e (tons per year)
Apache County – All Sources	15,150,672	3,547	251	15,353,162
Coconino County – All Sources	3,538,513	12,007	33	3,980,562
Gila County – All Sources	970,517	1,727	14	1,036,949
Navajo County – All Sources	6,121,739	5,881	115	6,367,851

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[9] The 2017 NEI does not have data for Nitrous Oxide emissions available for prescribed and wildfire sources.

Source - Geographic Area	Carbon Dioxide (tons per year)	Methane (tons per year)	Nitrous Oxide (tons per year)	CO2e (tons per year)
Yavapai County – All Sources	4,414,659	4,253	63	4,586,517
Arizona – All Sources	85,815,904	81,357	2,381	89,454,179
National – All Sources	5,381,953,222	6,247,460	142,348	5,649,281,475
Apache County – Prescribed Fires	358,725	1,820		424,231
Apache County – Wildfires	12,287	45		13,907
Coconino County – Prescribed Fires	850,657	4,192		1,001,572
Coconino County – Wildfires	924,980	4,106		1,072,805
Gila County – Prescribed Fires	68,677	325		80,388
Gila County – Wildfires	418,981	1,351		467,604
Navajo County – Prescribed Fires	114,815	614		136,932
Navajo County – Wildfires	16,831	74		19,495
Yavapai County – Prescribed Fires	27,696	107		31,539
Yavapai County – Wildfires	315,809	950		349,996
Arizona – Prescribed Fires	1,541,085	7,456		1,809,495
Arizona – Wildfires	4,652,066	18,180		5,306,541
National – Prescribed Fires	120,709,651	437,280		136,451,741
National – Wildfires	208,941,083	945,704		242,986,414

Table 5 shows the amount of smoke greenhouse gas emissions emission that would be produced if an Alternative 1 wildfire scenario were to burn the three major project area ecological response units that are proposed for restoration treatments under the action alternatives. A comparison of the emissions to Arizona's annual total wildfire emissions is shown. If a wildfire were to burn the entire 974,440 acre area the greenhouse gas emissions would be approximately 566 percent greater than the total Arizona annual wildfire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 5. Comparison of Alternative 1 wildfire scenario smoke greenhouse gas emissions to the action alternatives major project area ecological response units that are proposed for restoration treatments and Arizona annual emissions

RIM Country FEIS Alternative 1 Ecological Response Units	Burned Acres	CO2e Carbon Dioxide Plus Methane (tons)
Dry Mixed Conifer	59,858	2,662,484
Pine Oak	149,440	4,006,486
Ponderosa Pine	765,142	23,398,042
Total	**974,440**	**30,067,012**
Arizona Annual Wildfire Emissions		5,306,541

RIM Country FEIS Alternative 1 Ecological Response Units	Burned Acres	CO2e Carbon Dioxide Plus Methane (tons)
Percent Increase of Alternative 1 Wildfire Emission Compared to Arizona Annual Wildfire Emissions		566%

Visibility or Regional Haze

Technically under Alternative 1, the potential for increasing wildfire smoke emissions over time could adversely affect visibility, however wildfires are not regulated under the Regional Haze Rule like other human-caused emissions including smoke from prescribed fires.

Air Quality and Smoke Effects Common to the Action Alternatives

This section discloses the environmental effects common to the action alternatives.

Direct and Indirect Effects Common to the Action Alternatives

Nuisance Smoke

Nuisance smoke would generally be the same under all alternatives. As the project is implemented over twenty years the potential for uncontrolled wildfire emissions would be reduced and replaced by controlled prescribed fire emissions and, overtime, may reduce the reports of nuisance smoke connected to the project.

Exceedances of NAAQS

Implementation of the project would comply with the federal Clean Air Act (CAA) and the CAA is implemented at the state level under the ADEQ rules that require the project to not cause exceedances of the National and State Ambient Air Quality Standards in populated areas. The ADEQ is the agency having jurisdiction over determining permissive burn days and authorizing implementation of prescribed burning operations. The ADEQ requires the federal land management agencies to follow and use the emissions reduction and smoke management techniques stipulated in burning authorizations. A detailed description of the ADEQ’s smoke management regulation, Article 15, and the state’s smoke management program is described under Other Relevant Law, Regulation, or Policy below. The text of Article 15 is available under the reference section (ADEQ 2004).

Equipment use over the approximately twenty-year implementation timeframe of the project would include only tens of gasoline or diesel fuel powered vehicles and specialized tree harvesting equipment on any given day, spread out over a large area. Therefore the amount of emissions the equipment would produce would be insignificantly small and generally unknowable because it is not known at this time exactly where, when and how many acres would be treated on any given day, and the number of and types of vehicles or equipment that would be used, and their hours of operation. In most circumstances vehicle and equipment emissions disperse rapidly and in the potential concentrations caused by only tens of vehicles or equipment would not cause NAAQS exceedances.

Smoke Emissions – Criteria Air Pollutants

The amounts of criteria air pollutants and greenhouse gas emissions from burning live vegetation and dead fuels varies widely depending on many variables including vegetation types and their condition, fuel loadings, fuel moistures and weather parameters. Open stands support surface fire over crown fire under most conditions, and surface fire produces fewer particulates than crown fire. Stands that have burned more recently and more frequently also produce lower emissions. Figure 4-6 shows differences in emissions from wildfire and prescribed fires that would be burned at different stages in burn only and mechanical plus burn treatment cycles.

A comparison between alternatives can be made by looking at the effects of treatments that reduce the likelihood of active crown fire and heavy surface fuel loading. Active crown fire and heavy surface fuel loading produce large quantities of emissions. The action alternatives that alter stand structure to promote surface fire overactive crown fire and decrease surface fuel loading would have the least negative environmental consequences to air quality.

Up to two prescribed fires would be implemented, which may include activity fuels pile burning in advance of broadcast burns or underburning. To maintain Land Management Plan desired conditions for the three major project ERU's, prescribed fires should occur on an average of every ten years, depending on yearly fluctuations in climate and weather at different locations within the treatment area. Some areas would have had prescribed fire or wildfire within the last ten to fifteen years, so prescribed fires that are implemented would be maintenance burns. Limitations such as wildlife concerns, cumulative smoke effects and ADEQ burn day authorizations, funding, and resource availability may make it difficult to attain an average of a ten-year fire return interval across the proposed treatment area. Burning some areas on a slightly longer return interval may be warranted to reduce smoke effects to smoke sensitive areas although delays in re-burning would cause fuels to re-accumulate and subsequent prescribed burning would produce more smoke emissions.

First Entry Burns

First entry burns are those burns which are the first-time fire occurs in an area that has missed several fire cycles or after mechanical treatments are completed. In mechanical treatment unit's activity generated fuels may increase fuel loadings and first entry burns may produce more smoke compared to burn units that are not mechanically treated. First entry burns can cause mortality to shrubs, branch wood and small trees and these woody fuels can accumulate on forest floors over several years and increase overall surface fuel loadings to above pre first entry burn fuel loading.

Second Entry Burns

Second entry burns are those burns which occur within about ten years of a first entry burn in forest stands. For second entry burns, fuel loads would generally be lower than in first entry burns, producing less smoke and with lower potential for high severity fire. However, after first entry burns fire caused mortality to shrubs, branch wood and small trees can increase woody fuels accumulations on forest floors over several years and increase overall surface fuel loadings to above pre first entry burn fuel loading. A second entry burn should occur after surface fuels have recovered sufficiently to produce fire behavior sufficient to meet burn objectives.

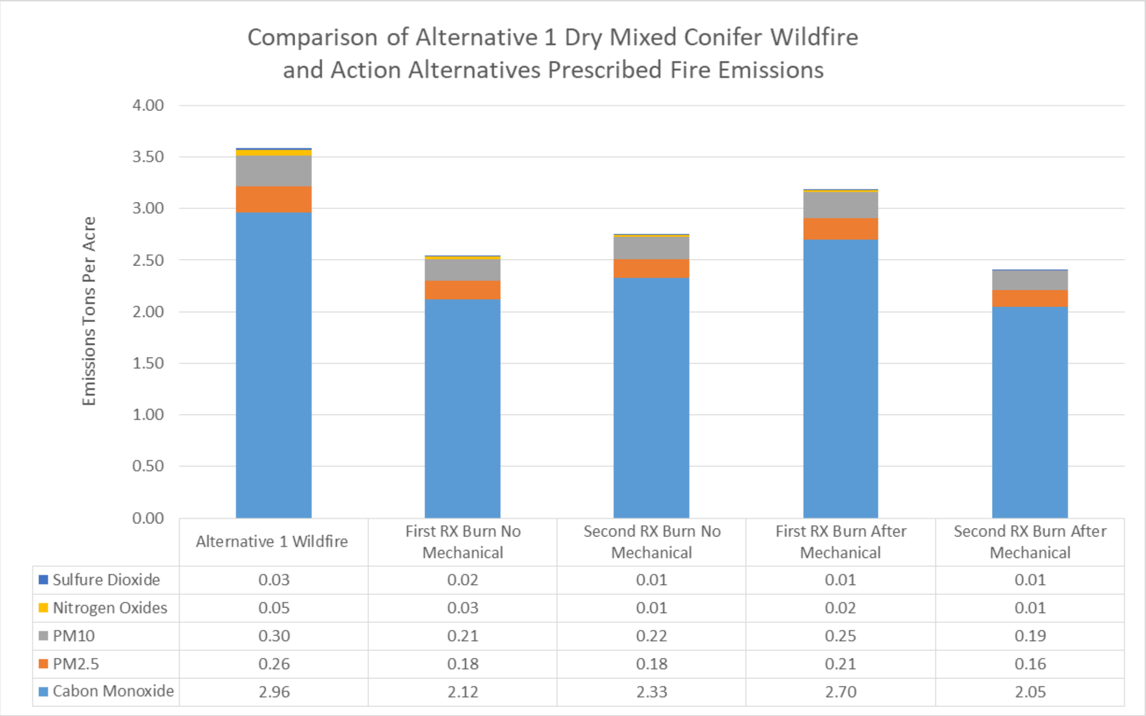
Maintenance Burns

Maintenance burns generally begin with the second or third burn in an area that is being restored. This could apply in areas within the treatment area that have burned from wildfire or prescribed fire within the last ten to fifteen years. Maintenance burns occur when ecosystem conditions are such that fire can play its historic role on the ecosystem, as a disturbance that establishes site-specific and landscape scale patterns, regulates flora and fauna, and other ecosystem functions. In ponderosa pine, these burns produce low severity effects, fewer emissions, and can be conducted with fewer resources. The timing of maintenance burns should mimic the natural seasonality of fire as closely as possible. For those areas which have had two or more fires (wildfire or prescribed fire) in the last twenty years, prescribed fires would be true maintenance burns, with minimal emissions (Robinson 2004), and only maintenance needed from the fire.

For many acres of the treatment area, prescribed fires would be maintenance burning and, from an ecological perspective, should occur in the summer months if possible (Fulé et al. 2007).

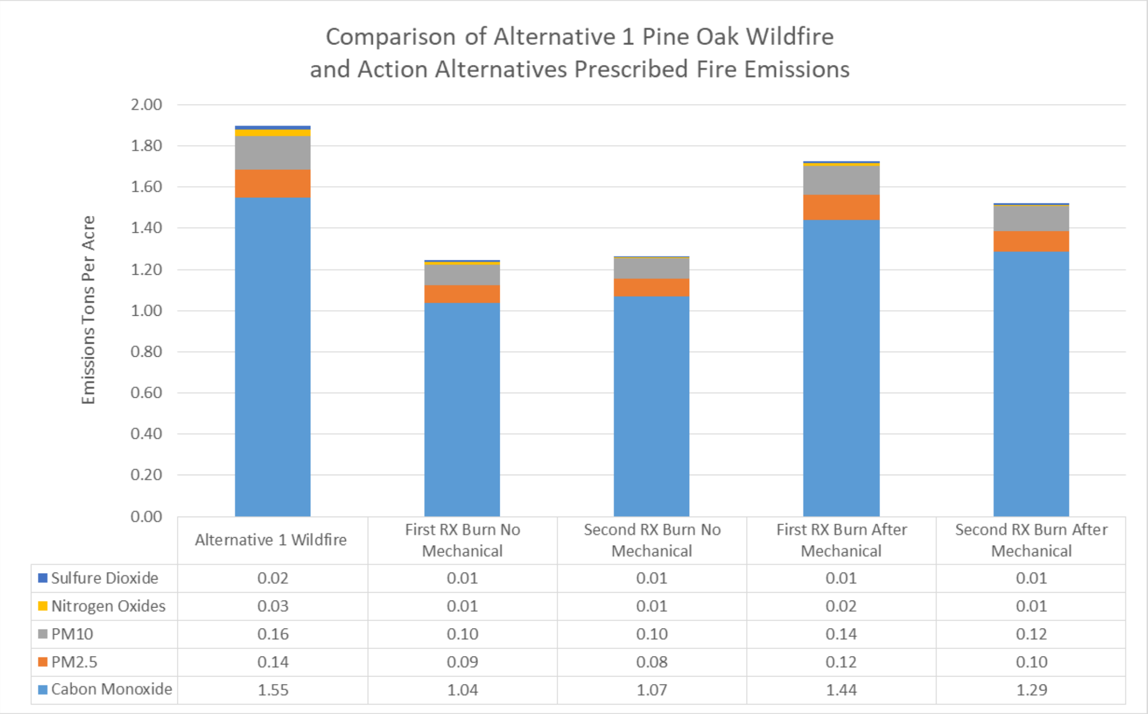
Figures 3-5 shows the estimated criteria air pollutant emissions for Alternative 1 and compares the emissions to the estimated action alternatives emissions for dry mixed conifer, pine oak and ponderosa pine ecological response units. For the action alternatives, four prescribed burning emissions scenarios are shown:

1. First entry prescribed burn without mechanical treatments.
2. Second entry prescribed burn without mechanical treatments.
3. First entry prescribed burn after mechanical treatments are completed.
4. Second entry prescribed burn after mechanical treatments are completed.



