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Service

**Southwestern
Region**

Fire Ecology, Fuels & Air Quality Specialist Report

Four-Forest Restoration Initiative

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Submitted by: ___________________________

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Introduction

"Although prescribed fire programs have been underway for several decades, the scale and intensity of these restoration efforts have been inadequate to reverse the overall trends of degradation in southwestern pine forests. Concerns about excessive smoke and the risks of prescribed burning have also constrained public support for the use of fire alone as a restoration treatment." (Allen et al. 2002)

Treatments designed primarily for fuels objectives differ from treatments designed for restoration objectives. Treatments based on fuel objectives can be effective at reducing fire behavior, but they do not provide the same breadth of benefits as restoration treatments designed to reset treated areas on a trajectory towards a fully functioning ecosystem (Sanchez Meador et al. 2009, Lynch et al. 2000). The goal of fuel management is to preemptively modify wildfire behavior though changes to the fuel complex (Finney 2001, Reinhardt et al. 2008). Restoration treatments mitigate fire behavior and effects, while providing multiple the additional benefits from an increasingly healthy ecosystem (Covington et al. 2001, Omi and Martinson 2004, Fulé et al. 2001a). Restoration treatments have been shown to have greater longevity in reducing undesirable fire behavior (Feidler and Keegan 2003, Triepke et al. 2011).

There are about 535 acres of proposed fuel treatments. The objective of those treatments is to reduce the potential intensity of a wildfire approaching a value at risk (Reinhardt et al. 2008). For the rest of the proposed treatments, the primary objective is restoration.

Using fire (wildfire and prescribed fire) as a management tool is difficult to do on a scale that matters because the low severity fires that typify the historic fire regime across most of the analysis area have a very low rate of spread, and would take days, weeks, or months. Challenges of using fire on a landscape scale include narrow burn windows, smoke impacts, and 100,000s of thousands of acres of forests too overgrown to manage appropriately with fire alone. This has sometimes led to mechanical treatments being used in place of fire, but one is not an appropriate substitute for the other, and the results are not equivalent. In an interview with the National Fire Protection Association in 2011, noted Fire Historian Stephen Pyne summarized it well, "Fire has a lot of other ecological effects besides consuming surplus fuel. It's a biochemical reaction - it releases nutrients and it rearranges things. That's why fire and logging are not equivalent operations. Logging takes the big stuff and leaves the little. Fire burns the little and leaves the big. One doesn't substitute for the other. It's the whole sense that these landscapes are now out of sync..."

Fire is a keystone process in healthy ponderosa pine ecosystems as well as grasslands, aspen, and other ecosystems within the analysis area. Fire Ecology is the study of the symbiotic relationship of fire with all spatial and temporal components of an ecosystem. These include climate, soil, flora, fauna, hydrology, and anything that affects, or is affected by, a fire regime. This report focuses on the effects of management actions proposed in each alternative on fire behavior and on the effects of fire. The effects of fire include emissions, which have ecological effects as well as effects on air quality.

The objective of the Four-Forest Restoration Initiative is to restore healthy ecological processes by manipulating the pattern, structure, and composition of ecosystem elements to improve ecological functions across the project area. The following questions were used to guide this analysis regarding the effectiveness of each alternative for moving the analysis area towards the desired condition.

Question 1: Would/how would proposed management actions move the area towards the desired condition of having a resilient forest by reducing the potential for undesirable fire behavior and effects? Metrics used to evaluate differences between alternatives include:

> **Type of fire** (surface or crown): Acres (quantitative measure) of each potential fire type following proposed treatments were evaluated (details on pg. 28).
>
> **Canopy Base Height (CBH) and Canopy Bulk Density (CBD)** (quantitative measures): These canopy characteristics significantly affect the potential fire type (details on pg. 29).
>
> **Surface fuel loading for this analysis, includes Coarse Woody Debris >3" diameter (CWD >3"), litter and duff** (quantitative measure): Used to qualitatively evaluate potential fire effects (details on pg. 30).
>
> **Fire Regime/Condition Class (FRCC)** (qualitative measure): FRCC was determined for ponderosa pine and grasslands which make up the largest vegetation types within the treatment area to determine the relative departure of those ecosystems from reference conditions before and following treatments (details on pg. 33 for).

Question 2: What are the expected effects of smoke/emissions from prescribed fire? Metrics used to evaluate differences between alternatives include:

> **Smoke/emissions (quantitative measure)** were evaluated quantitatively by modeled emission quantities in pounds/acre for the most common stand condition under different treatment scenarios.
>
> **Duff and Coarse Woody Debris >3 inches (quantitative measure)** produce the greatest percentages of emissions when they burn. A minimum amount of litter is necessary for a fire to move across the surface, so changes in those fuel components were modeled, and mapped for a qualitative assessment.

Purpose and Need for Action

The purpose and need for proposing an action was determined by comparing objectives and desired conditions in the Coconino NF and Kaibab NF Land Resource and Management Plans to existing conditions related to forest resiliency and forest function. Where plan information was dated or not explicit, local research and the best available science were utilized. The results of the comparison are displayed in this report in narrative, tables, graphs, and photographs. In summary, there is a need for:

- moving vegetation structure and diversity towards desired conditions by creating a mosaic of interspaces and tree groups of varying sizes and shapes
- moving towards a forest structure with all age and size classes represented as identified in the 1996 forest plan amendment for northern goshawk and Mexican spotted owl habitat
- managing for old age (pre-settlement) trees such that old forest structure is sustained over time across the landscape by moving towards forest plan old growth standards of 20% at a forest Ecological Management Area scale
- improving forest health by reducing the potential for stand density-related mortality and by reducing the level of dwarf mistletoe infection

- moving towards desired conditions for vegetation diversity and composition by maintaining and promoting Gambel oak, aspen, grasslands and pine-sage
- moving towards the desired condition of having a resilient forest by reducing the potential for undesirable fire behavior and its effects
- moving towards the desired condition of maintaining the mosaic of tree groups and interspaces with frequent, low-severity fire by having a forest structure that does not support wide-spread crown fire
- moving toward desired conditions in riparian ecosystems by having springs and seeps function at, or near, potential
- moving towards desired conditions for degraded ephemeral channels by restoring channel function
- moving towards restoring select closed and unauthorized roads to their natural condition by restoring soil function and understory species

Laws, Regulations and Policy affecting Fire Ecology, Fuels and Air Quality

National Level Direction

Federal laws, regulations, and policies affecting this project include:

- **Executive Order 13112; Invasive Species** (64 FR 6183, February 8, 1999). The 4FRI proposes ground disturbing activities, such as mechanical thinning, spring/stream restoration, and prescribed fire which may provide opportunities for invasive species to become established. To comply with this Executive Order, 4FRI would monitor populations within the treatment area, and restore native species and habitat conditions in areas that are invaded.
- **Organic Administration Act, June 4, 1897 (16 U. S.C.551)**. This act authorizes the Secretary of Agriculture to make provisions for the protection of national forests against destruction by fire. Treatments proposed by 4FRI would support the intent of the Organic Administration Act by reducing the potential for undesirable fire behavior and effects.
- **National Environmental Policy Act of 1970**. Compliance with this act requires analysis of proposed actions, including prescribed fire, so an analysis of the effects of prescribed fire as well as the resulting emissions are included as part of the documents.
- **Clean Air Act (CAA), as amended 1977 and 1990**. This act provides for protection and enhancement of national air resources by regulating air emissions from stationary and mobile sources. This law authorized the EPA to establish National Ambient Air Quality Standards (NAAQS) to protect public health and welfare and to regulate emissions of hazardous air pollutants. NAAQS were established for specific pollutants emitted in significant quantities throughout the country that may be a danger to public health and welfare. Areas that do not meet or "attain" the standards become non-attainment areas and must demonstrate to the public and the EPA how standards will be met in the future via a State Implementation Plan (SIP). Section 112 of the CAA addresses emissions of hazardous air pollutants, including smoke from wildfires and prescribed fires. Section 160 of the CAA requires measures "to preserve, protect, and enhance the air quality…" in national parks, national wilderness areas, and other areas of special national or regional natural, recreational, scenic, or historic value. Some of these are classified as Class I attainment areas. Implementation of the CAA is largely the responsibility of the states which may develop programs that are more restrictive than the CAA requires but never less. The CAA mandates states have a SIP to regulate pollutants. The 4FRI proposes using prescribed fire on 593,211 acres. To ensure compliance with the CAA, emissions from these acres were evaluated to determine the potential effects.