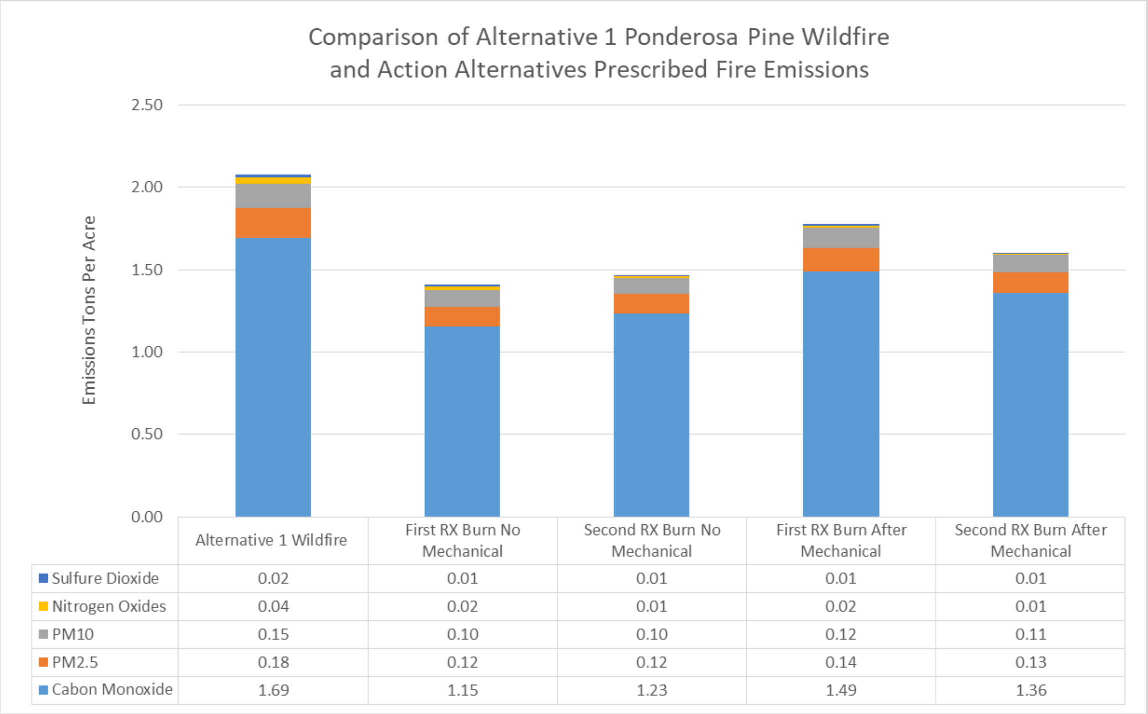
	Alternative 1 Wildfire	First RX Burn No Mechanical	Second RX Burn No Mechanical	First RX Burn After Mechanical	Second RX Burn After Mechanical
■ Sulfure Dioxide	0.03	0.02	0.01	0.01	0.01
■ Nitrogen Oxides	0.05	0.03	0.01	0.02	0.01
■ PM10	0.30	0.21	0.22	0.25	0.19
■ PM2.5	0.26	0.18	0.18	0.21	0.16
■ Cabon Monoxide	2.96	2.12	2.33	2.70	2.05

Figure 10. Comparison of Alternative 1 estimated criteria air pollutant emissions to the action alternatives estimated emissions for dry mixed conifer (tons per acre)



	Alternative 1 Wildfire	First RX Burn No Mechanical	Second RX Burn No Mechanical	First RX Burn After Mechanical	Second RX Burn After Mechanical
Sulfure Dioxide	0.02	0.01	0.01	0.01	0.01
Nitrogen Oxides	0.03	0.01	0.01	0.02	0.01
PM10	0.16	0.10	0.10	0.14	0.12
PM2.5	0.14	0.09	0.08	0.12	0.10
Cabon Monoxide	1.55	1.04	1.07	1.44	1.29

Figure 11. Comparison of Alternative 1 estimated criteria air pollutant emissions to the action alternatives estimated emissions for pine oak (tons per acre)



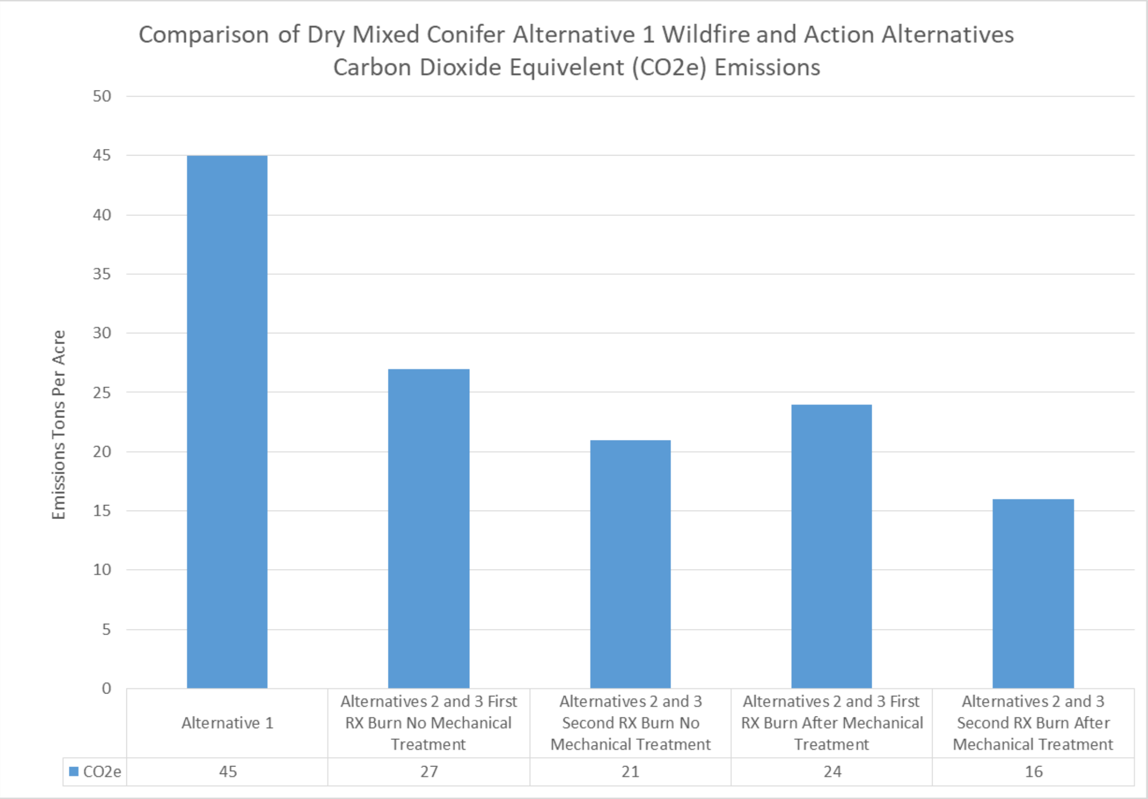
	Alternative 1 Wildfire	First RX Burn No Mechanical	Second RX Burn No Mechanical	First RX Burn After Mechanical	Second RX Burn After Mechanical
Sulfure Dioxide	0.02	0.01	0.01	0.01	0.01
Nitrogen Oxides	0.04	0.02	0.01	0.02	0.01
PM10	0.15	0.10	0.10	0.12	0.11
PM2.5	0.18	0.12	0.12	0.14	0.13
Cabon Monoxide	1.69	1.15	1.23	1.49	1.36

Figure 12. Comparison of Alternative 1 estimated criteria air pollutant emissions to the action alternatives estimated emissions for ponderosa pine (tons per acre)

Smoke Emissions – Greenhouse Gas Emissions

Figures 6-8 shows the estimated greenhouse gas emissions for Alternative 1 and compares the emissions to the estimated action alternatives emissions for dry mixed conifer, pine oak and ponderosa pine ecological response units. For the action alternatives, four prescribed burning emissions scenarios are shown:

1. First entry prescribed burn without mechanical treatments.
2. Second entry prescribed burn without mechanical treatments.
3. First entry prescribed burn after mechanical treatments are completed.
4. Second entry prescribed burn after mechanical treatments are completed.



	Alternative 1	Alternatives 2 and 3 First RX Burn No Mechanical Treatment	Alternatives 2 and 3 Second RX Burn No Mechanical Treatment	Alternatives 2 and 3 First RX Burn After Mechanical Treatment	Alternatives 2 and 3 Second RX Burn After Mechanical Treatment
■ CO2e	45	27	21	24	16

Figure 13. Comparison of Alternative 1 dry mixed conifer estimated greenhouse gas emissions to the action alternatives estimated emissions for mixed conifer (tons per acre)

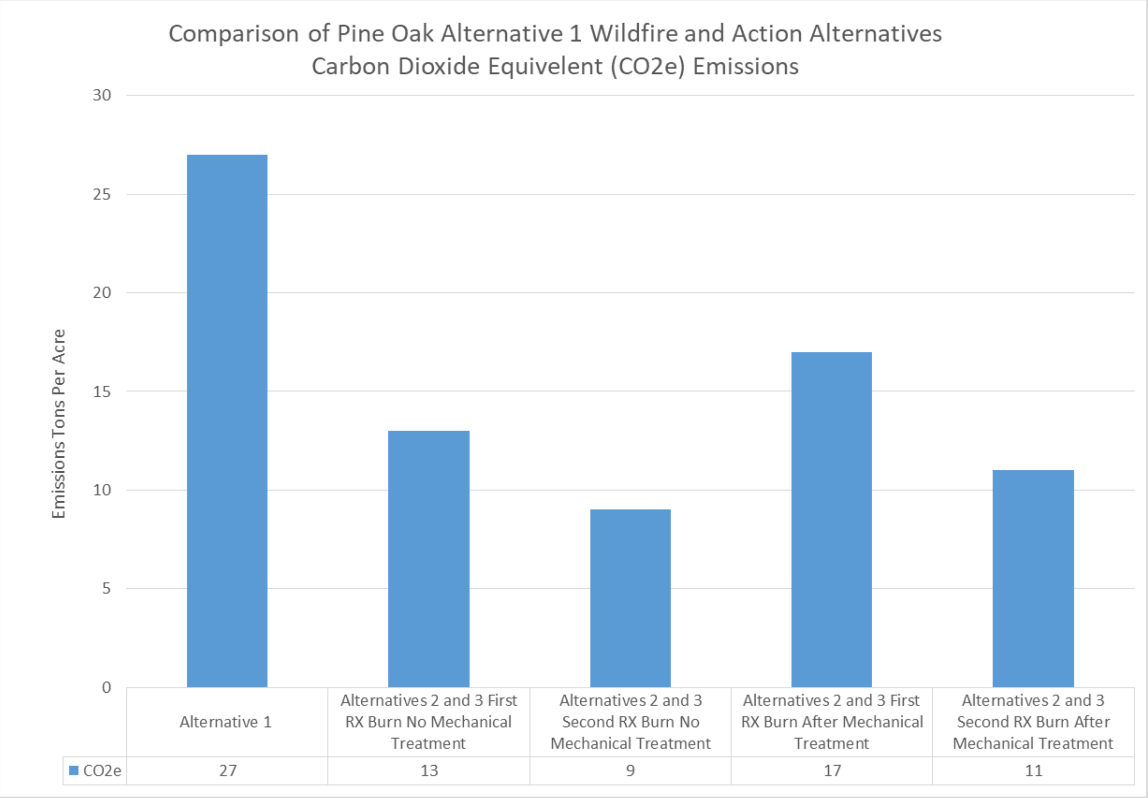


Figure 14. Comparison of Alternative 1 pine oak estimated greenhouse gas emissions to the action alternatives estimated emissions for pine oak (tons per acre)

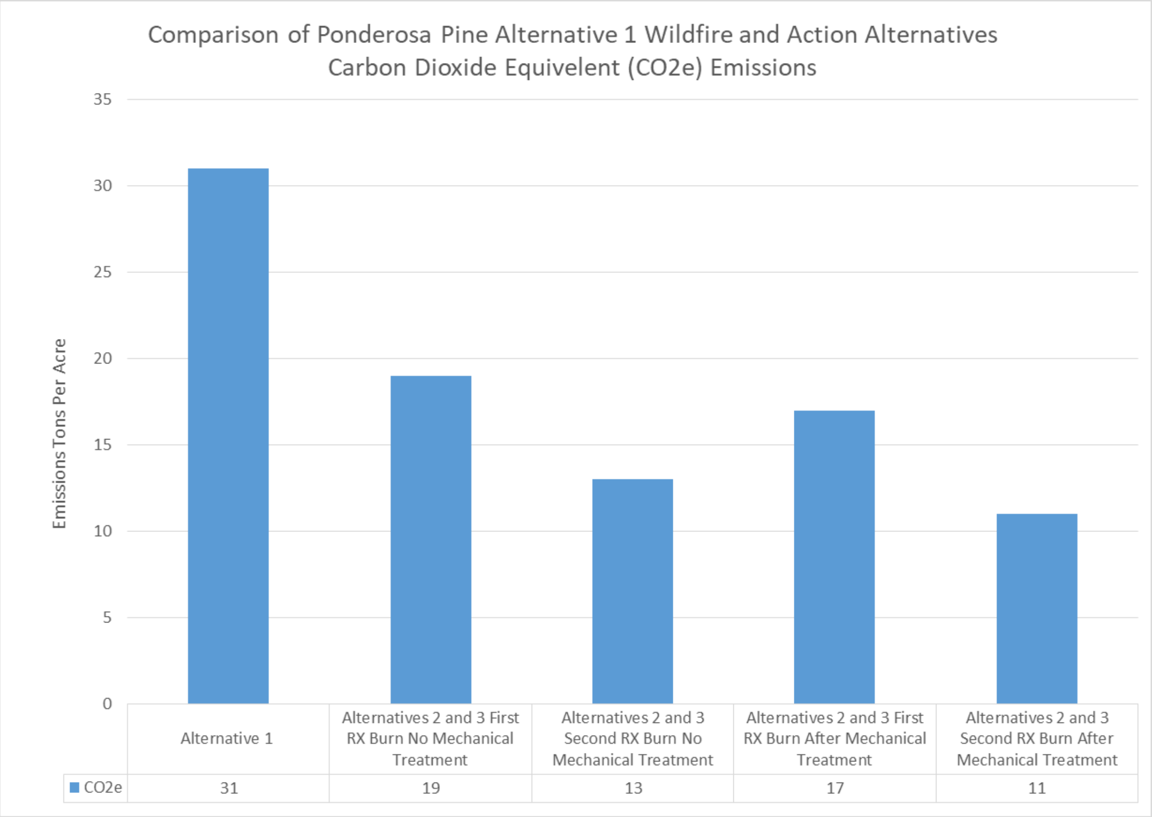


Figure 15. Comparison of Alternative 1 ponderosa pine estimated greenhouse gas emissions to the action alternatives estimated emissions for ponderosa pine (tons per acre)

Visibility or Regional Haze

Under the action alternatives prescribed fire smoke emissions would be controlled by the ADEQ and over time prescribed fire smoke does have at least some potential to impact the SIP.,

Proposed Action Alternative 2

This section discloses the environmental effects of alternative 2.

Direct and Indirect Effects of the Proposed Action, Alternative 2

Smoke Emissions – Criteria Air Pollutants and Greenhouse Gases

Alternative 2 would meet the project's purpose and need and Land Management Plan desired conditions for air quality. The number of days or duration of smoke exposure, as well as the intensity or concentration of the exposure are of concern to the public. While there could be the variability from year to year, under this alternative, prescribed fire would need to be implemented on up to 99,106 acres annually to produce an average fire return interval of 10 years across 991,060 acres proposed for prescribed fire treatment. Potential air quality effects during implementation of Alternative 2, and the necessary maintenance burning after the initial implementation has been completed would be noticeable, although National Ambient Air Quality Standards would not be exceeded.

Table 6-11 show the approximate amounts of criteria air pollutants and greenhouse gas emissions that would occur annually over the twenty spans of the project for four scenarios. The actual amounts of acreages that would be burned each year is currently unknown and the purpose of the information is for the comparison between the alternatives showing several scenarios. Table 6-7 show the approximate amounts of criteria air pollutants and greenhouse gas emissions the project would produce if only first entry burns were completed without mechanical treatment and with mechanical treatments over twenty years.

Table 6 and 7 shows the amount of smoke emissions that would be produced annually under Alternative 2 for two scenarios:

- Table 6 – first entry prescribed burning emissions without mechanical treatments over twenty years
- Table 7 – first entry prescribed burning emissions after mechanical treatments are completed over twenty years

The ERU acreages reflect the percentages that the three ERU's occur in the entire project area (991,060 acres) divided by twenty years. A comparison of the emissions to Arizona's annual total prescribed fire emissions is shown.

If first entry without mechanical treatments prescribed burning burns the acreages shown in Table 6 the criteria air pollutant emissions would range from approximately 37-58% and greenhouse emissions would be approximately 49% of the total Arizona annual prescribed fire emissions.

If first entry with mechanical treatments prescribed burning burns the acreages shown in Table 7, 47-58% of criteria pollutants and 46% of greenhouse gases would be produced compared to the Arizona annual prescribed fire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 6. Alternative 2 annual prescribed burning smoke emissions, first entry no mechanical treatment scenario over twenty years, compared to Arizona annual emissions

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	2,973 / 6%	6,303	535	624	89	59	80,093
First Entry Pine Oak	7,433 / 15%	7,730	669	743	74	74	94,696
First Entry Ponderosa Pine	38,156 / 77%	43,879	3,816	4,579	763	382	715,807
Total	**48,562**	**57,912**	**5,020**	**5,946**	**926**	**515**	**890,596**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 2 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		37%	39%	39%	58%	51%	49%

Table 7. Alternative 2 annual prescribed burning smoke emissions, first entry after mechanical treatment scenario over twenty years, compared to Arizona annual emissions

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	2,973 / 6%	8,027	624	743	30	30	70,936
First Entry Pine Oak	7,433 / 15%	10,704	892	1,041	149	149	128,888
First Entry Ponderosa Pine	38,156 / 77%	56,852	4,579	5,342	763	382	639,495
Total	**48,562**	**75,583**	**6,095**	**7,126**	**942**	**561**	**839,319**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 2 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		49%	47%	47%	58%	56%	46%

Table 8-11 show the amounts of criteria air pollutants and greenhouse gas emissions that would be produced annually over the twenty-year span of the project. The scenarios assume that the first entry burns would occur during the first decade and second entry burns would occur during the second decade and completed without mechanical treatment and with mechanical treatments over twenty years.

Table 8 and 9 shows the amount of smoke emissions that would be produced annually under Alternative 2 for two scenarios:

- Table 8 – first decade first entry annual prescribed burning emissions without mechanical treatments completed over ten years

- Table 9 – second decade second entry annual prescribed burning emissions without mechanical treatments completed over ten years

The ERU acreages reflect the percentages that the three ERU's occur in the entire project area (953,130 acres) divided by ten years. A comparison of the emissions to Arizona's annual total prescribed fire emissions is shown.