The "1995 Federal Wildland Fire Policy" is the principle document guiding fire management on Federal lands. The Policy was endorsed and implemented in 1995. The 1995 Federal Wildland Fire Policy was reviewed and updated in 2001 (Review and Update of the 1995 Federal Wildland Fire Management Policy, 2001). In 2003 the Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy was approved. The 2003 Implementation Strategy was replaced in 2009 with the adoption of the Guidance for Implementation of Federal Wildland Fire Management Policy which states that:

> “Fire, as a critical natural process, will be integrated into land and resource management plans and activities on a landscape scale, and across agency boundaries. Response to wildland fire is based on ecological, social, and legal consequences of fire. The circumstances under which a fire occurs, and the likely consequences on firefighter and public safety and welfare, natural and cultural resources, and values to be protected dictate the appropriate management response to fire.”

The Four-Forest Restoration Initiative (4FRI) is not intended to dictate any response to wildfires. However, the implementation of an action alternative would increase the decision space for Agency Administrators making decisions on how to manage lightning caused fires, while reducing the potential for undesirable fire behavior and effects. The effects of planned ignitions (prescribed fires) are discussed. This document provides direction, consistent with the forest plans of the Coconino and Kaibab National Forests regarding the use of planned ignitions in the proposed treatment area.

The 2009 Guidance for Implementation of Federal Wildland Fire Management Policy (USDA and USDOI 2009) provides the terminology related to fire used in this report. ‘Wildland fire’ is a general term describing any non-structural wildland fires, categorized in two distinct types:

- **Unplanned ignitions (wildfire)**. Wildfires are unplanned ignitions, including escaped prescribed fires that are declared wildfires. Wildfires may be ignited by natural causes, namely lightning, or human caused (NWCG 2009).
- **Planned ignitions (prescribed fire)**. Planned ignitions are fires initiated by the intentional initiation of a wildland fire by hand-held, mechanical or aerial device where the distance and timing between ignition lines or points and the sequence of igniting them is determined by environmental conditions (weather, fuel, topography), firing technique, and other factors which influence fire behavior and fire effects (NWCG 2009). “Prescribed fire” includes pile burning, jackpot burning, broadcast burns or other wildland fires originating from planned ignitions to meet specific objectives identified in a written, approved, burn plan for which NEPA requirements (where applicable) have been met prior to ignition (NWCG 2009, FSM 5100).

This report discusses effects of unplanned ignitions, but is not intended to provide any direction regarding the management of unplanned ignitions. This document is intended to provide direction, consistent with the forest plans of both the Coconino and Kaibab regarding the use of planned ignitions (prescribed fire) in the treatment area.

State Level Direction

Arizona Department of Environmental Quality (ADEQ) air quality regulations: Smoke produced by prescribed fires is subject to regulation by EPA regulations as enforced by the ADEQ. The State of Arizona has a State Implementation Plan that outlines how the State is implementing the goals of the Clean Air Act, and Statutes that regulate burning, including burning on Federal and State lands. Two types of air quality impacts are addressed by these laws and regulations: health hazards from pollutants, and visibility impacts in Class I Air Sheds.

The key policy resulting from the Enhanced Smoke Management Plan pertaining to prescribed burns in Arizona is Arizona Revised Statute Title 18 Chapter 2 Article 15. This law regulates fires managed on Federal and State lands, as well as on Tribal, private, and municipal jurisdictions where there is a Memorandum of Understanding with the Arizona Department of Environmental Quality (ADEQ). This Statute defines the request and approval process for all burns, and provides the mechanisms for tracking emissions from burns. Enforcement of this statute is facilitated by the Smoke Management Group, housed at ADEQ in the Air Quality Division. Prescribed fires implemented as treatments under the 4FRI would be subject to these same regulatory policies and statutes and meet the Enhanced Smoke Management Plan. The State of Arizona has an Enhanced Smoke Management Plan (ESMP) that is consistent with the Western Regional Air Partnership (WRAP) Enhanced Smoke Management Programs for Visibility. The State of Arizona conducts annual meetings of all affected parties to discuss smoke management issues and objectives. This approach calls for programs to be based on the criteria of efficiency, economics, law, emission reduction opportunities, land management objectives, and reduction of visibility impacts. An Enhanced Smoke Management Plan (ESMP) comprises a series of key policies and management practices. In general the ESMP must specifically address visibility effects and apply to all fire sources as do all smoke management plans in the State of Arizona. The ESMP should also apply uniformly to source sectors or be tailored to source sectors and/or geographical areas. In addition, the ESMP must provide the opportunity to work collaboratively with state, tribal, local, and federal agencies, and private parties while considering the criteria of efficiency, economics, law, emission reduction opportunities, land management objectives, and reduction of visibility impact.

Problem or Nuisance Smoke is defined by the Environmental Protection Agency (EPA) as the amount of smoke in the ambient air that interferes with a right or privilege common to members of the public, including the use or enjoyment of public or private resources. While there are no laws or regulations governing nuisance smoke, it can limit opportunities of land managers to use fire. Public concerns regarding nuisance smoke often occur long before smoke exposures reach levels that violate NAAQS (Achtemeier et al. 2001). “Probably the most common air quality issues facing wildland fire managers are those related to public complaints about nuisance smoke...about the odor or soiling effects of smoke, poor visibility, and impaired ability to breathe or other health-related effects. Sometimes complaints come from the fact that some people don’t like or are fearful of smoke intruding into their lives (Hardy et al. 2001b).” Prescribed fire treatments proposed though the action alternatives are likely to increase Nuisance Smoke.

Agency Level Direction

USDA Forest Service

Forest Service Manual 5100 (page 9) includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. The objectives of fire management on lands managed by the USFS are:

1. Forest Service fire management activities shall always put human life as the single, overriding priority.
2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement.

Coconino and Kaibab National Forests' Land & Resource Management Plans (LRMPs)

Forest Plans provide specific goals, objectives, standards, and guidelines for management activities on National Forest lands. The Coconino (USDA 1987, as amended 2012) and Kaibab (USDA 2014) National Forest have developed forest-wide and location-specific standards and guidelines for reducing the risk of uncharacteristic fire effects to resources.

The forest plans provide specific goals, objectives, standards, and guidelines for management activities on the Coconino and Kaibab National Forests. The forest-wide, management area (MA), or geographic area (GA) standards and guidelines referenced in Appendix A have fire-related (management of or reduced risk to resources values from) relevance to this analysis. Directions for other resources aimed at reducing the risk of fire have been incorporated into this analysis as appropriate.

Relevant direction from the 1987 Coconino National Forest Land Management Plan and the 2008 and 2014 Revisions of the Kaibab National Forest Land Management Plan is in Appendix A on page 288.

Alternatives Analyzed

Alternative A

This is the no action alternative as required by 40 CFR 1502.14(c). There would be no changes in current management and the forest plans would continue to be implemented. Approximately 166,897 acres of current and ongoing vegetation treatments and 195,076 acres of prescribed fire projects would continue to be implemented adjacent to the treatment area. Approximately 43,041 acres of vegetation treatments and 58,714 acres of prescribed fire and maintenance burning would be implemented adjacent to the treatment area by the Forests in the foreseeable future (within 5 years). Alternative A is the point of reference for assessing action alternatives B through E.

Alternative B

Alternative B, the proposed action, reflects incorporating comments received during scoping and collaborative efforts from January 2012 to August 2012. This alternative would mechanically treat 384,966 acres of vegetation and utilize prescribed fire on 583,330 acres (Table 1). It incorporates comments and recommendations received during eight months of collaboration with individuals, agencies, and organizations. It proposes mechanically treating up to 16-inch dbh in 18 Mexican spotted owl (MSO) Protected Activity Areas (PACs) and includes low-severity prescribed fire within 70 MSO PACs, including 54 core areas. Three non-significant forest plan amendments on the Coconino NF and two non-significant forest plan amendments on the Kaibab NF would be required to be in compliance with the plans.

Alternative C

Alternative C is the preferred alternative. Alternative C would mechanically treat 431,049 acres utilize prescribed fire on 586,110 acres (Table 1). It responds to Issue 2 (conservation of large trees), and Issue 4 (increased restoration and research). It adds grassland treatments on the Kaibab NF, incorporates wildlife and watershed research on both forests, and mechanically treats and uses prescribed fire within the proposed Garland Prairie Research Natural Area (Kaibab NF). It proposes mechanically treating up to 17.9 inch dbh in 18 MSO PACs and using low-severity prescribed fire in 70 MSO PACs, including 54 core areas. Key components of the stakeholder-created Large Tree Retention Strategy are incorporated into the alternative's implementation plan. Three non-significant forest plan amendments on the Coconino NF and three non-significant amendments on the Kaibab NF would be required to be in compliance with the plans.

Alternative D

Alternative D would mechanically treat 384,966 acres of vegetation and utilize prescribed fire on 178,441 acres (Table 1). This alternative was developed in response to Issue 1, Prescribed Fire Emissions. It decreases the acres that would receive prescribed fire by 30% compared to Alternative B (proposed action). It proposes mechanically treating up to 17.9-inch dbh in 18 Mexican spotted owl (MSO) Protected Activity Areas (PACs) but the PACs would not be treated with prescribed fire. Three non-significant forest plan amendments on the Coconino NF and two amendments would be required on the Kaibab NF to be in compliance with the plans.

Alternative E

This alternative would mechanically treat 403,218 acres of vegetation and utilize prescribed fire on 586,110 acres (Table 1). It responds to Issue 3 (post-treatment landscape openness and canopy cover), and Issue 5 (range of alternatives and comparison between alternatives). It is similar to Alternative C in that it adds acres of grassland treatments on the Kaibab NF and incorporates wildlife and watershed research on both forests. It proposes mechanically treating up to 9-inch dbh in 18 MSO PACs and includes low-severity prescribed fire within 70 MSO PACs, excluding

54 core areas. Key components of the stakeholder-created Large Tree Retention Strategy are incorporated into the alternative's implementation plan. No forest plan amendments are proposed.

Table 1.Summary of those Alternatives that were analyzed in detail.

Proposed Activity	Alt A	Alt B	Alt C	Alt D	Alt E
Vegetation Mechanical Treatment	Under forest plan implemen-tation	384,966 (acres)	431,049 (acres)	384,966 (acres)	403,218 (acres)
Prescribed Fire (all)		583,330 (acres)	586,110 (acres)	178,441 (acres)	403,218 (acres)
Burn Only		198,364 (acres)	155,061 (acres)	178,441 (acres)	177,801 (acres)
MSO PAC Habitat Treatments		Mechanically thin up to 16 inch dbh in 18 PACs (excluding core areas); 70 MSO PACs treated with prescribed fire; 54 core areas are excluded	Mechanically thin up to 17.9 inch dbh in 18 PACs (core areas are excluded) 70 MSO PACs treated with prescribed fire; core areas are excluded in 16 of them	Mechanically thin up to 17.9 inch dbh in 18 PACs (core areas are excluded), and manage these PACs for a minimum of 110 BA	Mechanically thin up to 9 inch dbh in 18 PACs (core areas are excluded); 70 MSO PACs treated with prescribed fire; 54 core areas are excluded
Grasslands mechanical		0	48,161 acres	0	48,161 acres
Grassland restoration		11,185 acres	11,185 acres	11,185 acres	0
Springs/Seeps Restored		74 Springs/Seeps			
Springs Protective Fence Construction		Up to 4 miles			
Aspen Protective Fencing		Up to 82 miles			
Ephemeral Stream Restoration		39 miles			
Road and Route Decommission		Up to 860 miles (Combines existing roads and unauthorized roads proposed for decommissioning)			
Temporary Road Construction		Up to 520 miles (Includes temporary roads and previously decommissioned roads proposed for temporary construction to be decommissioned when project is complete)			
Road Reconstruction		Up to 30 miles			

Methodology

To complete a useful analysis of the 4FRI project, fire behavior, emissions, and fuel characteristics that affect fire behavior and emissions were modeled. All mechanical treatments were modeled to have occurred in 2012, and all areas proposed for burning were modeled to have burned in 2015 and again in 2019 (except for the aspen, which only burned in 2015). In reality, treatments would be spread out over many years. The specific timing of mechanical treatments would depend on the contract/contractor, road conditions, and numerous factors that are impossible to predict years in advance. Prescribed fire implementation depends on weather conditions, fuel conditions, other fires in the area, and multiple other variables that are impossible to predict weeks in advance. During the implementation period, untreated areas would be vulnerable to the effects as described in Alternative A (no action). The prioritization of treatment areas is a part of implementation, based on modeled results from this document, and district priorities. Results were analyzed to evaluate the effectiveness of each action Alternative Against the “No-Action” Alternative. Concepts that are necessary for a thorough understanding of this analysis are discussed briefly in this section or when they are first presented. Additional information on modeling may be found in Appendix G.

Modeling results presented do not include partial treatment, such as would be the case partway through implementation. Details on the treatments modeled can be found in the Silvicultural report (McCusker et al. 2014).

Fire behavior was not remodeled for the entire project area after the Slide Fire in May of 2014. The acres where the proposed treatment area overlapped with the area burned in the Slide Fire was remodeled (pg. 288), but the tables in the report were not adjusted.

Data is typically reported to the nearest acre, mile, or percentage. Most values have been rounded from their actual decimal values. Totals were calculated before any values were rounded in order to give the most accurate sum. Any apparent inconsistency between the total values reported in a table and a sum resulting from adding up individual values in a table typically accounts for a discrepancy of about 1% in the case of rounding percentages or miles, and <2 acres in the case of acres.

In an attempt to avoid confusion over these kinds of inconsistencies, minor adjustments to the numbers in the EIS document were made to allow for numbers in tables to add up correctly as displayed. As a result, some numbers may not be exactly the same in the EIS document as compared to this report. The numbers in this report are the most accurate and any differences do not alter any determination of effects.

The discussion of effects assumes that all BMPs, design features, and mitigations described in Appendix E are applied during implementation. Effects discussions are based on modeled fire behavior and emissions, for which the methods and assumptions are detailed in this section and in Appendices D and E.

Emissions Modeling

Air impacts are felt, seen, and measured by the concentration of emissions at a given location, be it a town, a house, or an air quality monitor. There are no reliable methods of predicting concentrations at specific locations years in advance of a prescribed fire. This analysis does not attempt or pretend to predict the actual total emissions that would be produced under each alternative. Rather it aims to present a rationale for which alternatives are likely to produce “less” or “more” emissions. It assumes that, over time, there is some degree of correlation between total emission production, and total air quality impacts. Impacts are measured and evaluated based on the concentration of emissions at a specific location, not the total amount of emissions. Though meteorological conditions vary immensely by time of day, time of year, and from one weather system to the next, over the course of years the averaging effect over time of these varying conditions supports a correlation between total emissions and total impacts (Kleindienst 2012).

Smoke/emissions were evaluated both qualitatively and quantitatively by modeled emission quantities in pounds/acre for the most common stand condition under different treatment scenarios. Additionally, changes in those fuel components which produce the greatest percentages of emissions when they burn were modeled, and mapped. These include litter, duff, and CWD>3 inches (Lutes et al. 2009). Canopy fuels were not modeled to allow for a more accurate comparison because, while canopy fuels can make up the bulk of the initial burst of emissions from a crown fire, they would not be a significant contributor in prescribed fires in the vegetation types within the project area.