If first entry prescribed burning burns the acreages shown in Table 8, the criteria air pollutant emissions would range from approximately 75-116% and greenhouse gas emissions would be approximately 98% of the total Arizona annual prescribed fire emissions.

If second entry prescribed burning burns the averages shown in Table 9, the criteria pollutants emissions would range from 61-97% and greenhouse gases emissions would be about 68% of the total Arizona annual prescribed fire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 8. Alternative 2 first decade, first entry, no mechanical treatment scenario annual prescribed burning smoke emissions, completed within ten years, compared to Arizona annual emissions

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	5,946 / 6%	12,606	1,070	1,249	178	119	160,185
First Entry Pine Oak	14,866 / 15%	15,461	1,338	1,487	149	149	189,393
First Entry Ponderosa Pine	76,311 / 77%	87,758	7,631	9,157	1,526	763	1,431,594
Total	**97,123**	**115,825**	**10,039**	**11,893**	**1,853**	**1031**	**1,781,172**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 2 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		75%	78%	78%	116%	103%	98%

Table 9. Alternative 2 second decade, second entry, no mechanical treatment scenario annual prescribed burning smoke emissions, completed within ten years, compared to Arizona annual emissions

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
Second Entry Dry Mixed Conifer	5,946 / 6%	13,854	1,070	1,308	59	59	126,471
Second Entry Pine Oak	14,866 / 15%	15,906	1,189	1,487	149	149	139,294
Second Entry Ponderosa Pine	76,311 / 77%	93,863	7,631	9,157	763	763	956,940
Total	**97,123**	**123,623**	**9,890**	**11,952**	**971**	**971**	**1,222,705**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
Percent of Alternative 2 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		80%	765%	78%	61%	97%	68%

Table 10 and 11 shows the amount of smoke emissions that would be produced annually under Alternative 2 for two scenarios:

- Table 10 – first decade first entry annual prescribed burning emissions after mechanical treatments are completed over ten years
- Table 11 – second decade second entry annual prescribed burning emissions after mechanical treatments are completed over ten years

If first entry prescribed burning burns the acreages shown in Table 10, the criteria air pollutant emissions would range from approximately 93-118% and greenhouse gas emissions would be approximately 94% of the total Arizona annual prescribed fire emissions.

If second entry prescribed burning burns the acreages shown in Table 11, the criteria pollutant emissions would range from approximately 61-97% and greenhouse gas emissions would be approximately 61% of the total Arizona annual prescribed fire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 10. Alternative 2 first decade, first entry, after mechanical treatment scenario annual prescribed burning smoke emissions, completed within ten year, compared to Arizona annual emissions

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	5,946 / 6%	16,054	1,249	1,487	59	59	141,872
First Entry Pine Oak	14,866 / 15%	21,407	1,784	2,081	297	297	275,776
First Entry Ponderosa Pine	76,311 / 77%	113,703	9,157	10,684	1,526	763	1,278,972
Total	**97,123**	**151,164**	**12,190**	**14,252**	**1,882**	**1119**	**1,696,620**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 2 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		98%	94%	93%	118%	111%	94%

Table 11. Alternative 2 second decade, second entry, after mechanical treatment scenario annual prescribed burning smoke emissions, completed within ten year, compared to Arizona annual emissions

RIM Country FEIS Alternative 2 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
Second Entry Dry Mixed Conifer	5,946 / 6%	12,189	951	1,130	59	59	94,363
Second Entry Pine Oak	14,866 / 15%	19,177	1,487	1,784	149	149	169,770
Second Entry Ponderosa Pine	76,311 / 77%	103,783	8,394	9,920	763	763	836,369
Total	**97,123**	**135,149**	**10,832**	**12,834**	**971**	**971**	**1,100,502**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 2 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		87%	84%	84%	61%	97%	61%

Cumulative Effects of the Proposed Action Alternative 2

Smoke Emissions – Criteria Air Pollutants and Greenhouse Gases

The cumulative effects under Alternative 2 include the greatest number of acres being treated with prescribed fire across the project area. This alternative combined with current and reasonably foreseeable activities in and around the project area would result in an annual average of more than 140,000 acres of prescribed fire though annual amounts may vary considerably. The overall effects from this amount of prescribed fire is expected to be more than those associated with alternatives 1 and 3. All prescribed fires would be implemented in compliance with ADEQ rules that regulate criteria air pollutants as well as Land Management Plan direction to meet legal standards and provide for public safety.

Areas with potential for air pollution and visual effects include the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Petrified Forest National Park, Sierra Anches Wilderness Area and Mazatzal Wilderness Area. As more acres are treated, there would be broader burn windows, potentially resulting in more days of prescribed fire and days of air pollution and visual quality effects when added to prescribed burning occurring in the cumulative effects boundary.

Alternative 3

This section discloses the environmental effects of alternative 3.

Direct and Indirect Effects of Alternative 3

Smoke Emissions – Criteria Air Pollutants and Greenhouse Gases

This alternative would meet the purpose and need, and desired conditions for air quality. Effects to air quality from smoke emissions would be a mix of Alternative 1 and Alternative 2. 528,850 acres would be treated over twenty years resulting in lower emissions from a post-treatment wildfire. The remaining untreated project area acres would increase in potential wildfire emissions due to increases in surface fuel loadings, drought mortality and crown fire potential.

The number of days and duration of smoke effects, as well as the intensity and concentration of the effects are of concern to the public. While there would be variability from year to year, under Alternative 3, prescribed fire would need to be implemented on up to 52,885 acres annually to produce an average fire return interval of 10 years across 528,850 acres proposed for prescribed fire. Implementing prescribed fire as proposed in Alternative 3 would result in lower emissions than if the area burned in a wildfire because there would be less biomass to burn.

Table 12-15 show the amounts of criteria air pollutants and greenhouse gas emissions that would be produced annually over the twenty spans of the project.

Table 12 and 13 shows the amount of smoke emissions that would be produced annually under Alternative 3 for two scenarios.

Table 12 – first entry prescribed burning emissions without mechanical treatments over twenty years

Table 13 – first entry prescribed burning emissions after mechanical treatments are completed over twenty years

The scenarios assume the first entry burns would be completed over twenty years. The ERU acreages reflect the percentages that the three ERU's occur in the entire project area (528,850 acres) divided by twenty years. A comparison of the emissions to Arizona's annual total prescribed fire emissions is shown.

If first entry without mechanical treatments prescribed burning burns the acreages shown in Table 12, the criteria air pollutant emissions would range approximately from 20-31% and greenhouse emissions would be approximately 26% of the total Arizona annual prescribed fire emissions.

If first entry with mechanical treatments prescribed burning burns the acreages shown in Table 13, the criteria air pollutant emissions would range approximately from 25-31% and greenhouse gases would be approximately would be approximately 25% of the Arizona annual prescribed fire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 12. Alternative 3 first entry no mechanical treatment scenario annual prescribed burning smoke emissions over twenty years, compared to Arizona annual emissions

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	1,587 / 6%	3,364	286	333	48	32	42,754
First Entry Pine Oak	3,967 / 15%	4,126	397	397	40	40	50,540
First Entry Ponderosa Pine	20,361 / 77%	23,415	2,443	2,508	407	204	381,972
Total	**25,915**	**30,905**	**3,126**	**3,238**	**495**	**276**	**475,266**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 3 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		20%	24%	21%	31%	27%	26%

Table 13. Alternative 3 first entry after mechanical treatment completed scenario annual prescribed burning smoke emissions over twenty years, compared to Arizona annual emissions

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	1,587 / 6%	4,285	333	397	16	16	37,866
First Entry Pine Oak	3,967 / 15%	5,712	476	555	79	79	68,788
First Entry Ponderosa Pine	20,361 / 77%	30,338	2,443	2,851	407	204	341,250
Total	**25,915**	**40,335**	**3,252**	**3,803**	**502**	**299**	**447,904**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 3 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		26%	25%	25%	31%	30%	25%

Table 14 and 17 shows the amount of smoke emissions that would be produced annually under Alternative 3 for four scenarios.

Table 14 – first decade first entry annual prescribed burning emissions without mechanical treatments completed over ten years

Table 15 – second decade second entry annual prescribed burning emissions without mechanical treatments completed over ten years

The ERU acreages reflect the percentages that the three ERU’s occur in the entire project area (528,885 acres) divided by ten years. A comparison of the emissions to Arizona’s annual total prescribed fire emissions is shown.

If first entry prescribed burning burns the acreages shown in Table 14, the criteria air pollutant emissions would range approximately from 41-62% and greenhouse gas emissions would be approximately 53% of the total Arizona annual prescribed fire emissions.

If second entry prescribed burning burns the acreages shown in Table 15, the criteria air pollutant emissions would range approximately from shows 32-52% and greenhouse gases emissions would be approximately 36% of the Arizona annual prescribed fire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 14. Alternative 3 first decade, first entry, no mechanical treatment scenario annual prescribed burning smoke emissions, completed within ten years, compared to Arizona annual emissions

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	3,173 / 6%	6,727	571	666	95	63	85,481
First Entry Pine Oak	7,933 / 15%	8,250	714	793	79	79	101,066

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Ponderosa Pine	40,721 / 77%	48,829	4,072	4,887	814	407	763,926
Total	**51,827**	**63,806**	**5,357**	**6,346**	**988**	**549**	**950,473**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 3 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		41%	41%	42%	62%	55%	53%

Table 15. Alternative 3 second decade, second entry, no mechanical treatments scenario annual prescribed burning smoke emissions, completed within ten years, compared to Arizona annual emissions

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
Second Entry Dry Mixed Conifer	3,173 / 6%	7,393	571	698	32	32	67,490
Second Entry Pine Oak	7,933 / 15%	8,488	635	794	79	79	74,332
Second Entry Ponderosa Pine	40,721 / 77%	50,087	4,072	4,887	407	407	510,641
Total	**51,827**	**65,968**	**5,278**	**6,379**	**518**	**518**	**652,463**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 3 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		43%	41%	42%	32%	52%	36%

Table 16 and 17 shows the amount of smoke emissions that would be produced annually under Alternative 3 for two scenarios:

- Table 16 – first decade first entry annual prescribed burning emissions after mechanical treatments are completed over ten years
- Table 17 – second decade second entry annual prescribed burning emissions after mechanical treatments are completed over ten years

If first entry prescribed burning burns the acreages shown in Table 16, the criteria air pollutant emissions would range from approximately 50-64% and greenhouse gas emissions would be approximately 50% of the total Arizona annual prescribed fire emissions.

If second entry prescribed burning burns the acreages shown in Table 17, the criteria air pollutant emissions would range from approximately 32-52% and greenhouse gas emissions would be approximately 33% of the Arizona annual prescribed fire emissions (Appendix C – Air Emissions Calculator and Appendix D – Fuel Loadings and Emissions Calculations).

Table 16. Alternative 3 first decade, first entry, after mechanical treatment scenario annual prescribed burning smoke emissions, completed within ten year, compared to Arizona annual emissions

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
First Entry Dry Mixed Conifer	3,173 / 6%	8,567	666	793	32	32	75,708
First Entry Pine Oak	7,933 / 15%	11,424	952	1,111	159	159	137,558
First Entry Ponderosa Pine	40,721 / 77%	62,274	4,887	5,701	814	407	682,484
Total	**51,827**	**82,265**	**6,505**	**7,605**	**1005**	**598**	**895,750**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 3 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		53%	50%	50%	63%	60%	50%

Table 17. Alternative 3 second decade, after mechanical treatment scenario annual prescribed burning smoke emissions completed within ten years, compared to Arizona annual emissions

RIM Country FEIS Alternative 3 Ecological Response Units	Annual Burned Acres / Percent Project Area	Carbon Monoxide (tons)	PM2.5 (tons)	PM10 (tons)	Nitrogen Oxides (tons)	Sulfur Dioxide (tons)	CO2e Carbon Dioxide Plus Methane (tons)
Second Entry Dry Mixed Conifer	3,173 / 6%	6,505	508	603	32	32	50,356
Second Entry Pine Oak	7,933 / 15%	10,234	794	952	79	79	90,595
Second Entry Ponderosa Pine	40,721 / 77%	55,381	4,479	5,294	407	407	446,302
Total	**51,827**	**72,120**	**5,781**	**6,849**	**518**	**518**	**587,253**
Arizona Annual Prescribed Fire Emissions		154,561	12,937	15,265	1,596	1,005	1,809,495
Percent of Alternative 3 Prescribed Burning Emissions Compared to Arizona Annual Prescribed Fire Emissions		47%	45%	45%	32%	52%	33%

Cumulative Effects of Alternative 3

Smoke Emissions – Criteria Air Pollutants and Greenhouse Gases

Cumulatively, Alternative 3 combined with current and reasonably foreseeable activities would result in an annual average of more than 97,000 acres of prescribed fire though annual amounts may vary considerably. The overall effects from this amount of prescribed fire is expected to be nearly a third less than those associated with alternative 2, but more than alternative 1. The potential for higher overall emissions associated with wildfires burning in areas not identified for treatment under Alternative 3 would result in more emissions in these areas than alternative 2. All prescribed fires would be implemented in compliance with ADEQ rules that regulate criteria air pollutants as well as Land Management Plan direction to meet legal standards and provide for public safety.

Areas with potential for air pollution and visual effects include the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Petrified Forest National Park, Sierra Anches Wilderness Area and Mazatzal Wilderness Area. As more acres are treated, there would be broader burn windows, potentially resulting in more days of prescribed fire and days of air pollution and visual quality effects when added to prescribed burning occurring in the cumulative effects boundary.

Consistency with Relevant Laws, Rules, and Policy

Land and Resource Management Plan

Apache-Sitgreaves National Forest

Air Quality

Temporary decreases in air quality from management activities on the Apache-Sitgreaves NFs are primarily from prescribed fire. Wildfires also produce emissions and are subject to conformance with State rules (see appendix D). The NAAQS pollutant of concern from wildland fire is fine particulate matter, both PM10 and PM2.5. Studies indicate that 90 percent of smoke particles emitted from wildland fires are PM10, and about 90 percent of PM10 is PM2.5. Because of its small size, PM2.5 has an especially long residence time in the atmosphere and penetrates deeply into the lungs.

Desired Conditions

Landscape Scale Desired Conditions (10,000 acres or greater)

•Air quality related values, including high quality visual conditions, are maintained within the Class I airshed over Mount Baldy Wilderness.

• Class II airsheds meet State of Arizona air quality standards including those for visibility and public health.

Guidelines

• During extended periods of burning, smoke should be monitored, in cooperation with the Arizona Department of Environmental Quality, for levels that may have impacts to human health from fine particulates

Management Approaches

• The Apache-Sitgreaves NFs participate with the State of Arizona in the air quality regulatory process. Specialists review air permit applications for new and modified industrial facilities to ensure that their air emissions do not adversely impact the air quality related values (e.g., visibility) of federally protected Class I wilderness areas. Forest managers consider impacts to Chapter 2. Forest wide Direction 20 Apache-Sitgreaves National Forests Land Management Plan Class I and II areas and follow State of Arizona permit and regulatory requirements for smoke production to help determine the management response for wildfires. Site-specific mitigation for fugitive dust is incorporated into ground-disturbing projects through implementation of best management practices (BMPs) and retention and replacement of ground cover.

Coconino National Forest

Air Quality

Desired Conditions and Guidelines

Air quality would meet State and Federal air quality standards, including Class I airsheds, and fire management documents would identify smoke sensitive areas and Class I airsheds, and use best management practices (BMPs), design features, and mitigations to address concerns and issues. Night skies are clear and dark, providing for stargazing and professional astronomy.

Management Approaches

To promote public awareness and protection of human health and safety, notify stakeholders and the public in advance of potential air quality impacts through advanced notification using media as well as smoke warning signs along roads when visibility may be impacted. Coordinate with ADEQ during prescribed burns to comply with State and Federal regulatory requirements for impacts to Class I areas, and to ensure ADEQ is aware of potential smoke impacts to receptors.

Tonto National Forest (1985 Land Management Plan)

Air Quality

Page 50 (page 70 in the pdf) the bottom two paragraphs and number list and page 51 the second paragraph.