Emissions were modeled with the First Order Fire Effects Model (FOFEM) for a group of stands that represent one of the most common conditions on the landscape (see Appendix F for details). These conditions have some of the highest emissions potential of all stands within the proposed treatment area.

Fire Behavior Modeling

The intent of the modeling was to identify the areas at greatest risk of high severity fire effects. If conditions are modeled at conditions that are too extreme, or too mild, it can ‘wash out’ the area modeled, much as turning the contrast on a computer or TV screen up or down causes details to be lost. Modeling conditions that can support a large, high severity fire, but do not lose the contrast and variability across the landscape is the best way to identify areas at the greatest risk. Additionally, Roccaforte et al. (2008) showed that, as wind speed is increased in modeling, additional areas of extreme fire behavior that show up are likely to be in the vicinity of those acres already shown. This can identify opportunities to break up larger areas of potential undesirable fire behavior that would show up with more extreme conditions.

Some of the public have asked about modeling fire behavior under 85th and/or 97th percentile weather conditions. When weather percentiles are modeled, it is less representative of real fire behavior than modeling the conditions under which large fires have actually occurred (see appendix D for more details). For example, modeling for the 97th weather percentile for temperature, relative humidity, wind speed, fuel moistures, etc. would all be modeled as if the 97th percentile for all these parameters occurred on the same day – which has not happened in at least 12 years (see percentile analysis in Appendix D). Modeling fire behavior under the weather conditions under which a large fire is known to have occurred allows for calibration of the model (McHugh, 2006), increasing the accuracy of post-treatment modeling results. This analysis used the Schultz Fire, which was a wind driven fire that burned in 2010 on the Coconino NF, including some of the area analyzed for the 4FRI. Conditions under which the Schultz Fire burned are not unique, and are not extreme for the area. This made it representative of some of the most likely fire behavior and effects that are experienced in the 4FRI area annually. Although the steady wind speed at the Flagstaff Remote Automated Weather Station (RAWS) was generally over 95th percentile, other parameters were at or below the 90th percentile (Table 2). Fire type was analyzed using the weather parameters from the Schultz Fire (Table 2).

Fuel moisture and weather parameters used were based on readings from the weather station at the Flagstaff airport on June 20th, 2010. That was the day the Schultz Fire started, the day it burned the most acres, and the day it produced the majority of the high severity effects. The Flagstaff weather station is the closest one to Schultz Pass, where the fire started. The conditions were not extreme, and similar conditions occur on many days every year, as indicated by the weather parameters shown (Table 2). However, although FlamMap 3.1 (used for modeling fire behavior in this analysis) can account for some variations to wind speed and direction based on topography and surface heating, all pixels 'burn' at the same instant, outputs do not show the effects of shifting wind directions. On a real landscape, areas such as chimneys, saddles, passes, and canyons can channel winds, significantly increasing the speed and the potential for extreme fire behavior. Conversely, areas sheltered from the wind have lower potential for extreme fire behavior.

Table 2. Below are the fire weather conditions used for modeling, Schultz Fire conditions, and 97th percentile weather conditions.*

Variable	Weather parameter used for modeling (percentile)	Schultz Fire Weather**	97th percentile weather*
Maximum Temperature (°F)	77°F (50th percentile)	77°F (50th percentile)	90°F
Minimum RH (%)	11 (85th percentile)	11 (85th percentile)	7%
Maximum 20' Wind speed	20 (95th percentile)	~23** (98th percentile)	22
1 hr fuel moisture (%)***	4 (74th percentile)	3 (86th percentile)	2%
10 hr fuel moisture (%)***	4 (90th percentile)	3 (95th percentile)	3%
100 hr fuel moisture (%)***	6 (90th percentile)	6 (90th percentile)	5%

*Percentiles were determined using readings from the Flagstaff RAWS through April 15th though September 15th, 1968 – 2012.

**Weather conditions change throughout the day, and the effects of topography and surface heating produced gusts over twice as high on Schultz Pass as those shown above. At the RAWS station, wind speed averaged ~19 mph, gusting up to 28. We used 20 mph in order to preserve the contrast in potential fire behavior.

***When modeling fire behavior, fuel moistures are set for each 'fuel model'. Fuel moistures above indicate what was applied to the majority of the acres modeled.

Fire behavior (surface, passive and active crown fire) for existing conditions was modeled for the project area using default Landfire Refresh 08 data. Results were reviewed by local fire experts (district, forest, National Park Service and local non-federal firefighters and managers), and adjustments made to improve model accuracy. The process was repeated to further improve results.

Fire behavior for post-treatment conditions was modeled using FlamMap and a combination of Landfire Refresh 2008 data and FVS-FFE data (LANDFIRE 2010a, LANDFIRE2010b). Post-treatment canopy characteristics and fuel loading were modeled with the Fire and Fuels Extension (FFE) (Reinhardt and Crookston 2003) to the Forest Vegetation Simulator, FVS (Dixon 2002).

In fire modeling, fuel models are critical variables affecting outputs (such as fire type). Post treatment fuel models must to take into account changes in total fuel loading and fuel structure. The process used to assign post-post treatment fuel models is included in Appendix D.

Landfire data must be manipulated to produce post-treatment conditions for fire modeling, so outputs from FFE were used to develop post-treatment fuel models. The modeled post-treatment fire behavior data are the result of combined stand data from the Forest Vegetation Simulator (FVS) and Landfire Refresh 2008 data. Post-treatment fire type was modeled by using outputs from FVS-FFE to adjust the percent of change to canopy characteristics and surface fuel loading and to inform the assignation of post-treatment fuel models. Details of the process for assigning post-treatment fuel models for modeling fire type are included in Appendix D.

FVS outputs used were stand averages that were used to give a general idea of what stand conditions would look like, but could not address the spatial distribution of specific metrics on the same scale as the Landfire data. Landfire/FlamMap data are gridded (raster) data, with a resolution of 30 meters. FVS/FFE data is vector based, with smallest units being the size of individual stands. The 'hills and valleys' of the stand characteristics were smoothed out when the stand data were averaged, resulting in the fire behavior also being 'smoothed out' somewhat. This means that subtle differences between alternatives, particularly B and E are not likely to be apparent in the modeling outputs.

A stand is 'typed' as a single vegetation type, though it may have a mix, for example, of pine forest and grassy openings. Habitat types (e.g. core areas, restricted habitat, etc.) were classified at the stand level to facilitate silvicultural analysis. Fire behavior was modeled at the 30 meter scale. The resolution for modeled fire behavior is 30 meters.

Metrics

The following metrics were used to evaluate the effectiveness of the alternative/s in meeting the purpose and need of the project, and are described in detail below: Fire Type, Canopy Characteristics, Surface Fuel Loading, Fire Regime Condition Class, Emissions (Table 3). A comparison of the outputs of these metrics between alternatives is displayed in Table 136.

Table 3. Brief description of the metrics used in this analysis.

Metric	Application
Crown fire potential	Indicates potential fire behavior at all scales analyzed. Crown fire is an indicator of fire effects.
Canopy Base Height (CBH)	CBH is an indicator of the potential for crown fire initiation
Canopy Bulk Density (CBD)	CBD is an indicator of the potential for active crown fire and fire intensity
Canopy cover (CC)	CC is an indicator of the potential for active crown fire and affects surface conditions relating to surface fire behavior and effects (temperature, wind, rh).
Fire Regime/Condition Class (FRCC)	FRCC is used at a coarse scale to indicate how out of sync ponderosa pine ecosystems are in relation to reference conditions
Vegetation Condition Class (VCC)	VCC is used at a coarse scale to indicate how out of sync ponderosa pine vegetation is in relation to reference conditions
Surface fuel loading	Surface fuel loading is used to indicate potential for surface fire severity and intensity, particularly in areas where there may not be crown fire. It

(Litter + Duff + CWD)	is also used as an indicator of potential emissions.
Emissions	Various components of emissions (CO, particulate matter, etc.) were modeled based on various treatment types, and discussed in context with each alternative.

Fire Behavior (Fire Type)

In ponderosa pine and most of its associated vegetative communities, the type of fire behavior is a good indicator of the health and resilience of the ecosystem. Crown fire in ponderosa pine produces high severity effects. Desired condition is for less than 10% of the treatment area to support crown fire under the conditions modeled. In grasslands, desired conditions are for less than 3% crown fire. Types of fire include active crown fire, passive crown fire, and surface fire as described below.

a. **Active Crown fire:** A fire that advances from crown to crown in the tops of trees or shrubs (NWCG 2008). Active crown fires generally produce high severity effects and are considered 'stand replacing' because they topkill, kill and/or consume most of the dominant overstory vegetation. Active crown fire is linked to surface fire, perpetuated by a combination of surface and canopy fuels.

    i. **Conditional Crown Fire:** Conditional crown fire is a fire that moves though the crowns of trees, but is not linked to surface fire. Crown fire must initiate in an adjacent stand and spread through canopy fuels alone. Conditional crown fires burn in areas where canopy base heights are too high for crown fire to initiate within the stand, but there is sufficient horizontal continuity of canopy fuels to carry a crown fire if initiated.

b. **Passive Crown Fire:** Individual trees or groups of trees 'torch', as fire moves up into the canopy, ignited by the passing front of a surface fire. The fire climbs up ladder fuels (low branches, shrubs, or herbaceous vegetation that can produce flame lengths long enough to allow a fire to 'climb' into the crown of a tree) into the crown of a tree, igniting the crown ('torching' it), but does not spread very far into adjacent crowns (NWCG 2008).

c. **Surface Fire:** These are fires that burn in surface fuels only. Such fires consume surface fuels such as litter, duff, dead/down woody fuels, and herbaceous or shrubby fuels that are cured enough to be available fuel. Surface fire can be beneficial or detrimental in ponderosa pine, depending on the fuel loading, and the conditions under which the fire burns.

Fire type was evaluated down to the subunit (SU) in order to facilitate a more thorough analysis of specific fire effects to different areas. Fire type was also evaluated at the vegetation/habitat level in order to determine potential effects by ecosystem characteristics as well. For example, 100 acres of active crown fire in a 200,000 acre unit may not be considered a problem. If those 100 acres occurred on a 400 acre PAC, those 100 acres would be more of a concern because they would represent a larger percentage of whatever habitat or area they burned in). Therefore, fire type is considered at the project scale (all treatment areas), the Restoration Unit, and the subunit, as well as the vegetation type and habitat type.

Canopy Characteristics and Surface Fuel loading

The ability of a forest to maintain its resilience to fire depends, in part, on how close it is to threshold conditions. Canopy characteristics and surface fuel loading combine to produce combinations of surface fire intensity (flame length is a good proxy for fireline intensity – the higher the intensity, the longer the flame length) and physical structure (the height, density, and horizontal and vertical continuity of canopy fuels) that can produce crown fire under a given set of conditions (Keyes and O'Hara 2002, Stratton 2006). The closer conditions are to a threshold, the faster they would deteriorate to a point where crown fire is possible.

Reducing canopy fuel loading may increase surface fire behavior because more wind and sunlight can reach the surface, however overall fire behavior is more significant:

> "Modifying canopy fuels as prescribed in this method may lead to increased surface fire intensity and spread rate under the same environmental conditions, even if surface fuels are the same before and after canopy treatment. Reducing CBD to preclude crown fire leads to increases in the wind adjustment factor (the proportion of 20-ft windspeed that reaches midflame height). Also, a more open canopy may lead to lower fine dead fuel moisture content. These factors increase surface fire intensity and spread rate. Therefore, canopy fuel treatments reduce the potential for crown fire at the expense of slightly increased surface fire spread rate and intensity. However, critical levels of fire behavior (limit of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires, as all crown fires are uncontrollable. Though surface intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally controllable" (Scott 2003).

However, following prescribed fire, surface fuel loading would be lower, effectively decreasing the potential fire intensity.

Canopy Characteristics

Canopy Bulk Density (CBD) for ponderosa pine and pine-oak stands. CBD is a good indicator of potential active crown fire (Stratton 2009, Scott 2003; Keane et al. 2005, Scott and Reinhardt 2002). The desired condition is for average CBD to be less than 0.05 kg/m^3 in ponderosa pine.

Canopy Base Height (CBH) is a critical factor in crown fire initiation, and can be used as an indicator of the potential for crown fire initiation (Agee and Skinner 2005, Stratton 2009, Scott 2003, Scott and Reinhardt 2002). The desired condition is for CBH to be greater than 18 feet in ponderosa pine (Nicolet 2012).

Canopy Cover (CC), along with CBD and CBH, is an important component for modeling and evaluating potential fire behavior and/or effects, affecting the potential for active crown fire. There are no desired conditions for CC, but the trends shown in modeling, combined with CBH and CBD are a good indicator of the improvement or deterioration of forest health in regard to potential fire type.

Fuel models (see glossary), used for modeling fire behavior, rarely use measured canopy characteristics. Modeling fire behavior entails 'gaming' fuel models, adjusting various characteristics until the modeled fire behavior most closely represents known fire behavior (in this analysis, the Schultz Fire). In this manner, canopy characteristics are adjusted by the percentage change indicated by FVS (details in the Silviculture report). Canopy characteristics contribute significantly towards the type of fire that can occur (Scott and Reinhardt 2001). CBD, CBH, CC directly affect the incidence and behavior of crown fires and are used for modeling potential fire behavior (Scott 2003, Scott and Reinhardt 2005, Agee and Skinner 2005).

Stand data were used with FVS (see below) to simulate post-treatment changes for the different alternatives. Canopy characteristics were evaluated by desired openness (details in the Silviculture report).

The desired conditions are written for silvicultural stand averages and therefore allow for some areas within a stand to be outside of the desired condition range but surrounded by conditions closer to overall desired conditions. For example the desired condition for crown bulk density (CBD) in ponderosa pine is for an average that is below .05 kg/m^3. This could mean that many patches within the stand have much higher CBD but have interspaces between these dense groups of trees where CBD is much lower than .05 and therefore the average for the stand is within acceptable limits. Where CBD is higher it is important to also have higher canopy base height (CBH) (Nicolet 2011).

Surface fuel loading

There is no desired condition for total surface fuel loading, though it can contribute significantly to fire effects, fire behavior, and air quality. There is forest guidance for both forests for coarse woody debris based on wildlife and soil needs. However, there are additional considerations that contribute either directly or indirectly to meeting desired conditions and forest plan guidance, including fire hazard, reference conditions, air quality, and soil heating (Neary et al. 2005, Brown et al. 2003, Passovoy and Fulé 2006). In order to allow a wide buffer for modeling error, and variability on the landscape, in this analysis, 20 tons/acre was used as a 'recommended' average stand-level maximum for surface fuel loading totals of CWD, litter, and duff, though site-specific needs may vary with habitat, or vegetation type. CWD is an important component of healthy forest soils, of many habitat types, and it can be a significant source of emissions. Duff can be a significant source of ignitions, and plays a role in feeder root structure, as well as soil heating and emissions. Litter is a necessary component of surface fuel loading that helps a fire move across the surface.

Surface fuel loading contributes significantly to fire behavior and effects (both direct and indirect), and can indicate potential high severity effects are likely even if crown fire is not indicated by modeling. Additionally, Coarse Woody Debris >3" diameter (CWD >3"), litter, and duff contribute significantly to emissions. Forest plan direction sets a narrow range of desired conditions for the Coconino NF (5 – 7 tons/acre), and a wider range for the Kaibab NF (3 – 10 tons/acre) for CWD >3", but there is no direction regarding litter, duff, or other surface fuel load components. Therefore, in this analysis, CWD >3" litter, and duff were combined as 'surface fuel loading" in tons/acre, and is considered and evaluated both qualitatively and quantitatively regarding potential fire effects.