Decision Units	Activities	Applicable Management Areas	Standards and Guidelines
DU 56	P16	All	Management activities will be planned so that air quality will [be] equal to or better than that required by applicable federal, State, and local standards or rules. Forest activities, primarily prescribed burning, will be conducted within Arizona State Air Quality standards which require less air pollution than the following baseline quantities:[10] 1. 24-hour secondary (non-health) standard – 150 micrograms per cubic meter. 2. 24-hour primary (health) standard – 260 micrograms per cubic meter. 3. Annual/standard – 75 micrograms per cubic meter.

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[10] Since the release of the Tonto National LMP in 1985 these health standards have been superseded by more stringent standards issued by the EPA and the ADEQ.

1A, 1B, 2A, 3A, 3B, 3C, 4A, 5A, 6A, 6B	Perform in-depth review of Prevention of Significant Deterioration (PSD) permit applications, to determine the potential effect that increased emissions from the involved major stationary source(s) would have on Air Quality Related Values (AQRV's) on the Superstition, Mazatzal, and/or Sierra Ancha Class 1 areas.

Rim Country FEIS

Implementation of the Rim Country FEIS will comply with all applicable Land Management Plan air quality desired conditions, management direction, standards and guides.

Other Relevant Law, Regulation, or Policy

Federal Law – Air Quality

Federal Clean Air Act (CAA) of 1955 as amended in 1967, 1970, 1977, and 1990; Clean Air Act. 42 USC §§ 7409, 7410, and 7502-7514

The act is a legal mandate designed to protect public health and welfare from air pollution. Although this policy creates the foundation for air quality regulation, states and counties are often responsible for implementation of the air quality standards. The Clean Air Act establishes human health and welfare standards for air quality and affords Class I wilderness areas protection from air pollution. EPA and Federal Land Managers (FLM) work closely with state air regulators to protect air quality for the benefit of human health and the natural environment. The task of identifying NAAQS is assigned by the Clean Air Act to the EPA. The EPA evaluates and updates these standards every 5 years. The Act and requires geographic areas within a state to be designated as attainment, nonattainment, or unclassifiable based on NAAQS monitoring data. It also requires States to prepare State Implementation Plans (SIP's) for assuring that the NAAQS are met. Further, the Act requires Federal agencies to comply with General Conformity rules. Under General Conformity, Federal actions must not interfere with goals of the SIP. Federal oversight of the law is provided by the U.S. Environmental Protection Agency (EPA).

In Arizona the CAA is administered by the ADEQ. The CAA is implemented at the National Forest level when activities under the control of the Forests' are required to comply with state law and air quality rules.

National Ambient Air Quality Standards

The CAA requires the Environmental Protection Agency to set the NAAQS for ambient concentrations of criteria air pollutants that are considered harmful to public health and the environment. The NAAQS has two forms: primary and secondary. The primary standard sets limits for the protection of public health, including the health of sensitive populations, like asthmatics, children, and the elderly. The secondary standard sets limits for the protection of public welfare, including visibility impairment and damage to animals, crops, vegetation, and buildings. Criteria pollutants for both forms of the NAAQS include particulate matter (PM10 and PM2.5), ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), and lead (Pb). Geographic areas not meeting the NAAQS are designated as nonattainment based on the ambient criteria pollutant concentration.

An exceedance of a NAAQS is defined in 40 CFR 50.1 as "one occurrence of a measured or modeled concentration that exceeds the specified concentration level of such standard for the averaging period specified by the standard." A violation of the NAAQS consists of one or more exceedances of a NAAQS.

The precise number of exceedances necessary to cause a violation to depend on the form of the standard and other factors, including data quality, defined in federal rules such as 40 CFR 50.

The ADEQ is the state agency having jurisdictional authority over air pollution control and sets guidelines to attain and maintain the national and state ambient air quality standards within the state of Arizona. The ADEQ enforces the CAA NAAQS.

Nonattainment and Maintenance Areas

Nonattainment Areas are designated by EPA based upon air quality monitoring data or modeling studies that indicate an area violates or contributes to violations of the NAAQS. States are required to submit a State Implement Plan (SIP), which defines the strategies used to control air pollution in order to bring air quality into attainment. After air quality improves and no longer violates the NAAQS, EPA may re-designate the area as attainment and these areas are known as maintenance areas. The CAA and EPA rules impose requirements for Federal agencies to work with State and local governments in nonattainment and maintenance areas to ensure that federal actions conform to the initiatives established in the applicable SIP. These rules are defined under the CAA General Conformity Rule.

There are no nonattainment areas in the Rim Country project area.

General Conformity 42 USC 7571-7574

The CAA requires federal agencies to ensure that actions they undertake in nonattainment and maintenance areas are consistent with federally enforceable air quality management plans for those areas. Under the General Conformity Rule, federal agencies must work with State and local governments in nonattainment and maintenance areas to ensure that federal actions conform to the initiatives established in the applicable state implementation plan. General Conformity is typically addressed during the NEPA process. The preamble to EPA’s rulemaking on general conformity States that conformity "should be viewed in a manner that fits within a broader view including NEPA activities," and that "EPA expects the conformity analysis to be coupled with the NEPA analysis and, thus, not result in undue delays" (58 FR 63214, November 30, 1993). In addition, the Council on Environmental Quality’s NEPA rules state that Federal agencies shall integrate NEPA requirements for a proposed action with other environmental review and consultation requirements to the fullest extent possible (40 CFR 1502.25(a)). Oversight is provided by the Federal agency responsible for the proposed Federal action. Consistent with the requirements of the Rule, a Federal agency must make its own General Conformity Determination (GCD) indicating that its actions would conform to the appropriate state implementation plan (SIP). However, a GCD is not required for Federal actions that are considered De Minimis or where the total of direct and indirect emissions is below the emissions levels specified under 40 CFR 93.153(b)(1) and (2).

Prescribed burning that is regulated by States having approved smoke management plans complies with the Clean Air Act. In Arizona the State’s smoke management plan rules are implemented at the state level by the ADEQ. The Forest Service is required to comply with the State’s smoke management plan and therefore, prescribed fire projects in nonattainment or maintenance areas are presumed to comply with, or “conform” to the federal Clean Air Act’s conformity rules.

1999 Regional Haze Rule 40 CFR Parts 51 and 52 (RHR)

Under the CAA the 1999 RHR mandates that states address control of man-made air pollution that impacts visibility in designated Class I areas. Class I areas include wilderness, national parks and monuments greater than 5000 acres which existed as of August 7, 1977. The goal of the RHR is to return visibility conditions in Class I areas to natural background conditions by the year 2064. EPA defines “regional haze” as visibility impairment produced by sources and activities that emit fine particles and their precursor emissions across a broad geographic area, which can interfere with the scenic vistas integral to our national parks, forests, and wilderness areas.

The ADEQ is developing a SIP to remedy existing and prevent future visibility impairment at mandatory Class I Federal areas. The SIP is required under the contextual requirements defined under 40 CFR Part 51 Section 300 through 309 of the Regional Haze Rule and will provide reasonable progress and long-term strategies for Arizona's twelve Class I areas.

The Forest's responsibility about visibility involves coordination with the EPA, and State, county, and tribal air regulatory agencies in managing and mitigating the emissions of air pollutants resulting from Forest Service activities, such as the application of planned fire ignitions. If conditions prescribed by the Regional Haze Rule and the Arizona regional haze state implementation plan are met, visibility is expected to improve over time in the Rim Country project area.

Prevention of Significant Deterioration (PSD)

The CAA requires federal land managers "…to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, … and other areas of special national or regional natural, recreational, scenic, or historic value." PSD addresses resource protection through the establishment of ceilings on additional amounts of air pollution over base-line levels in "clean" air areas, the protection of the air quality-related values of certain special areas, and additional protection for the visibility values of certain special areas. The PSD Program sets emission limitations for major new or modified stationary sources of air pollution such as coal-fired electrical power generation plants and sets limits to an increase of pollutants in Class I and Class II areas. A permittee wishing to build a major new (or significantly modify an existing) facility in a clean air region must obtain a prevention of significant deterioration (PSD) permit from the state. Where emissions from new or modified facilities might affect Class I areas, the Federal Land Manager (FLM) must be notified by the air quality regulator having jurisdiction (state or local authorities).

The PSD program is relevant to stationary air polluting sources. The Rim Country project is an air pollution area source from prescribed burning and is therefore not covered by the PSD Program.

National Forest Management Act

The National Forest Management Act of 1976 (NFMA) requires national forests and grasslands to create land management plans. The law states "National Forests are ecosystems and their management… requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems."

The Rim Country project National Forests meet NFMA air quality requirements by complying with the Clean Air Act.

Wilderness Act

The 1964 Wilderness Act identified management goals for all wilderness areas, both Class I (protected under the Clean Air Act) and Class II. It requires wilderness areas to be administered "for the use of the American people in such manner as would leave them unimpaired for future use and enjoyment as wilderness." National Forest System Wilderness Implementing Rules: "Wilderness Resources shall be managed to promote perpetuate and where necessary restore the wilderness character of the land."

The Rim Country project National ForestsS meet Wilderness Act air quality requirements by complying with the Clean Air Act.

Class I Wilderness Areas

Air pollution affects the natural quality of Forest lands, particularly wilderness areas or Air Quality Related Values (AQRV) or Wilderness Air Quality Values (WAQV). High ozone concentrations can injure sensitive vegetation. Fossil fuel burning emits sulfur dioxide (SO2) and nitrogen oxides (NOx) into the atmosphere. Certain types of agricultural activities, such as livestock grazing and dairy production, emit ammonia (NH3) to the atmosphere. Such emissions can lead to atmospheric deposition of sulfuric acids, nitric acids, and ammonium to national forest ecosystems above critical load (CL) thresholds. Atmospheric deposition can cause lake body acidification, eutrophication, and hypoxia, soil nutrient changes, and vegetation impacts. Deposition of toxic metals such as mercury and lead can be harmful to both aquatic and terrestrial ecosystems. Visibility in most national forests is obscured some portion of the year by anthropogenic haze of fine pollutant particles. Fire smoke emissions is the greatest source of pollution affecting visibility in the wilderness areas in and around the Rim Country project. In addition, the Clean Air Act (CAA) requires Forest Service operations, visitor use including OHV, and permitted operations such as prescribed burning, fossil fuels development and production, and mining to comply with NAAQS and protection of AQRV/WAQV.

State and Local Law

In Arizona prescribed fire smoke emissions is regulated by the ADEQ, Arizona Revised Statute Title 18 Chapter 2 Article 15, Forest and Range Management Burns. The ADEQ Smoke Management Program is certified by the EPA. The program is specific to forest and range management burns done by federal and state land managers, along with municipal fire departments. Prescribed burning is necessary to help prevent catastrophic wildfires because of Arizona's arid climate. Elements of ADEQ's Smoke Management Program include:

- Evaluating smoke dispersion potential of prescribed fires and wildfires
- Gathering prescribed burn data
- Permitting daily prescribed burn activity
- Notifying the public of approved prescribed burns
- Assisting in air quality monitoring related to smoke from prescribed burns and wildfires
- Enforce Emission Reduction Techniques and Smoke Management Techniques
- Encouraging regional coordination between burners for adherence to EPA's Regional Haze Rule

The National Forests are required by law to comply with Article 15 and participate and cooperate in the State's Smoke Management Program.

Conclusion

Nuisance Smoke

Nuisance smoke would generally be the same under all the alternatives. As the project is implemented over twenty years the potential for uncontrolled wildfire emissions would be reduced and replaced by controlled prescribed fire emissions and, overtime, may reduce the reports of nuisance smoke connected to the project.

Exceedances of NAAQS

Implementation of the project would comply with the federal Clean Air Act (CAA) and the CAA is implemented at the state level under the ADEQ rules that require the project to not cause exceedances of the National and State Ambient Air Quality Standards in populated areas.

Smoke Emissions – Criteria Air Pollutants and Greenhouse Gases

First Entry Burns

First entry burns are those burns which are the first-time fire occurs in an area that has missed several fire cycles or after mechanical treatments are completed. In mechanical treatment unit's activity generated fuels may increase fuel loadings and first entry burns may produce more smoke compared to burn units that are not mechanically treated. First entry burns can cause mortality to shrubs, branch wood and small trees and these woody fuels can accumulate on forest floors over several years and increase overall surface fuel loadings to above pre first entry burn fuel loading.

Second Entry Burns

Second entry burns are those burns which occur within about ten years of a first entry burn in forest stands. For second entry burns, fuel loads would generally be lower than in first entry burns, producing less smoke and with lower potential for high severity fire. However, after first entry burns fire caused mortality to shrubs, branch wood and small trees can increase woody fuels accumulations on forest floors over several years and increase overall surface fuel loadings to above pre first entry burn fuel loading. A second entry burn should occur after surface fuels have recovered sufficiently to produce fire behavior sufficient to meet burn objectives.

Maintenance Burns

Maintenance burns in ponderosa pine generally begin with the second or third burn in an area that is being restored. This could apply in areas within the treatment area that have burned from wildfire or prescribed fire within the last ten to fifteen years. Maintenance burns occur when ecosystem conditions are such that fire can play its historic role on the ecosystem, as a disturbance that establishes site-specific and landscape scale patterns, regulates flora and fauna, and other ecosystem functions. In ponderosa pine, these burns produce low severity effects, fewer emissions, and are able to be conducted with fewer resources. The timing of maintenance burns should mimic the natural seasonality of fire as closely as possible. For those areas which have had two or more fires (wildfire or prescribed fire) in the last twenty years, prescribed fires would be true maintenance burns, with minimal emissions (Robinson, 2004), and only maintenance needed from the fire.

Alternative 1

If the entire project area were to burn in an uncontrolled wildfire the criteria air pollutant emissions would be approximately 461-684%, and greenhouse gas emissions would be approximately 566% of Arizona annual statewide prescribed fire emissions.

Alternative 2

Six different treatment scenarios described under Alternative 2 above would produce approximately 37-118% of criteria air pollutant emissions, and approximately 46-98% of greenhouse gas emissions compared to Arizona annual statewide prescribed fire emissions.

Alternative 3

Six different treatment scenarios described under Alternative 3 above would produce approximately 20-64% of criteria air pollutant emissions, and approximately 25-52% of greenhouse gas emissions compared to Arizona annual statewide prescribed fire emissions.

Table 18 shows a comparison of criteria air pollutants and greenhouse gas emissions between the alternatives compared to the annul Arizona statewide prescribed fire emissions. Total Alternative 1 criteria pollutants would range from 461-684%, and total Alternative 1 greenhouse gases would be approximately 566%.

Table 18. Comparison of criteria air pollutants and greenhouse gas emissions between the alternatives compared to the annul Arizona statewide prescribed fire emissions

Rim Country Project Treatment Scenario	Alternative 2 Criteria Pollutants (annual)	Alternative 2 Greenhouse Gases (annual)	Alternative 3 Criteria Pollutants (annual)	Alternative 3 Greenhouse Gases (annual)
First entry prescribed burning emissions without mechanical treatments over twenty years	37-58%	49%	20-31%	26%
First entry prescribed burning emissions after mechanical treatments are completed over twenty years	47-58%	46%	25-31%	25%
First decade first entry annual prescribed burning emissions without mechanical treatments completed over ten years	75-116%	98%	41-62%	53%
Second decade second entry annual prescribed burning emissions without mechanical treatments completed over ten years	61-97%	68%	32-52%	36%
First decade first entry annual prescribed burning emissions after mechanical treatments are completed over ten years	93-118%	94%	50-64%	50%
Second decade second entry annual prescribed burning emissions after mechanical treatments are completed over ten years	61-97%	61%	32-52%	33%

Visibility or Regional Haze

Under Alternative 1, the potential for increasing wildfire smoke emissions over time could adversely affect the implementation of the Arizona State Regional Haze plan and prolong the period of time the State would take in meeting regional haze goals.

Under Alternatives 2 and 3, prescribed fire smoke emissions would be controlled by the ADEQ and over time, compared to Alternative 1, smoke emissions would have less of an effect to the implementation of the Arizona State Regional Haze plan and meeting regional haze goals.

Areas with the potential for adverse effects would be the Colorado River airshed, the Little Colorado River watershed, and he Verde River watershed. Class 1 airsheds that could be affected include the Grand Canyon National Park, and the Sycamore Canyon Wilderness Area.