Site specificity varies tremendously in fuel loading, so recommendations regarding fuel loading must be considered as averages. Litter, duff, and CWD >3" were combined to provide a rough evaluation of the expected effects of surface fuel loading on fire effects. In dry, warm forests of the northwest, a desirable range for CWD >3 inches is between 5 and 20 tons/acre (Brown et al. 2003). Graham et al. (1994), recommended 5 – 13 tons/acre of CWD in ponderosa pine, including sites within the project area. Forests in the project area are assumed to be slightly warmer and drier than those in the northwest, so slightly lower numbers would apply (Brown et al. 2003, Graham et al.1994). Brown et al. (2003) further recommend that, from a fire hazard perspective, the recommended level of CWD would be lower where there are more than 8-10 tons/acres of small woody debris (<3 inches diameter). Passovoy and Fulé (2006) found that post fire conditions from a number of wildfires, including several within the project area, did not exceed these recommendations. Duff loadings of <2.4 tons/acre (~1/2 inch deep) have been considered to be an average that represents historic conditions in ponderosa pine stands with frequent fire (Brown et al. 2003, Roccaforte et al. 2012). Combining maximum recommended fuel loadings from the Coconino Forest Plan direction; duff loadings of not more than 4.8 tons/acre of duff (to allow for a wide range of conditions) and; up to 5 tons/acre for litter (allowing some decay for the production of ~1.8 tons/acre of litter annually in a healthy ponderosa pine forest that historically burned on average at least once every 5-10 years (see 1st paragraph in Litter and Duff below)), 20 tons/acre seems like a generous average for the combined weight of these three components (CWD>3", litter, and duff), particularly when one recognizes that finer woody debris are not included. It is reasonable to assume that if these three total >20 tons/acre, the potential direct and indirect fire effects could include sufficient heat to increase tree mortality from needle scorch and/or root/cambium damage, consume organic matter in the top layers of soil, including living roots, seeds, mycorrhizae, or cause other undesirable fire effects, such as the impacts of emissions on humans and wildlife if those areas burn under conditions that are not optimum for smoke dispersal (Neary et al. 2005). While this does not represent a 'desired condition', it can inform a discussion on the potential fire effects from surface fuel loading. This does not specifically relate to wildlife requirements, but includes other fuel loading components and considerations. This metric (20 tons per acre of the combination of CWD>3", duff, and litter) was used as a general recommendation, though site specific needs may vary across the treatment area.

FVS data were used to model fuel loading for each alternative for post-treatment (2020) and thirty years later (2050, and assuming no disturbance of any kind (thinning, fire, drought, insects, etc.) occur following the completion of treatments in 2020).

Litter and Duff

One of the more difficult problems to address in the restoration of a ponderosa pine forest from which fire has been excluded is the accumulation of litter and duff. The frequent surface fires that characterized the historic fire regime would have consumed much of these fine fuels, as well as small twigs and branches every few years. Historically, larger fuels would have been consumed as well, particularly the rotten logs (Covington and Sackett 1984), although herbaceous fuel loading is probably greatly reduced in the contemporary forest (Fulé et al. 1997a). The ratio of larger woody fuels to litter and duff would be very different in a forest that burns frequently than in a forest that burns on a frequency of 20 or more years. A Southwestern ponderosa pine forest can produce up to 1.8 tons per acre of litter annually (Sackett et al. 1996, Biswell et al. 1966). Generally, the litter layer contributes to fire *intensity*, while the duff layer contributes to fire *severity*, (Sackett and Haase 1996, Hood 2007). These layers cannot be addressed by mechanical means across the entire area proposed for treatment under any of the action alternatives, even if it was ecologically sound to do so. Mechanical treatments may move duff and litter around, creating temporary discontinuities in the surface litter layer, but the biomass remains onsite. Decades of fire suppression have allowed litter and duff layers to accumulate to levels that cause a multitude of problems that include direct and indirect fire effects and behavior, effects on soil productivity, interception of precipitation before it can reach the soil, nutrients locked up in organic matter, changes to soil chemistry, emissions, and physical suppression of surface vegetation contributing to a decrease in species diversity (Covington and Sackett 1984, Neary et al. 2005, Moir 1988, Abella et al. 2007, Varner et al. 2007).

Historically, fine surface fuel loads were made up primarily of herbaceous material. Herbaceous litter that is less than a couple of years old is loosely arranged, and fire burning though it would move relatively quickly, with a short residence time and a high rate of consumption. Repeated fires would consume CWD a little at a time, allowing natural recruitment of more from branches or snags to maintain equilibrium based mostly on fire frequency. Currently, across much of the project area, surface fuels are dominated by needle litter and duff. Several years to decades of accumulated needle litter are more closely packed than herbaceous fuel, and duff layers still more so. Fire burning through these fuels will have a longer residence time than in herbaceous fuels, and the lower layers may smolder for extended periods, transferring more heat to the soil, roots, and boles of trees (Lutes et al. 2009). The longer residence time is also likely to consume a greater portion of dead/down fuels in a single fire. Additionally, duff combined with Coarse Woody Debris, produce the majority of emissions.

Fire naturally regulates the pattern and density of seedlings, a necessary ecological function that cannot be duplicated by mechanical thinning operations**.** Needle litter accumulating under larger trees can provide sufficient fuel in just a few years to prevent germination or seedling survival when it burns (Cooper 1960), naturally regulating the pattern and density of seedlings as they regenerate following thinning or fire, and creating a natural, sustainable mosaic.

Litter and duff cones have accumulated around the base of many large and/or old trees in the project area (Figure 1) and are likely to cause, or contribute to, undesirable mortality if they burn under conditions (wildfire or prescribed fire) that produce long residence times that can damage the cambium, damage or kill roots, (Egan 2011) or produce high burn severity (soil fire effects) . The ‘duff cone’ under the tree in Figure 1 has built up because of a lack of fire. If it burns under extreme conditions (very hot and very dry), the heat may be sufficient to damage or even kill the tree, although large trees may take 2-3 years to die. Prescribed fire can produce fire behavior that is less likely to cause lethal damage. These fuels cannot be effectively treated by mechanical methods across the ~600,000 acres proposed for treatment.

Figure 1 shows a duff cone under an old ponderosa pine in Restoration Unit 6.

In areas where litter has been accumulating for a long time, the time that has passed affects how fires burn. Fungii often colonize layers of old needles, decreasing their flammability under all but the driest conditions, often in dense thickets of pine or the lower layers of the deepest litter. This may affect the mosaic fire creates when it burns. When fire burns though these areas, most of the fungi are destroyed, so needles that fall after the fire aren't likely to become infected, and the next fire can burn with higher intensity and will consume a greater amount of surface litter (Sackett and Haase 1998). Duff that does not burn acts as an insulator and duff that does burn acts as a conductor (Valette et al. 1994, Sackett and Haase 1996). Conversely, litter that has accumulated for just a few years, will burn almost completely, and quickly, with little detrimental impact from heat (Garlough and Keys 2011, Covington and Sackett 1992, Sackett and Haase 1998). When deep layers of duff do burn, they generally have long residence times, conducting excessive heat into the soil if they burn completely (Valette 1994).

Fire Regime/Condition Class (FRCC)

FRCC is an ecological evaluation protocol developed to support planning and risk assessments, particularly in regards to fire (Barrett et al. 2010, Hardy et al. 2001a, Schmidt et al. 2002, Hann et al. 2004). It is a largely a qualitative measure using three classes for describing the relative degree of departure from reference conditions, particularly in regards to fire regimes, and the risk of the loss of key ecosystem components in the event of a disturbance, such as a fire (Table 4). This method of evaluation was originally developed for use at a large scale to facilitate landscape-level planning, because ecosystem trends are not always discernible at smaller scales. In this assessment, it will be discussed only at the landscape scale.

Table 4. Condition classes (adapted from Schmidt et al. 2002).

	Departure from historic Fire Regime
Condition Class 1	Fire regimes within historical ranges. Risk of losing key ecosystem components is low. Vegetation attributes are intact and functioning within historical ranges.
Condition Class 2	Fire regimes moderately altered from historical range. Risk of losing key ecosystem components is moderate. Fire frequencies are departed from historical ranges by one or more return intervals. This has resulted in moderate changes to one or more of the following: fire size, intensity, severity, and/or landscape patterns. Vegetation attributes have been moderately altered from historical ranges.
Condition Class 3	Fire regimes significantly altered from historical ranges. Risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals resulting in dramatic alterations to: fire size, intensity, severity, and landscape patterns, and/or vegetation attributes.

Fire Regime Condition Class Software Application Version 3.0.3.0 (Havalina et al. 2010) was used (NIFTT 2010) to evaluate changes to FRCC for each alternative. The reference condition used is from the Biophysical Setting (BpS) for Ponderosa Pine (Colorado Plateau) (PPIN5). The software compares reference fire frequency, severity for the area being analyzed, as well as the Vegetation Condition Class (VCC). VCC is determined by comparing the current percent of each of, in this case six, seral stages with a reference condition (details in Appendix D). As with FRCC, VCC is quantified into three Condition Classes (VCC1, VCC2, and VCC3), which indicate the degree of departure from the reference composition. VCC is computed in acres. Details of the modeling can be found in Appendix D (pgs. 339 – 363).

Fire Regime/Condition Class (FRCC) was calculated for the ponderosa pine in the proposed treatment area using acres of crown fire as modeled with Schultz Fire conditions as a surrogate for severity in ponderosa pine. In ponderosa pine, a true FRCC1 would include dominance of old and/or large trees (Harrington and Sackett 1992). It would take decades, regardless of treatments, to move areas lacking in large and/or old trees to a VCC1. It is not possible to evaluate the number of large, old trees, vs. large trees, so a crosswalk was developed to using VSS classes from the Silvicultural database (McCusker 2012) as surrogates for the BpS seral stages (details in Appendix D). Fire return intervals were determined by using the initial calculated fire return intervals and adjusting them to the proposed treatment area, as described above.

No disturbances of any kind (thinning, fire, insects, drought, etc.) were modeled from 2020 to 2050. Although it is likely there WOULD be some sort of treatments or wildfires or insects/disease, it is speculative to try to determine affected acres for the next 30 years. As a result, the data show a shift 'down' a class for many acres, though not back to pre-treatment levels. The data that were used for this assessment distinguished by size class rather than age, so FRCC1 acres may be a bit high.

Therefore, the desired condition would be to have the treatment area move from its current classification of FRCC3 to an FRCC2. Additionally, a desired condition would be to have no acres remaining in VCC3.

Scales of analysis

This analysis is classified in three ways; area, vegetation/habitat, and treatment type.

1. Size. In order of decreasing size, with the largest first:

    a. **Project Area**: 988,764 acres that were analyzed to determine where the greatest need for change was. It represents the 'core' area of ponderosa pine on two National Forests, and includes some aspen, oak, pinyon/juniper, and grasslands. Acres having special designations (Wilderness, Special Interest Areas, state/county/private etc.), or covered by other planning efforts were only included in Cumulative Effects (**Figure 2**).

    b. **Treatment area**: The area within the project area for which treatment (or no treatment) decisions will be made based on this EIS. Unless used in a context that is specific to an alternative, the area referenced is the 588,716 acres proposed for treatment in Alternative C, the most acres of any alternative.

    c. **Restoration Unit (RU)**: Restoration Units are divisions of the project area delineated by roads or natural barriers. RUs range from 43,578 acres (RU6) to 165,803 acres (RU4). RU2 had so few acres of ponderosa pine available for treatment that the team decided to exclude it from this analysis (**Figure 2**).

    d. **Subunit (SU):** Subunits are divisions of Restoration Units and are delineated primarily by roads and 6th level watersheds. There are 19 SUs, ranging from 3,870 acres (SU6-4) to 81,541 acres (SU4-4).

2. **Vegetation/habitat type:** This scale of analysis discusses the expected effects of

proposed actions to a specific vegetation or habitat type. These are sometimes small areas on the landscape (such as aspen at a total of ~1,500 acres), but have greater ecological and/or social values than some of the larger areas, or have different legal requirements (such as those relating to the Mexican Spotted Owl).

3. **Desired Openness:** This is an indication of the relative desired post treatment interspace/tree group condition. For example, 'High', indicates a more open condition, with a mosaic of groups and interspaces. 'Very Low (Core Areas)' indicates a more closed condition with very few discernible interspaces (McCusker et al. 2014).

Data sources and models

The models and data listed below were used as described for modeling potential fire behavior and effects. More detailed descriptions are in Appendix C.

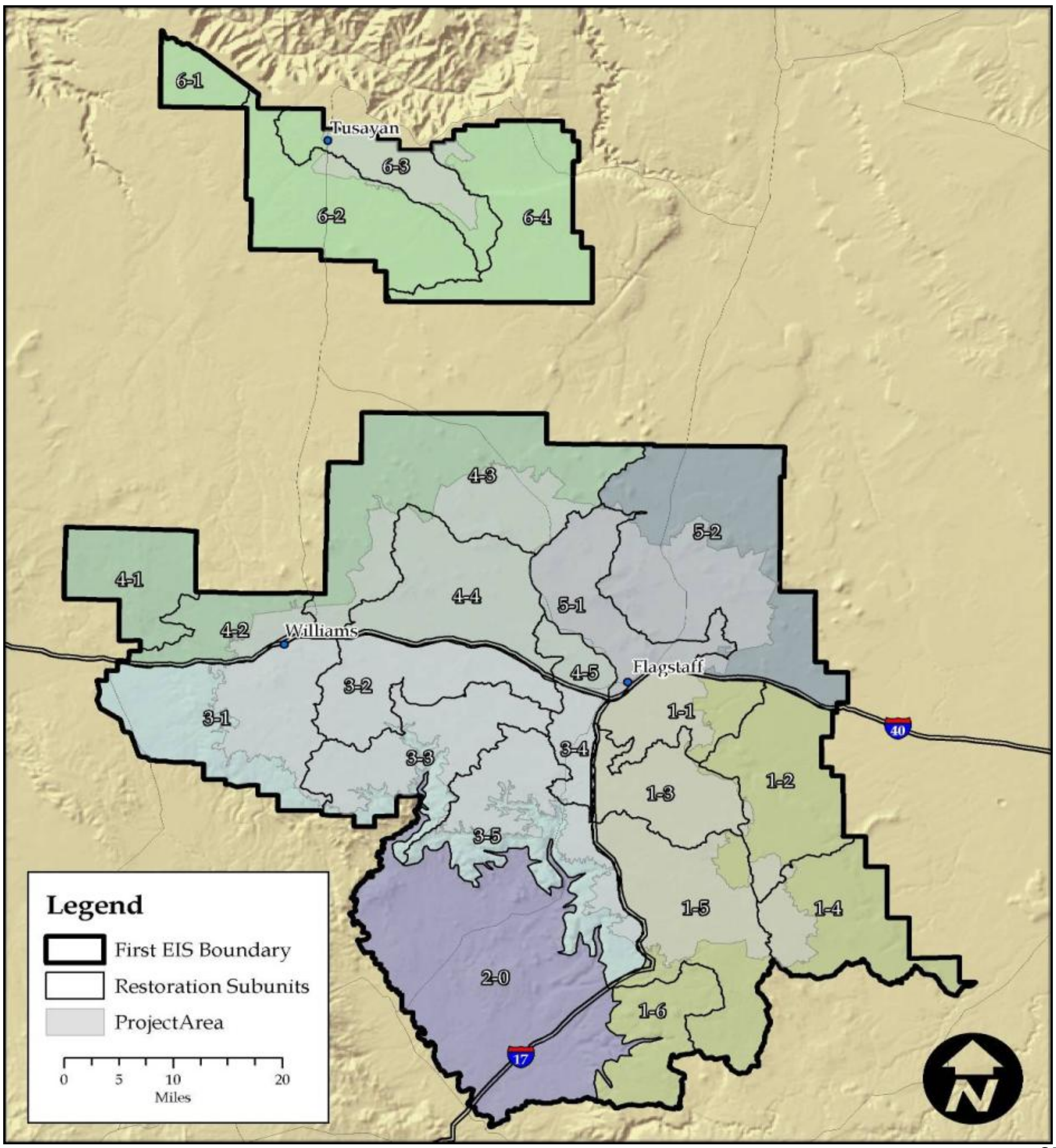


Figure 2 shows the boundaries used at different scales of analysis.