Cumulative Effects

Nuisance Smoke and Exceedances of NAAQS

Compared to the other current and planned prescribed burning projects in Arizona the Rim Country project would produce large amounts of smoke emissions over twenty years. This analysis shows the approximate amounts of emissions using several burning scenarios. While this information can be useful for comparing the project's emissions to other emissions sources the amounts of emissions does not easily equate into knowing what the smoke concentrations would be in populated or smoke sensitive areas. Estimating smoke concentrations would require smoke dispersion modeling that generally is available for up to a 72-hour forecast period based on weather forecast models. The ADEQ uses such modeling for forecasting the capacity of the atmosphere to disperse smoke emissions. The department bases burn day authorizations on the amounts of burning the land management agencies have requested to complete, weather forecasts and smoke dispersion modeling.

Smoke Emissions – Criteria Air Pollutants and Greenhouse Gases

The cumulative effects under Alternative 2 include the greatest number of acres being treated with prescribed fire across the project area. This alternative combined with current and reasonably foreseeable activities in and around the project area would result in an annual average of more than 140,000 acres of prescribed fire though annual amounts may vary considerably. The overall effects from this amount of prescribed fire is expected to be more than those associated with alternatives 1 and 3.

Cumulatively, Alternative 3 combined with current and reasonably foreseeable activities would result in an annual average of more than 97,000 acres of prescribed fire though annual amounts may vary considerably. The overall effects from this amount of prescribed fire is expected to be nearly a third less than those associated with alternative 2, but more than alternative 1. The potential for higher overall emissions associated with wildfires burning in areas not identified for treatment under Alternative 3 would result in more emissions in these areas than alternative 2.

For both action alternatives Areas with potential for air pollution and visual effects include the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Petrified Forest National Park, Sierra Anches Wilderness Area and Mazatzal Wilderness Area. As more acres are treated, there would be broader burn windows, potentially resulting in more days of prescribed fire and days of air pollution and visual quality effects when added to prescribed burning occurring in the cumulative effects boundary.

All prescribed fires would be implemented in compliance with ADEQ rules that regulate criteria air pollutants as well as Land Management Plan direction to meet legal standards and provide for public safety.

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Appendix A – Models and Processes

Fire models are tools to help depict relative change in fire behavior and effects across the landscape. Although there are limitations to fire modeling, the model outputs provide useful information for planning and assessing restoration treatments (Stratton 2004, Stratton 2006). Interpretation, professional judgment and local knowledge of fire behavior and effects were used to evaluate the outputs from the models. Data used for modeling fire across a landscape rarely uses the exact numbers as measured in the field for canopy characteristics. The intent of fire modeling is to find the combination of fuel models, fuel characteristics (canopy base height, canopy bulk density, canopy cover, canopy height), fuel moistures, and weather parameters that produce the most accurate modeled fire behavior. That usually means 'gaming' the fuel models, adjusting various characteristics until the modeled fire behavior most closely represents known fire behavior. In this manner, canopy cover in a fuel model is adjusted by the same age as shown in modeled silvicultural change/s. The degree of change is what is important for the modeling exercise, and that requires canopy cover numbers that are measured in a consistent manner so that the change is valid.

The models and data listed below were used as described for modeling potential fire behavior and effects.

Nexus

Version 2.1 – Nexus was used to model fire type (Finney 2006). Scott and Burgan (2005) fuel models were used to model fire type relative to each management alternative.

Forest Vegetation Simulator (FVS)

The FVS is a model used for predicting forest stand dynamics throughout the United States and is the standard model used by various government agencies including the USDA Forest Service, USDOI Bureau of Land Management, and USDOI Bureau of Indian Affairs (Dixon 2008). The FVS is an individual tree, distance independent growth and yield model with linkable modules called extensions, which simulate various insect and pathogen impacts, fire effects, fuel loading, snag dynamics, and development of understory tree vegetation. FVS can simulate a wide variety of forest types, stand structures, and pure or mixed species stands (CRVAR 2010). Forest managers have used FVS extensively to summarize current stand conditions, predict future stand conditions under various management alternatives, and update inventory statistics.

Geographic variants of FVS have been developed for most of the forested lands in the United States. New "variants" of the FVS model are created by imbedding new tree growth, mortality, and volume equations for a particular geographic area into the FVS framework (CRVAR 2010). The Central Rockies (CR) variant covers all forested land in Forest Service Regions 2 and 3 and was used in the vegetation analysis for this project area. This variant was initially developed in 1990 and has been continually updated to correct known deficiencies and quirks, take advantage of advances in FVS technology, incorporate additional data into model relationships, and improve default values and surrogate species assignments (CRVAR 2010).

For simulation purposes, each data set was grouped by current forest type, VSS code, site class and treatment type. Simulations were developed for each treatment based on desired conditions. A multitude of vegetation and fuels attributes were computed for each growth cycle. Attributes include tree density (trees per acre, basal area and SDI) by species or species groups and VSS size class, dwarf mistletoe infection, cubic feet of biomass removed, canopy base height and bulk density, live and dead surface fuel loading, live and dead standing wood, coarse woody debris and snags. These attributes were then averaged for all the data sets represented in the simulation. The averaged computed attributes from FVS were also used to calculate other attributes such as dominate VSS size class, canopy density and even-aged or uneven-aged structure. All of these attributes were then compiled into an "effects" database by Alternative and used to analyze and display the direct and indirect effects to the vegetation resource.

Fire/Fuels Extension (FVS-FFE)

The Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS) links models of fire behavior, fire effects and fuels loading to tree growth metrics (Dixon 2003; Rebain 2016). For more details on the FVS-FFE modeling, see the Silviculture Specialists' The Fire and Fuels Extension (FFE) to FVS was used to simulate fuel dynamics over time. Those data were used to inform the process of assigning post-treatment fuel models. Additionally, FFE provided the data for evaluating modeled treatment

FlamMap

FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics over an entire landscape for given weather and fuel moisture conditions. FlamMap uses GIS-based raster inputs for terrain and fuel characteristics (elevation, slope, aspect, fire behavior fuel models, and canopy characteristics), computes fire behavior outputs for a given landscape using standard fire behavior prediction models, and generates raster maps of potential fire behavior characteristics (spread rate, flame length, crown fire activity, etc.) over an entire landscape.

Uniform Conditions

FlamMap employs the fire behavior model (Rothermel 1972). The Rothermel fire behavior model makes several assumptions which include:

- The fire is free-burning

- Fire behavior is predicted for the flaming front of a surface fire

- Fine fuels are the primary carrier of the initial fire front

- Fuels are continuous and uniform

FlamMap then utilizes Van Wagner's 1977 crown fire initiation model, Rothermel's 1991 crown fire spread model, and Nelson's 2000 dead fuel moisture model to model both crown fire.

Fire behavior outputs generated from modeling exercises only reflect static conditions and do not take into account changing weather conditions. Any change in these factors could drastically affect fire behavior. Given the uncertainty of any modeling exercise, the results are best used to compare the relative effects of the alternatives, rather than as an indicator of absolute effects. Interpretation, professional judgment, and local knowledge of fire behavior were used to evaluate the outputs from the models and adjustments made as necessary to refine the predictions.

FlamMap assumptions and limitations

Since FlamMap uses the same underlying models (Rothermel's 1972, 1991, Van Wagner's 1977, and Nelson's 2000) for surface fire spread, crown fire spread, and dead fuel moisture, it will inherently have the same assumptions and limitations as each of those models. In addition, FlamMap 3.0 has a number of additional limitations:

- Modeling results assume that all mechanical treatments occurred in 2012, and prescribed fires occurred across all areas proposed for treatment in 2015 and again in 2019. In reality, the treatments would be spread out over the life of the project. This means that desired conditions across the entire landscape may not occur concurrently.

- All fire behavior calculations in FlamMap Basic assume that fuel moisture,

- wind speed, and wind direction are constant for the simulation period.

- The fire behavior calculations are performed independently for each cell on the gridded landscape.

- Flammap doesn’t use a 24 hour clock, so diurnal weather changes, which could affect fire behavior, are not accounted for

- Canopy characteristic in the Landfire data were adjusted by the percent change indicated by the changes in the FVS data to represent post-treatment conditions.

Canopy cover for fire modeling:

Canopy cover (cc) is one of four canopy characteristics are necessary for evaluating and modeling fire behavior and/or effects. In the fire models, canopy cover affects outputs for:

- Active crown fire (horizontal continuity)

- Passive crown fire (as it affects surface fire intensity)

- Fireline intensity/flame length (more wind means higher intensity, longer flame lengths, affects crown fire initiation)

- Rate of spread (open canopies allow higher winds at the surface)

Fuel models, used for modeling fire, rarely use measured canopy characteristics. The intent is to find the combination of fuel models, fuel moistures, and weather parameters that allow models to most accurately predict fire behavior. That usually means ‘gaming’ the fuel models, adjusting various characteristics until the modeled fire behavior most closely represents known fire behavior. In this manner, canopy cover in a fuel model is adjusted by the same percentage as shown in modeled silvicultural change/s. The degree of change is what is important for the modeling exercise, and that requires canopy characteristic data that are obtained in a consistent manner so that the percent change is valid.

Farsite

Fire Area Simulator Version 4.1.055. This was used to generate initial input files for wind, fuel moisture, and weather, as well as for making adjustments needed for calibrating landscape (.lcp) file layers. These files were then loaded into FlamMap to model fire (Finney 2004). In the context of this analysis, Farsite was only used to edit the .lcp files used in FlamMap.

FireFamilyPlus (FF+)

Version 4.2– Used to determine percentile weather

FireFamilyPlus is a software system for summarizing and analyzing historical daily fire weather observations and fire occurrences and computing fire danger indices based on the National Fire Danger

Rating System or the Canadian Fire Danger Rating System. Fire occurrence data can also be analyzed and cross referenced with weather data to help determine critical fire weather, fuel moistures, and fire danger for an area. FF+ was used to:

- Evaluate weather percentiles for determining the overall context of the Rodeo/Chediski Fire conditions.
- Identify fires of interest to this analysis (this was verified with local fire managers)
- Produce wind roses and wind data
- Produce precipitation data from the three Remote Automated Weather Stations most pertinent to the project area.

Post-treatment fuel model assignments

Fuel, fuel moisture, wind, and slope are assumed to be constant during the time for which predictions are to be applied. Because fires almost always burn under non-uniform conditions, the length of projection period and choice of fuel model must be carefully considered to obtain useful predictions. The more uniform the conditions are, the longer the projected time can be. The number of simulations for which fuel models needed to be assigned expanded from ~17 (in August of 2011) to 1,492 (February, 2012). During this time, the following process was developed to assign fuel models based on the following outputs from FVS and defined fuel model characteristics (Scott and Burgen 2005).

To more accurately assign post-treatment fuel models, the assumptions described in the previous section on Mortality and Consumption were applied as follows for each variable of interest for each simulation:

IF:

a = 2012 tons/acre = 120

b = 2015 tons/acre = 70

c = 2012 – 2015 = -50 tons/acre (amount consumed in the burn)

d = in 2012 70 of ‘a’ that was affected by the burn = 84 tons/acre

e = in 2012 30 of ‘a’ that was not affected by the burn = 36 tons/acre

SO,

c = 59 of d that was consumed (for first simulation with 70:30)

SO, for each simulation for which it was 80:20 (the ratio deemed more realistic for the second burn):

(a*. 7) = 84 tons/acre

59 of 96 tons/acre = 57 tons/acre

a*. 3 = 36 tons/acre

2012 – ((((2012 – 2015)/(2012 * . 7))*(2012 * . 7)) + (2012 * . 3)) = 2015 value

Inputs:

FVS-FFE output data from the following categories was used/considered. Those in italics used the data adjusted for mortality, those in standard font did not.

- B = pj tpa<5"(Trees/acre less than 5" dbh of Pinyon/Juniper)
- C = pj tpa >5" (Trees/acre greater than 5" dbh of Pinyon/Juniper)
- D = potr tpa <5" (Trees/acre less than 5" dbh of aspen)
- E = potr tpa >5" (Trees/acre greater than 5" dbh of aspen)
- F = mc tpa<5" (Trees/acre less than 5" dbh of mixed conifer)
- H = cc (canopy cover ( ))
- I = cbh (feet)
- J = cbd (kg/m3 * 100)
- K = shb (tons/acre)
- L = quga tpa<5" (Trees/acre less than 5" dbh of Gambel Oak)
- M = quga tpa>5" (Trees/acre greater than 5" dbh of Gambel Oak)
- N = herb (herbaceous surface vegetation in tons/acre)
- = Litt (adj) (tons/acre)
- P = Duff (adj) (tons/acre)
- Q = Fines (Litt+1hr) (tons/acre)
- R = 1hr (adj) (1 hour fuels (<1/4" diameter) in tons/acre)
- S = 10hr (adj) (10 hour fuels (>1/4 and <1" diameter) in tons/acre)
- T = 100hr (adj) (100 hour fuels (<1" and >3" diameter) in tons/acre)
- U = 1000hr (adj) (1000 hour fuels (>3" diameter) in tons/acre)
- AA = Canopy Density (A, B, or C)

Fuel Model Characteristics considered (Scott and Burgen 2005):

Fine fuel load (T/a)

- Potential FL (very dry)
- Potential ROS (very dry)
- Coarse fuel load (T/a)
- Species (deciduous vs. Conifer; aspen dominant)

Process:

Step 1: Apply formula to account for the difference in area between modeled area burned and the adjusted area (to account for a more complete burn) area burned for years 2015, 2020, and 2040. There were no treatments after 2020 so, in order to account for the differences in surface fuels from the earlier burns, the 2040 Adjusted fuels were adjusted by the change between 2020 and 2020 Adjusted.

Step 2: Apply the formulas below to the appropriate data into the 'first cut' sheet to assign simulations to either: Timber, Shrub, or Grass based on the following criteria. This is an initial cut only, and as further classifications are completed in this process, simulations may be moved from their original assignation to other types.

Grass (GR) and grass/shrub (GS) fuel models:

CBH > 17.99 ft. And CC <30

Rationale: A combination of CC and CBH can determine if crown fire is possible under most situations. CBH for initiation, CC for active vs. passive. Surface fuels alone could produce sufficient surface fire intensity to initiate crown fire in some high canopy base heights but, for this first cut, if these criteria were met the simulation was classified as 'GR'.

Shrub fuel models (SH):

CBH <17.99 ft, CC < 30

Rationale: CC isn't sufficient to be able to carry a fire through the canopy, so it isn't a timber model (<30% CC) but CBH may be low enough to initiate cf in whatever woody veg there is (CBH<18.00). This was a more challenging category, but it seemed to pick out PJ, Sage, and other potentially shrubby fuel types. This was just the first cut so simulations that fell into this category could be moved if further classification indicated it was better elsewhere (such as GS or TU).

Timber Litter (TL) and timber understory (TU) models:

CC > 29.99 (See assumptions below)

Rationale: Observations in the field are supported by the stand data and modeling to show that CC affects surface fuel loading for all types (herbaceous, CWD, duff, litter), as well as the potential for crown fire. 30% is a common number used to define savanna vs. Forest Service.

Assumptions:

- QUGA and POTR are deciduous and, therefore they, and their leaf litter, have different characteristics than ppine or mixed conifer
- PJ <5" MC <5" have more flammable morphology (lower and denser canopies) and have greater CBD than QUGA, so more QUGA <5" were deemed necessary to justify classification as having a shrub fuel component
- In 10 years, all stands had been rx burned twice and, all proposed mechanical treatment were completed.
- In stands where aspen dominates, the ecosystem is different. More cool season species, moister understory conditions much of the time as compared with conifers and oak. The dead/down component

also appeared to be much higher in most aspen stands (in the FVS data) than in other species, so aspen was given a fuel model (186) of its own

Step 3: Assign models as per the formulas below. Note that simulations classified initially as 'TL' will be split into TL and TU (see below) before specific fuel models are assigned.

GR (grass)

101:

Rationale: Only a little shrub/woody component. Litter was the differentiating factor. Spread rate moderate to low compared with other grass models, depending largely on the continuity of the fuel. Most of this would be in dry, open areas. Much of the herbaceous fuel would be discontinuous, so burns wouldn't be 100. PJ and MC variables present in 102 classification made no difference for this classification, and were removed.

(Litter + 1 hr) <0.72 AND shrub < 0.25

OR

(litter + 1 hr) < 0.72 AND (tpa QUGA <5") <300

102:

Greater fine fuel loading than 101, and fuels more contiguous. ROS moderate, may be high in wet years or small areas. This allows a small component of woody fuels (quga, pj, and/or mc).

((Litter + 1 hr) > 0.72 <2) AND shrub < 0.25 AND (tpa QUGA <5") > 400 AND (TPA<5" mixed conifer and PJ) < 25

GS (grass/shrub)

SHB must be a component (see above), as well as greater fine fuel/litter loading than in the GR models.

121:

(Shrub>0.35<0.79) AND ((litter + 1 hr) >0.9<1.7) AND ((tpa quga <5")>160<300)

OR

(litter + 1 hr) >0.9 AND (TPA<5" mixed conifer and PJ) >25<40

OR

(litter + 1 hr) >0.9< 1.7 AND (tpa quga <5")>300<500) AND (TPA mixed conifer and PJ <5") <20

Rationale: A minimum of .25 T/acre of shrub-like fuels, and a potentially greater (though still low) component of woody fuels in the form of 1 hr or small shrub-like trees (PJ, MC, quga). Less contiguous fuel than 122, but with very small areas of higher severity where there is a woody component, though not continuous.

122:

(litter + 1 hr) > 1.5 AND shrub>0.75

OR

(litter + 1 hr) >1.2 AND (tpa quga >5”) > 500 AND (TPA<5” mixed conifer and PJ) >40

Rationale: Similar to 121, but greater fuel loadings. Overall fuels are more contiguous than 121. Woody fuels may be more frequent, but are still not contiguous. FL moderate and ROS high because mostly contiguous fuels.

SH (shrub)

Shrub/PJ are the main component defining 141, 142, and 145.

141:

CC<26 AND CBH < 17 AND (tpa all PJ) >10, (tpa PJ >5”) < 40; herbaceous > 0.17

OR

CC < 26 AND shrub > 0.75 AND (litter + 1 hr) >0.75<2. 1

OR

CC < 26 AND shrub > 0. 5 AND (litter + 1 hr) >0.75<2.1 AND (TPA<5” mixed conifer and PJ) >40

Rationale: This is broad enough to include those areas with a number of small trees, but low fine fuel loading. Includes a fair amount of PJ. Fire behavior is expected to be low with spread being minimal without a strong wind. Flame length and ROS low, mostly because of discontinuous fuel.

142:

Herbaceous <0.15

OR

Herbaceous <0.165 AND (tpa quga <5”) >300<400)

Rationale: Low potential for spread without wind, almost no herbaceous fuel present, so wind is required for much spread. With sufficient wind, intensity is potentially high in places, but spotty and discontinuous. Includes a variety of fuel types, but picked up the higher fuel loadings of PJ.

145:

(TPA PJ<5”) > 200 AND CBH < 10 AND CC > 25

Rationale: With much wind, this can produce high intensity fire and, as classified, included simulations with a moderately high component of QUGA <5” as well so, combined with the canopy characteristics, this is likely to produce a crown fire with high rates of spread and high flame lengths.

TU/TL (Timber Understory/Timber Litter)

NOTE: in reviewing the TL models (after the original TL/TU split), the highest values for PJ<5”, MC<5” were reviewed and, if L5 was greater than 500, it was moved to TU. Any remaining TL models with CC<30 were moved to TU, and the lowest CC values were reviewed to see if any of them should be moved to TU or GR/GS. The assumption was that a more open canopy would produce sufficient surface fuels to contribute to fire bx, and insufficient needle litter to really qualify as TL.

TU (Timber Understory)

CC < 60 AND Canopy closure = A (open)

OR

CC < 60 AND Canopy Closure = A or B AND (herbaceous + shrub) > 0.4

OR

CC < 60 AND (herbaceous + shrub) > .75 AND (tpa quga <5”) >900 AND (TPA mixed conifer < 5” and PJ < 5”) >60

Rationale: This should be common across much of the 4FRI landscape with surface fire being the norm unless conditions are extreme. Herb or shrub component required. The shrub component may be represented by small MC or small PJ. Canopy should not be entirely closed in order to allow a surface fuel component of vegetation instead of just dead/down fuels, litter, and duff.

TL (Timber Litter): Not as above.

161:

(tpa pj <5” + mixed conifer <5”) < 152 AND (quga <5”) <1500

Rationale: This picked up a lot of simulations, as it should. Some passive crown fire may occur in this fuel model, but spread rate and flame length are low. Surface vegetation, including herbaceous, shrubs, and small conifers is present. The canopy is open enough to assume that there will be at least a moderate amount of herbaceous fuels.

162:

(tpa pj <5” + mixed conifer <5”) > 150 < 500

OR

(tpa quga <5”) > 1500 < 3000 AND (tpa pj <5” + mixed conifer <5”) > 150 < 500

Rationale: This fuel model is intended to pick up the moderate amount of fuel loading and passive crown fire potential in areas not well represented by 161 or 165. It is generally a humid climate model, so fuel moistures were modeled lower for this than for the other TU models. Spread rate is moderate because of more contiguous fuel than 161, crown fire is more likely than in 161, but not as likely as 165. Flame lengths can be moderate, depending on burning conditions.

165:

(tpa pj <5” + mixed conifer <5”) > 500 AND (tpa quga <5”) >3000

Rationale: Higher fuel loading, with potential for undesirable fire effects. Lots of ladder fuels, good potential for crown fire initiation. Rate of spread and flame length moderate.

TL (Timber Litter)

Timber litter is the primary carrier of the fire. Canopies are mostly closed, and/or surface fuel loading other than dead/down woody debris, litter, and duff is minimal.

181:

Duff < 1.5 AND (litter + 1 hr) > 0.75 < 2.75 AND (potr < 5” + quga < 5” + potr > 5” + quga > 5”) < 50 AND (tpa pj < 5” + tpa mc <5”) <50)

Rationale: Light surface fuel loading because of low surface productivity, or recent burns. Canopy cover may be lower in this fuel model. Flame length and rate of spread should be low as litter is the primary carrier of the fire. Surface fuels may be discontiguous in places.

182:

(tpa quga <5”) >450 AND (tpa quga >5”) >75 AND (100 hr + 1000 hr) <12

OR

(tpa all potr + tpa all quga) >50 AND duff <6 AND (litter + 1 hr) > 1 < 7 AND (tpa pj <5” + tpa mc <5”) < 50 AND (100 hr + 1000 hr) <12

Rationale: Surface fuel loading is low to moderate, with contiguous fuels prevalent. One aspect of the fuel model picks up areas with higher deciduous components (excluding those dominated by aspen). In general, this fuel model picks up low to moderate surface fuel models in a wide variety of pine and pine oak forests.

183:

Duff > 1.5 < 6.7 AND (1 hr + 10 hr) < 7 AND (tpa potr < 5” + tpa mc <5”) <50.85 AND (tpa PJ <5” + tpa mixed conifer <5”) <50 AND ((100 hr + 1000 hr) AND (litter + 1 hr) < 7.1

Rationale: Fuel model 183 has low to moderate fuel loading. Canopies are mostly open, and canopy base heights moderately high. These should be areas that have been thinned and/or have had fire in the last 10 years so that fire behavior produces mostly low severity effects that are beneficial to the ecosystems.

184:

(100 hr + 1000 hr) >12<16 AND (tpa PJ <5” + tpa mixed conifer <5”) <50 AND 1 hr >0.1<1.4 AND duff < 15 AND (litter + duff) <11

Rationale: High surface fuel loading (23 – 30 tons/acre) with a CWD (>3”) component averaging 9 tons/acre. Canopies are more open than the ‘higher’ timber litter models though so, although surface effects have potential to be negative, heat can escape upwards in most simulated areas with less scorch/damage to the canopy. Spread rate and flame lengths would be low to moderate, with the range depending on the openness of the stand (mid-flame wind).

185:

CC > 60 AND (100 hr + 1000 hr) < 13 (100 hr + 10 hr) >6 AND (litter + 1 hr) > 7 AND (tpa PJ <5" + tpa mixed conifer <5") < 50

OR

(100 hr + 1000 hr) >7<12 AND (litter + 1 hr) >7 AND duff >4<10

Rationale: Fuel model 185 represents high fuel loading, with a mix of fuel sizes. Surface fuel loading exceeds 21 tons/acre, with over 7 tons from litter and 1 hour fuels. Closed canopies may contribute to excessive scorch and negative surface and soil effects even when no crown fire occurs.

186:

(tpa potr <5")>600 AND (tpa potr >5") >50

Rationale: This fuel model, in this analysis, represents stands dominated by aspen. Fire would be of mixed severity most of the time, lower flammability than the surrounding grasslands and conifer forests most of the time. For many of the simulations of aspen stands (7 out of 20), large CWD exceeds 14 tons/acre, and for 9 out of 20, fine dead surface fuels (litter and 1 hr) exceed 8 tons/acre. However, litter in aspen burns differently than in conifers, and is less flammable than oak so flame lengths would be low and ROS moderate except under extreme conditions.

187:

(100 hr + 1000 hr) > 15. 99 AND (tpa pj <5" + tpa mixed conifer <5") <50

Rationale: Fuel model 187 has high surface fuel loading, with a high component of large CWD sufficient to cause high severity surface effects in the event of a fire burning in extreme conditions. Crown fire is possible, but not necessary to cause high severity effects to soils and vegetation, since they could come from high quantities of surface fuels burning hot. Surface fuel loading ranges from 26 tons/acre to 57 tons/acre.

188:

Duff > 15 AND (100 hr + 1000 hr) <15.99

OR

CC > 45 < 60 AND (litter + 1 hr) > 7.5 AND (tpa pj <5" + tpa mixed conifer <5") <50 AND 1000 hr < 8 AND (tpa quga <5") <300

Rationale: This fuel model picks up mostly closed canopy pine where there has been no fire for decades. Surface fuel loads are high, but dominated by litter/duff/1 hr fuels with only a low to moderate load of dead/down CWD. Unless/until crown fire is initiated, flame lengths are low and ROS is moderate to low. These areas have high potential for high severity effects in ponderosa pine because of contiguous canopies and surface fuel loads sufficient to scorch canopies where there is no crown fire. Surface fuel loading ranges from 20 to over 32 tons/acre and in most simulations, duff loading exceeds 15 tons/acre.

Step 4: Review simulations to ensure they make sense. If there are duplicates assigned, or no fuel model assigned (these should constitute less than 10 of all simulations), review variables and assign fuel model. Simulations may be moved from one category to another if perusal of the variables and the formula do not place it in an appropriate category.

Landfire 2014

LF_1.4.0 – LANDFIRE products are designed to be used at a landscape-scale in support of strategic vegetation, fire, and fuels management planning to evaluate management alternatives across boundaries. Landfire is the only existing source of the type of data needed for this type of analysis that is consistent across ownership boundaries. It is a combination of Landsat8 images and plot data, with well over 1,000,000 plots. Landfire data was combined with Lidar data to create the 'base' data used for fire modeling.

Lidar data

This set of data was collected in 2013, 2014. It was converted into data sets with a resolution of 30m x 30m that was compatible for fire modeling, and used to inform the assignation of fuel model, canopy height, canopy bulk density, and canopy cover.

Fire Hazard Index

Seven datasets were used to identify areas of high probability for severe fire effects and/or extreme behavior. These datasets are crown fire potential, fireline intensity, heat per unit area, fuel model, slope, soils with high erosion hazard, and WUI areas. Pixels were rated according to the matrix below. The total points possible are 12.

As a general rule, the amount and size of plants top-killed by fire increases with an increase in either the rate of heat energy released (fire intensity) or total amount of heat energy released (heat/unit/area). Estimates of the rate and amount of this heat release are thus important descriptors of fire behavior (Wade 2013). Thus, two measures of energy were used, and are described below.

Heat per unit area (hua): 'hua' is the total amount of heat released in a given area of the flaming fire front, usually expressed as Btu per square foot, though in this process kJ/m2 was used. All of the heat given off in the flaming front is included in this value, regardless of the length of time that the flaming front persists. This allows a better estimate of burn severity (fire effects to soil) than the more commonly used fireline intensity (see description below). Heat released after the flaming front has passed (smoldering combustion) is not included in heat per unit area. Categories used are based on an index developed for the Flagstaff Watershed Protection Project by Mary Lata (Fire Ecologist, 4FRI); Tom Runyon (Hydrologist/BAER, Coconino National Forest), and Wes Hall (Prescribed Fire Specialist, Coconino National Forest). Heat/unit/area is given in kJ/m2 as follows: high soil burn severity was assumed at or above 60,500 kJ/ m2; moderate heat/unit/area was assumed between 8,700 – 60,499 kJ/m2.

Fireline intensity (fli). This is the amount of heat given off by a fire along each foot of the leading edge of the fire each second, usually expressed as Btu per linear foot of fireline per second. This measure is useful for evaluating control objectives because there is almost a 1:1 correlation between fli and Flame Length (FL) (Stratton 2009). This also can give an indication of scorch, or how imminent crown fire might be since flame lengths of half the canopy base height can ignite the canopy. Thresholds set for the expected fire severity (effects to vegetation) at different fireline intensities are based on fireline intensity levels documented in a case study of a wildfire on the Coconino National Forest (Campbell et al. 1977), these levels are:

Moderate severity at 2,500 – 10,000 BTU/sec/ft. This correlates with Flame Lengths of at least ~35'.

High severity >=10,000 BTU/sec/ft. This correlated with Flame Lengths of over 90'.

Crown Fire. This is when a fire burns the canopy of trees.

Active Crown Fire: Causes 100% mortality in most conifers in the Rim Country project area. The two exceptions are Alligator Juniper (Juniper depeanna) and Chihuahua Pine (Pinus leiophylla), both of which may sprout if top-killed or damaged by fire. Additionally, active crown fire is difficult to control since direct attack is not possible, and spotting is common.

Passive Crown Fire: Passive crown fire at some levels is a normal part of the fire ecology in ponderosa pine and related systems. Nonetheless, when it occurs in proximity to active crown fire, or if there are large areas that have potential for passive crown fire, small shifts in wind may cause it to become active, or result in spotting. As such, it was given a value of 1 in the rating process below.

Surface Fire: This was not given any points because, in general, it is not a threat for control and, without further information on hua or fli, wouldn't be expected to produce undesirable fire effects.

Fuel Model. The fuel model on a given pixel is an indicator of potential fire behavior and effects. Fuel models can represent the type of fire behavior and effects that could be expected in a given location.

Soil – High Erosion Hazard. Soil and water are fundamental to every terrestrial ecosystem on earth. When soil is damaged to the point that it is vulnerable to erosion by water or wind, the potential effects to an ecosystem may be considered permanent since, with changing climates, it is unknown how long the soil-forming process would take, and what soil/s would be formed. Soil is one of the ecological characteristics that defines the potential of a site, and there is a symbiotic relationship between soil and the flora and fauna that inhabit an ecosystem. So permanent or long term changes to the soil are likely to change the potential of a site.

Wildland Urban Interface. All areas buffered as WUI (1 mile to the southwest of private land, and 0.25 mile around the rest of the boundary) that show potential for active crown fire or high fireline intensity as modeled will be considered to have the highest rating for fire hazard.

Slope. Slope is a factor in the permanence of second order fire effects because of the potential for surface layers to be lost to erosion. Surface soil layers are critical to site potential, and can take 100s of years to reform, if they can reform. A 30% slope was used as a generalized threshold at which many soils become vulnerable to erosion.

Crown fire Active 3 Includes conditional crown fire

Passive 1 Single tree or group torching

Heat per unit area High 2 >60,500 kJ/m2

Moderate 1 8,700 – 60,499 kJ/m2

Surface fire intensity(fli) > 10,000 (high) 3 BTU/ft/sec Indicates fl > ~90 ft. (Stratton 2009)
2,500 – 9,999 (moderate) 2 BTU/ft/sec Indicates fl > ~30 ft.

Slope >30% 1 Increases likelihood of negative impacts to onsite resources (seed bank, soil, etc) as well as potential downslope effects (debris flows, etc)

Fuel Model 1 145, 147, 165, 185, 187, 188, 201 (SH5, SH7, TU5, TL5, TL7, TL9, SB1)

Soil - High Erosion Hazard 1 TEU soil types indicating a severe erosion hazard

Scoring: To be rated at all, there must be active or passive crown fire or high or moderate fireline intensity.

1 hua mod OR

passive cf

2 mod fli

hua mod + passive crown fire OR

hua mod + slope OR

hua mod + fuel model OR

hua mod + erosion haz OR

passive crown fire + slope OR

passive crown fire + fuel model OR

passive crown fire + erosion haz

3 active crown fire OR

high fli OR

passive crown fire + mod hua + slope OR

passive crown fire + mod hua + fuel model OR

passive crown fire + mod hua + erosion haz OR

passive crown fire + high fli OR

passive crown fire + slope + fuel model OR

passive crown fire + slope + erosion haz OR

passive crown fire + fuel model + erosion haz OR

mod fli + mod hua OR

mod fli + slope OR

mod fli + fuel model OR

mod fli + erosion haz

4 active cf + mod hua OR

active cf + slope OR

active crown fire + fuel model OR

active crown fire + erosion haz OR

high fli + mod hua OR

high fli + slope OR

high fli + fuel model OR

high fli + erosion haz OR

passive cf + mod hua + slope + fuel model OR

passive cf + mod hua + slope + erosion haz OR

passive cf + high hua + slope OR

passive cf + high hua + fuel model OR

passive cf + high hua + erosion haz OR

mod fli + slope + fuel model OR

mod fli + slope + erosion haz OR

mod fli + fuel model + erosion haz

5 active cf + high hua OR

active cf + mod hua + slope OR

active cf + mod hua + fuel model OR

active cf + mod hua + erosion haz OR

active cf + mod fli OR

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high fli + mod hua + erosion haz OR

high fli + high fire fli OR

high fli + slope + fuel model OR

high fli + slope + erosion haz OR

high fli + fuel model + erosion haz OR

mod fli + slope + fuel model + erosion haz

6 active cf + high hua + slope OR

active cf + high fli OR

active cf + high hua + fuel model OR

active cf + high hua + erosion haz OR

active cf + mod hua + slope + fuel model OR

active cf + mod hua + slope + erosion haz OR

active cf + mod hua + fuel model + erosion haz OR

passive cf + high hua + high fli OR

passive cf + high hua + mod fli + slope OR

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passive cf + high hua + mod fli + erosion haz OR

high fli + high hua + slope OR

high fli + high hua + fuel model OR

high fli + high hua + erosion haz OR

high fli + mod hua + slope + fuel model OR

high fli + mod hua + slope + erosion haz OR

high fli + mod hua + fuel model + erosion haz

7 active cf + high hua + mod fli OR

active cf + high hua + slope + fuel model OR

active cf + high hua + slope + erosion haz OR

active cf + high hua + fuel model + erosion haz

active cf + mod hua + slope + fuel model + erosion haz OR active cf + mod hua + high fli OR

active cf + high fli + mod hua OR

active cf + high fli + slope OR

active cf + high fli + fuel model OR

active cf + high fli + erosion haz

active cf + mod fli + slope + fuel model OR

active cf + mod fli + slope + erosion haz OR

active cf + mod fli + fuel model + erosion haz OR

high fli + high hua + slope + fuel model OR

high fli + high hua + slope + erosion haz OR

high fli + high hua + fuel model + erosion haz OR

high fli + mod hua + slope + fuel model + erosion haz OR

mod fli + high hua + slope + fuel model + erosion haz

8 active cf + high hua + high fli OR

active cf + high hua + mod fli + slope OR

active cf + high hua + mod fli i + fuel model OR

active cf + high hua + mod fli + erosion haz OR

active cf + mod hua + mod fli + slope + fuel model

active cf + mod hua + mod fli + slope + erosion haz OR

active cf + mod hua + mod fli + fuel model + erosion haz OR

passive cf + high hua + high fli + slope + fuel model OR

passive cf + high hua + high fli + slope + erosion haz OR

passive cf + high hua + high fli + fuel model + erosion haz OR

passive cf + mod hua + high fli + slope + fuel model + erosion haz OR

high fli + high hua + slope + fuel model + erosion haz

9 active cf + high hua + mod fli + slope OR

active cf + high hua + mod fli i + fuel model OR

active cf + high hua + mod fli + erosion haz OR active cf + mod hua + high fli + slope OR

active cf + mod hua + high fli + fuel model OR

active cf + mod hua + high fli + erosion haz OR

active cf + extreme fli + slope + fuel model + erosion haz

10 active cf + high hua + high fli + slope + fuel model OR

active cf + high hua + high fli + slope + erosion haz OR

active cf + high hua + high fli + fuel model + erosion haz OR

active cf + mod hua + high fli + slope + fuel model + erosion haz

11 active cf + high hua + high fli + slope + fuel model + erosion haz

12 WUI + high fli OR WUI + active cf

The scores in the table above were further classified into:

Score from above Rating Comments

1, 2 1 – average need for treatment From a fire perspective, some passive crown fire is not a problem, and moderate hua is a moderate need for treatment. The larger the contiguous area, the greater the need.

3, 4, 5, 6, 7 2 – Moderate need for treatment Either extreme fire behavior/effects, or multiple factors are included in this rating, but the inclusion of passive crown fire.

8, 9, 10, 11 3 – High need for treatment This is the level at which it is possible to have the highest levels of all the fire behavior metrics.

12 4 – Greatest need for treatment The greatest need for treatment is where there is potential for extreme fire behavior in close proximity to WUI.

Modeling Assumptions

Fire Behavior, surface fuels, and canopy fuels modeling

Percentile weather fire modeling

Modeling percentiles of fire weather and fuel characteristics is used to model various fire indices, such as Energy Release Component, Burning Index, or Spread Component, modeling straight weather percentiles is not a good tool for planning. Sometimes fire behavior is modeled, but it is more useful for some research questions, or in instances that do not involve implementing site-specific management. Percentile weather and fuel conditions are the conditions for which a specific number of days per year are above or below a given percentile. For example, if one were to model the 97th percentile for a given area, the relative humidity (rh) and fuel moistures use represent levels for which on 97% of days per year it is higher. So, if the 97th percentile rh is 10%, it means that for 97% of the days per year, minimum humidity is at or greater than 10%. If the 97th percentile temperature is 80°F, it means that, for 97% of days per year, temperatures are at or lower than 80°F, and so on. The chances of the 97th percentile relative humidity; temperature; wind speed;1, 10, 100, 1000 hr, foliar, woody, and herbaceous fuel moistures, and wind direction all occurring on the same day are very small. Therefore, results of such modeling usually over-predict fire behavior. Even for extreme fire behavior, such as occurred in the Wallow, Schultz, and Rodeo/Chediski fires, the percentiles for weather and fuel parameters were not the same on any given day. Therefore, for this EIS, fire behavior was characterized based on the conditions under which the Schultz Fire burned on June 20th, 2010. McHugh (2006) states the process of modeling includes the following:

“Define the modeling objective or question

- Model selection based on modeling objective or question
- Spatial and temporal data development required by selected model
- Gather supporting spatial and temporal data
- Data critique and analysis of developed data
- Calibration of the model to a past event(s)
- Simulations, evaluation and critique of results, and documentation
- Gaming-out, and what-if scenarios of fuel treatment location and prescription
- Evaluation, write-ups, and presentation of results

…Calibration of modeling scenarios to past events is critical. Calibration provides a mechanism for testing interactions of the data and model, allows one to evaluate model and data performance in predicting or matching to past documented fire events, provides insight into the respective fire models and how the interactions of data and user-defined model settings can affect modeled outputs. Additionally, and most importantly, it provides a means to evaluate the relevancy and accuracy of the data and instill confidence in future modeling projections.”

There are indices, such as Energy Release Component (ERC), or Burning Index (BI), which are usually referenced by percentiles, and there are specific weather variables for each of these percentiles. Using the 97th percentile ERC or BI, and the parameters associated with them is not the same as modeling the 97th weather percentiles. Fuel moistures are the primary inputs for calculating ERC, and wind and slope are not included, though they are critical components in evaluating and/or modeling fire behavior. We used FireFamilyPlus to analyze 20 years of data (1998 – 2016) from the Heber, Pleasant Valley, and Lakeside RAWS. In order to include other RAWS in the project area and/or in the vicinity of the Rodeo/Chediski fire, we included the Payson RAWS and the Promontory RAWS but, there were only 7 years of contiguous data from the Payson RAWS (2009 – 2016) and 12 years of contiguous data from the Promontory RAWS (2004 – 2016). We determined 97th percentile weather parameters based on all contiguous data up to 20 years (1998) in each of five RAWS in the vicinity of the Rodeo/Chediski Fire. Three critical weather factors that are recorded by RAWS, are used in modeling fire, and are significant variables in fire behavior on the ground were evaluated to determine if all three occurred at the 97th percentile or greater on the same day. These variables were: Maximum Temperatures (MxT), Minimum Relative Humidity (MinRH), and Wind Speed (WS). Not a single day of all the years of data indicated all three indices at or above the 97th percentile on the same day.

97th percentiles for critical weather factors at five RAWS stations.

	Days at or above 97th percentile	97th percentile WS + 97th of MxT OR MinRH

		WS	MxT	MinRH						
	Days of	data	days	% days	days	% days	days	% days	days	% days
Heber	6,653	102	2%	151	2%	488	7%	6	0.1%	
Lakeside		6,832	107	2%	198	3%	314	5%	4	0.1%
PV	6,804	212	3%	270	4%	337	5%	11	0.2%	
Payson	2,882	68	2%	152	5%	143	5%	4	0.1%	
Promontory		4,601	21	0%	147	3%	221	5%	1	0.0%
All	27,772	510	2%	918	3%	1,503	5%	26	0.1%	

Wind is the single most important fire weather factor for wildfire spread in and near the Rim Country project area. There are two aspects of wind that are considered in modeling fire: steady wind speed and wind gusts. Wind gusts are tricky because the strength and unpredictability of gusts is included by adjusting the steady wind speed upwards. Additionally, they are not always recorded by weather stations. Wind speeds at or above the 97th percentile occurred on 510 (2%) of the 27,772 days included in this analysis. 97th percentile wind speed ranged from 13 at Promontory to 17 at Lakeside. 97th percentile winds co-occurred with one of the other two other variables on less than one percent of the time. Using percentile weather conditions to model fire gives it equal value with other variables (such as MinRH, MxT, and fuel moistures) which, though important, are not as important as wind, thus, giving less accurate information on where and how fires are likely to burn on the landscape.

Climate Change - Carbon Storage

Climate change impacts are analyzed by resource throughout chapter 3 and greenhouse gas emissions are analyzed in the Air Quality section. This section focuses on Carbon Storage.[11]

Affected Environment

Carbon sequestration is an important dynamic of climate change that has been and continues to be affected by current and past forest management. Fire suppression practices have changed the dynamics of fire in ponderosa pine forests across the southwest, resulting in greater fuel-loads and increased risk of uncharacteristic fire. Under current conditions, dense forest stands can store more carbon than open forests, shrublands, or grasslands, although it is not a stable state. These forests are prone to increasingly large, high-severity wildfires, which release a pulse of carbon emissions, shifting carbon storage from live trees to standing dead trees and woody debris (North et al. 2009, Kolb et al. 2007) have shown that biomass and carbon may fail to recover; the Horseshoe Fire was still a net carbon source 15 years after the fire (Figure 26). Savage and Mast (2005) showed that these conditions can persist for decades.

High-severity fire in ponderosa pine forests releases large quantities of CO2 to the atmosphere (Air Quality – Smoke Emissions Greenhouse Gas Emissions section). The emissions below are associated with ponderosa pine within an existing, healthy fire regime. Far more carbon is stored in the healthy ponderosa pine forest than the area recovering from a high-severity fire (Figure 27).

Figure 16. The Horseshoe Fire was still a net carbon source 15 years after the fire (photo from November 2011)

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[11] Carbon sequestration refers to the process of removing Carbon from the atmosphere and depositing it in a reservoir, while Carbon storage refers to the quantity of Carbon stored in a reservoir.

Figure 17. A healthy ponderosa pine forest

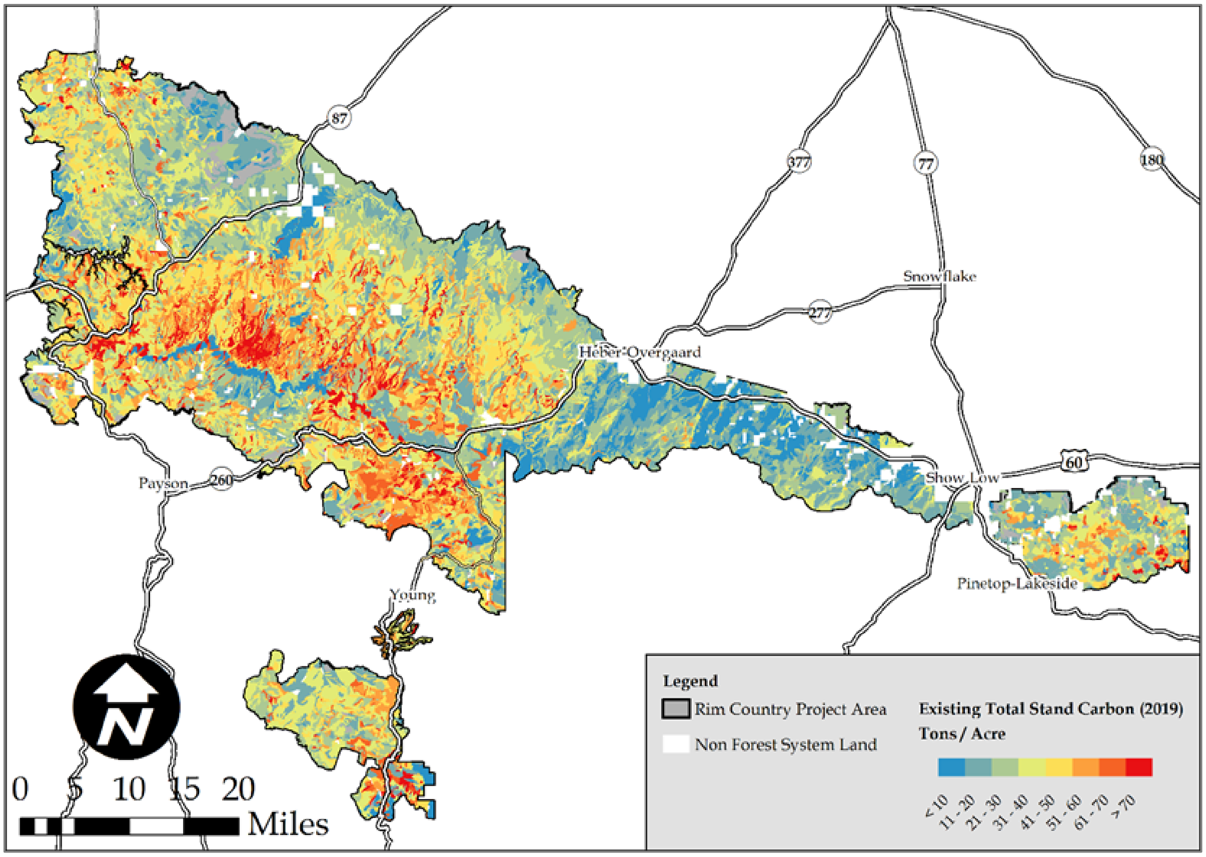

Figure 18. Total estimated above and below ground sequestered carbon in 2019 for the Rim Country project area

Environmental Consequences

Effects Common to All Alternatives

Climate scientists agree that the earth is undergoing a warming trend, and that human-caused elevations in atmospheric concentrations of carbon dioxide and other greenhouse gases are among the causes of global temperature increases. Forests serve as carbon reservoirs; however, large-scale fire events can counter this benefit by releasing significant amounts of carbon into the atmosphere. Restoration treatments including thinning and prescribed fire as identified in the proposed action, promote low-density stand structures, characterized by larger, fire-resistant trees. This strategy should afford for greater carbon storage in southwestern fire-adapted ecosystems over time (Hurteau and North 2009). Although fire-excluded forests contain higher carbon stocks, this benefit is outweighed in the long term by the loss that would be likely from uncharacteristic stand-replacing fires if left untreated (Hurteau et al. 2011). Research has also shown that the long-term gains acquired through prescribed fire and mechanical thinning outweighs short-term losses in sequestered carbon. In the long term (100 years) thinning and burning would create more resilient forests, less prone to stand-replacing fire.

Finkral and Evans (2008) examined the full effects on carbon of an actual restoration thinning treatment in a ponderosa pine forest. They found that while the treatment initially produced a 30 percent reduction in the carbon held in live trees, it significantly reduced the threat of an active crown fire, which they predicted would kill all the trees and release 3.7 tons of carbon per acre in any untreated areas. Such findings are especially important when one considers that climate change is expected to make the conditions for damaging wildfire and insect outbreaks even more prevalent in the western United States.

Both thinning and prescribed burning would help to mitigate the negative impacts of stand-replacing fire in dry, dense forests, by consuming less biomass and releasing less carbon into the atmosphere (Finkral and Evans 2008, Wiedinmyer and Hurteau 2010). Thinning, prescribed burning, or allowing wildfires that produce only low to moderate-severity effects reduces on-site carbon stocks and releases carbon into the atmosphere at a lower rate than high-severity fire. Woods et al. (2012) found that, although burn frequency affected the rate and total amount of carbon storage in a ponderosa pine forest, both 20 year and 10 year fire return intervals produced forests that were net carbon sinks, while the no action alternative forest became a net carbon source.

In the long term, approximately 100 years, the action alternatives would create more resilient forests, less prone to stand-replacing wildfires and mortality caused by severe drought, and subsequently able to store more carbon by an increased availability of live, healthy trees, harvested wood products, and energy products created from resulting slash which are used in place of fossil fuels (North and Hurteau 2011, Sorenson et al. 2011, Woods et al. 2012). Not all forest products store carbon equally. For example, products with longer average lifespans such as buildings made of wood components, have a greater potential to store carbon than short lived products such as fence posts and unmaintained gazebos. In addition, biomass products created from slash can be used in place of fossil fuels greatly reducing carbon emissions into the atmosphere (Ryan et al. 2010). Wood products, which substitute standard building materials such as steel and concrete, produce far less greenhouse gas emissions during their production while simultaneously storing carbon (Ryan et al. 2010). Thoughtful incorporation of carbon effects in landscape-scale planning should help implementation of Rim Country actions improve the ability of the project area to store carbon in a stable condition.

In a recent study McCauley (2019) found:

> Despite initial decreases in carbon in the first two decades due to accelerated harvest and prescribed fire, the moderate[1] and fast[2]-4FRI scenarios resulted in greater carbon storage by the end of the century than the status quo and no-harvest scenarios and that pattern remained consistent among the climate models. Depending on the climate model, the overall increases in Total Environmental Carbon (TEC) for the fast-4FRI scenario were 9–18% higher than the no-harvest scenario, equating to an increase of 6.3 million–12.7 million metric tons of carbon across the 4FRI project area. Climate models that predicted the largest temperature increases by late (21st) century showed greater decreases in TEC in all restoration scenarios by the end of the century (McCauley et al. 2019).

Thinning and burning, as proposed at various levels in all action alternatives would:

- temporarily lower the amount of biomass in the forest and, thus, the amount of carbon the forest stores over the short term
- reduce the amount of competition for water and nutrients, allowing the remaining trees to grow larger and, subsequently, sequester more carbon over the long term
- works with the ecology of the ponderosa pine system to restore a condition in which carbon is stored in its most stable form within the vegetation and soil
- softens the effects of uncharacteristic disturbances (such as wildfires, insects, disease), allowing natural disturbances (such as low-severity surface fires) to play their essential roles

Figure 29 shows a comparison between the alternatives of total above and below ground project carbon storage n in 2019, 2029, 2039, and 2049[12]. For comparison purposes, the total estimated amounts of forest ecosystem sequestered carbon in all U.S. forested areas declined from 740,753,201 tons in 1990, to 684,535,324 tons in 2017[13] (Domke et al. 2019). For alternative 1, this assumes that above and below ground carbon storage would increase primarily due to vegetation growth accumulation that is not reduced by drought stress or insect infestations and wildfires.

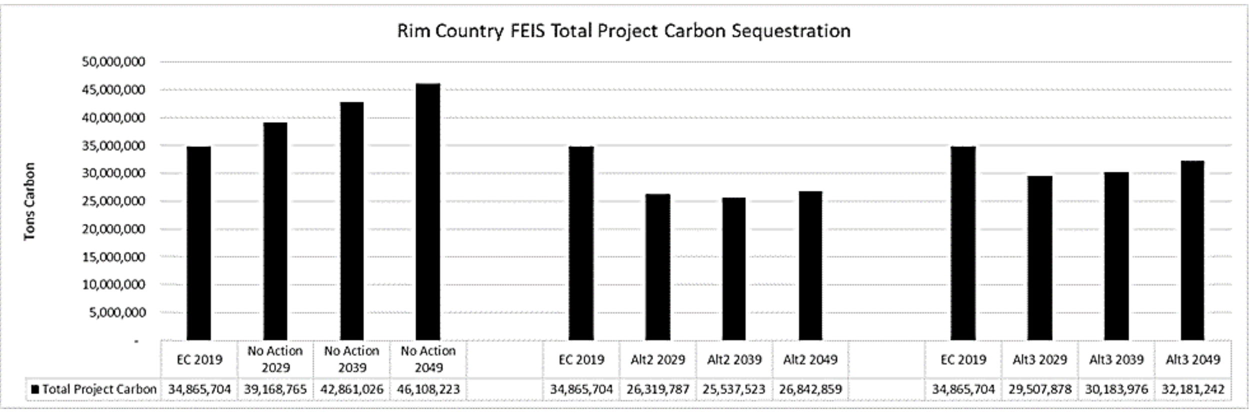

Figure 19. Comparison between the alternatives of total above and below ground carbon stores in 2019, 2029, 2039 and 2049 (tons)

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[12] The use of the term above and below ground here includes aboveground biomass; belowground biomass; dead wood; and litter.

[13] Forest ecosystem includes aboveground biomass; belowground biomass; dead wood; litter, soil (mineral); soil (organic); drained organic soil; harvested wood; products in use; and solid waste disposal sites.

Alternative 1 – No Action

Under alternative 1, Figure 30 shows an increase in total above and below ground carbon over time (2019-2049) depending upon no disturbances occurring such as from wildfires or mortality caused by severe droughts.

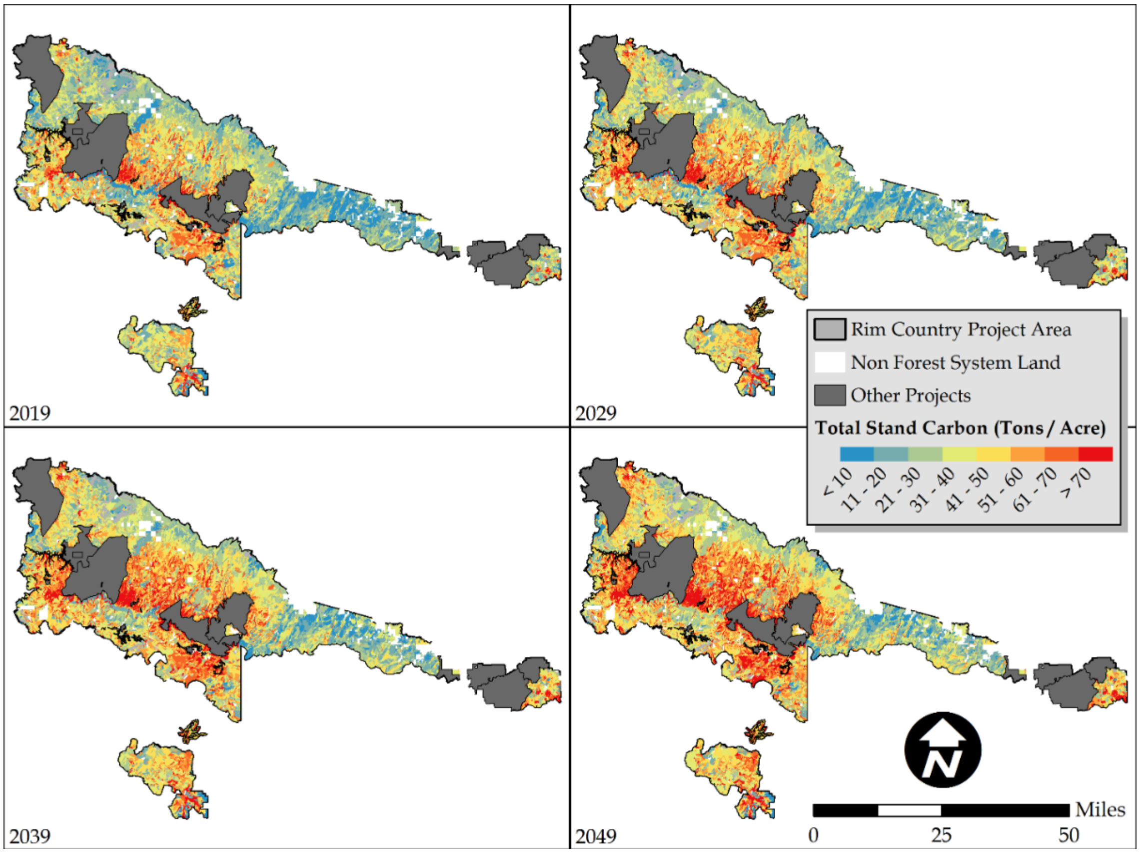

Figure 20. Alternative 1 increases in total above and below ground carbon over time - 2019-2049 (tons per acre)

Alternative 2 – Modified Proposed Action

Under alternative 2, Figure 31 shows the greatest short-term decrease in total above and below ground carbon from 2029-2049 compared to all other alternatives. The reduction in carbon would be due to forest thinning and prescribed burning. The maps do not include the potential for other disturbances that could occur such as from wildfires or mortality caused by severe droughts.

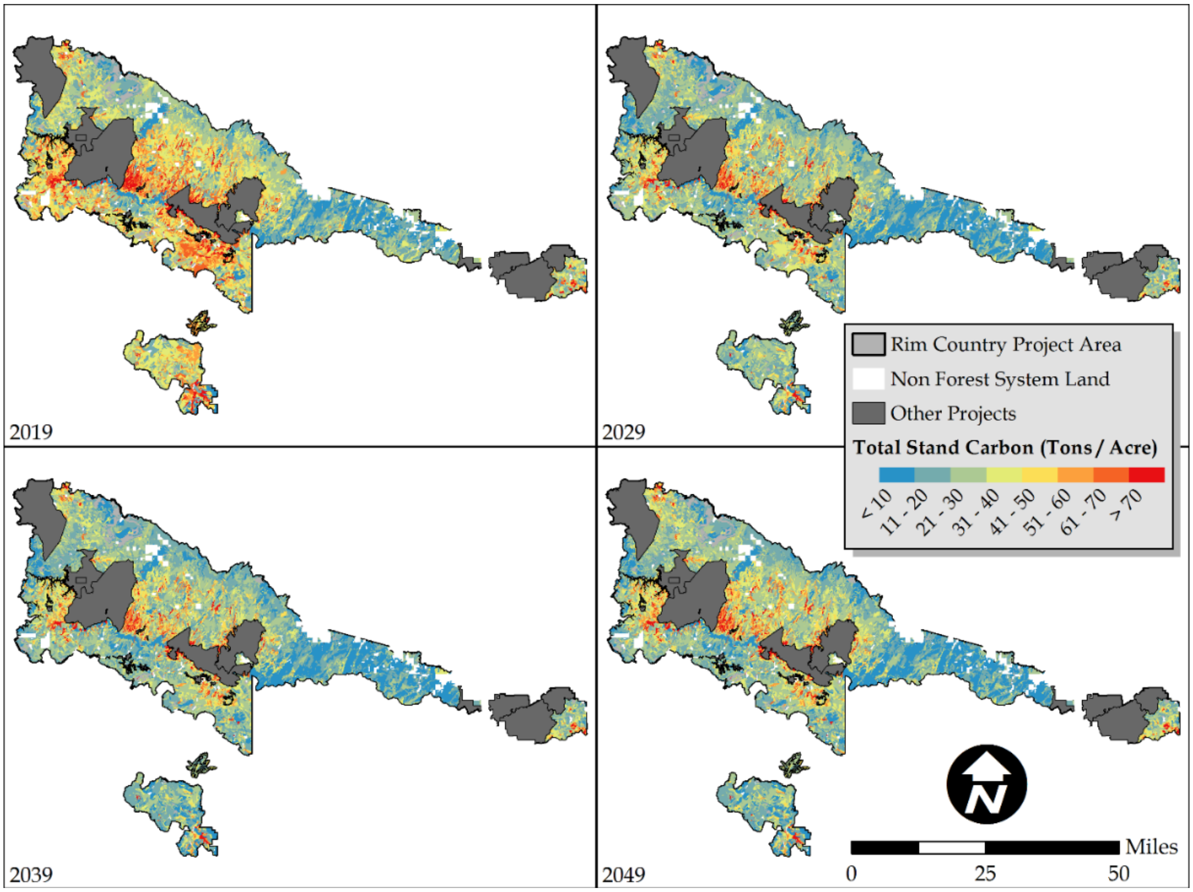

Figure 21. Alternative 2 changes in total above and below ground carbon over time 2019-2049 (tons per acre)

Alternative 3 – Focused Restoration

Under alternative 3, Figure 32 shows the short-term decrease in total above and below ground carbon from 2029-2049 more than alternative 1 and less than alternative 2. The reduction in carbon would be due to forest thinning and prescribed burning. The maps do not include the potential for other disturbances that could occur such as from wildfires or mortality caused by severe droughts.

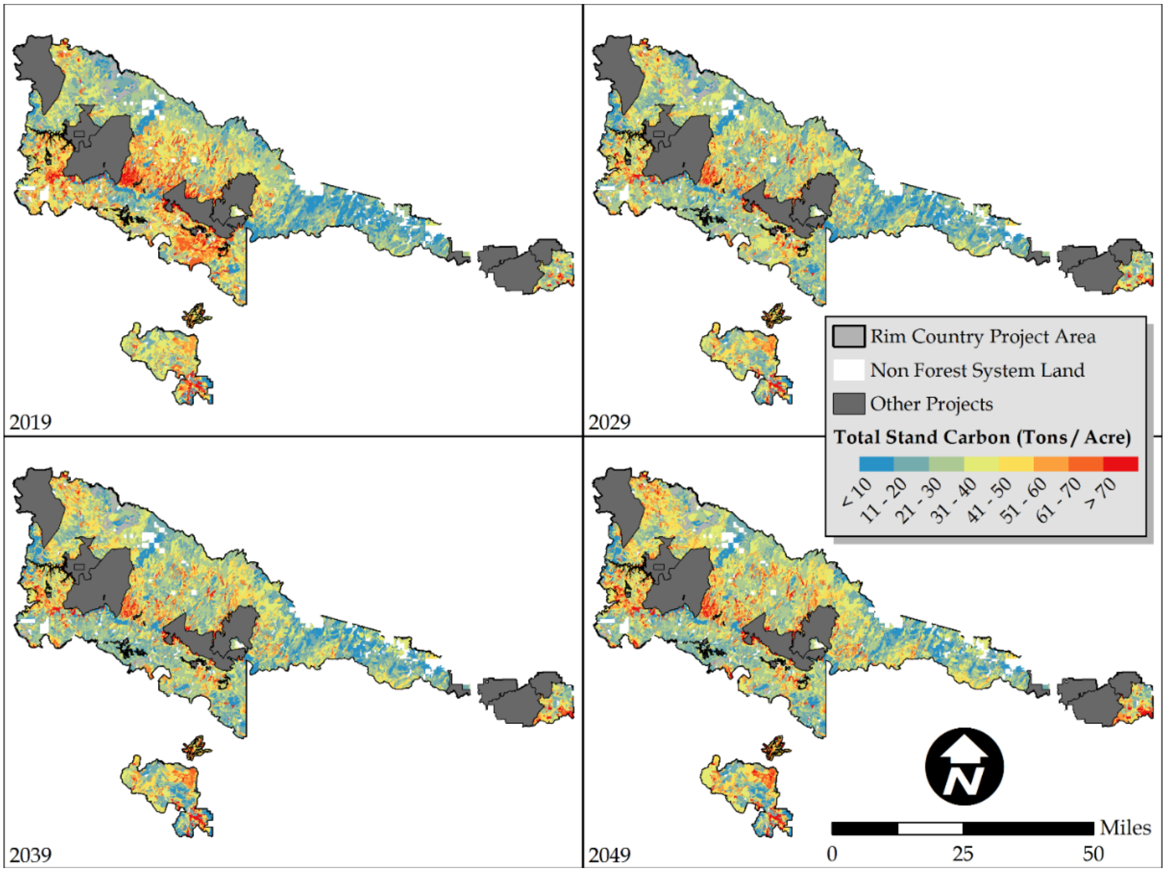

Figure 22. Alternative 3 changes in total above and below ground carbon over time - 2019-2049 (tons per acre)