FRCC Software Version 3.0.3.0 – this software computes FRCC at various scales, generating reports with the percent and acres in each Condition Class. For this analysis, it was used to determine FRCC for ponderosa pine within the project area (Havalina et al. 2010).

Farsite – Used to generate 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 potential fire type (Finney 2004).

FireFamilyPlus – Used to determine what the percentile weather was during the Schultz Fire using data from the Flagstaff Remote Automated Weather Station (RAWS) (for percentile weather, see Glossary, Appendix C).

FlamMap – FlamMap 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 Ecosystem Restoration Analysis Project (ForestERA) generated spatial data – ForestERA produced spatial layers that were used to update the fire type data to reflect vegetation/fuels changes that occurred between 2008 and August of 2010 (ForestERA 2010).

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 (Reinhardt and Crookston 2003). For more details on the FVS-FFE modeling, see the Silviculture Specialists' Report (McCusker 2012). Used to produce post-treatment stand data that was used to model fire type, FRCC, fuel loading, and CBH/CBD.

Landfire – 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 2010). Landfire is the only existing source of the type of data needed for this type of analysis that is consistent across ownership boundaries.

Stand data – Input data for running FVS-FFE (McCusker 2012).

Concepts applied to analysis

An understanding of some concepts is important for understanding the details of this analysis. Some are summarized below, but additional information can be found in Appendix G.

Fire Regime

A simple definition for 'fire regime' describes the role fire plays in an ecosystem. Fire interacts with other disturbances, such as insects, drought, wind and other weather related events to create spatial and temporal patterns that maintain an ecosystem within a certain range of conditions. Table 5 describes the classifications of fire regimes most commonly used (Havalina et al. 2010, adapted from FRCC 2010 Guidebook, page 15).

Note: 'severity' is not a reference to mortality, though there is often a correlation (see discussion, next section). Over 90% of the treatment area historically was a Fire Regime 1 or II, with some aspen and PJ that is more likely to be Fire Regime III, IV or V.

The cumulative impacts of frequent, low severity surface fire effects can be difficult to identify if only one or two fires are considered. However, the fire regime is what maintains an ecosystem, not just one or two fires, and the fire regime has a profound influence on ecosystem dynamics, including tree seedling dynamics, low and mid-level canopy structure dynamics, understory plant species diversity and mosaics, nutrient cycling and other soil properties, plant growth, the diversity of vertebrate and invertebrate fauna, and many other ecosystem properties including (Swetnam and Baison, 1996).

Table 5. Frequency and severity characteristics of fire regime groups and applicable areas.

Group	Frequency	Severity	Severity Description	Vegetation types that would be affected by treatments proposed under 4FRI
I	0 – 35 years	Low/ mixed	Mostly low severity replaces less than 25% of dominant overstory vegetation. May include mixed-severity fires that replace up to 75%	In pure ponderosa pine, pine/oak, and savanna ponderosa pine is the dominant species, so the severity of a burn is related to the fire effects on the pine.
II	0 – 35 years	High	High severity replaces greater than 75% of dominant overstory (grasslands).	Grasslands. The herbaceous layer (grasses and forbs) are the dominant species. Greater than 75% of these are generally topkilled by a fire, so it is considered high severity.
III	35 - 100 years	Mixed/ low	Generally mixed-severity; may also include low severity fires.	Mixed conifer falls into this category. Mixed conifer is not being treated under 4FRI, but its adjacency means it may affect or be affected by 4FRI treatments (see cumulative effects).
IV	35 - 200 years	High	High severity.	Aspen often falls into this category.
V	200+ years	High /any severity	Any severity may be included, but mostly replacement severity; may include any severity with this frequency	Much of the Piñon/Juniper (PJ) falls into this category, though there are different types of PJ systems and the fire return intervals vary.

Across the 4FRI landscape, the disruption of the Fire Regime over the last century has been largely responsible for the deteriorating health of the ecosystems within the project area. Evaluating the departure from the natural fire regime was part of the process used to determine FRCC for the project area. Data used to calculate the FRCC is located in Appendix D of this report.

Fire Return Interval (FRI)

FRI is a characteristic of a fire regime that can be quantified based on spatial and temporal data. It is the average length of time between fires for a given area. Across the project area, the desired FRI would average 10 years, though it would vary somewhat between the southern and northern portions of the project area. FRI is one of the inputs used to determine FRCC (see Appendix D).

Maintenance Fire Return Interval

There is evidence that shows that a FRI that is longer than what is generally considered historical, or natural can maintain a relatively open, crown-fire resistant forest structure (Fulé and Laughlin 2007, Fulé 2011 personal communication, Covington 2011 Science Friday), although other components of the area, such as species composition, would be affected. A ‘maintenance’ FRI does not represent a fully restored ecosystem; it represents a minimal level of fire that is needed to keep woody growth and fuel loading below a level at which they are likely to produce undesirable fire effects and behavior (including controlling woody species encroachment into grasslands). In the project area, this is a larger and more immediate problem than unnatural understory vegetative components because of the potential results of uncharacteristically severe fire effects in these areas. It is not intended to represent an FRI that would maintain historic habitat/plant communities. Its true range would vary with precipitation, masting years, and the coincidence of growing conditions with cone/seed production. Some level of maintenance with surface fire is critical to retaining open forest conditions and relatively low crown fire hazard into the future (Roccaforte et al 2008).

Fire Intensity versus Fire Severity

Fire intensity and fire severity are often confused, though both are commonly used in descriptions of fire regimes. Fire severity is used to determine FRCC and in evaluating the desirability of a fire's effects. Fire intensity was used as one input to determine which parts of the project area are currently at the greatest risk of undesirable fire effects and behavior (see Appendix D). Fire intensity is a *quantitative* measure of the fire itself, usually defining energy release rates. Fire severity is a *qualitative* evaluation of the effects of a fire as produced by the heat pulse on the biotic and abiotic components of an ecosystem (Agee 1997, Keeley 2009), and is generally evaluated after fire has burned though an area.

Flame length is a good surrogate for fireline intensity. Above the flames of the surface fire in a forest, there is a zone within which foliage will be scorched and killed by hot gasses rising from the flames. To die by cambial damage alone, a tree must be girdled, and any fire intense enough to girdle a large tree is usually intense enough to scorch all of its foliage as well, even without any crown fire (Figure 3). Death follows quickly from complete crown scorch in ponderosa pine, but may take several years following girdling (Van Wagner 1973).

Figure 3. Lethally scorched trees from a high *severity*, low *intensity* surface fire. Note the lack of crown fire.

Crown fire is always high intensity fire, but high intensity fire is not always crown fire. A low-intensity fire that is creeping slowly across a forest floor that has decades of accumulated fuels may produce high severity effects because the residence time is sufficient to allow lethal levels of heat to transfer into the soil, tree and shrub cambiums, and roots/seeds/biota in the upper layer of soil (Valette et al. 1994, Lata 2006). When surface fire burns in a forest with a closed canopy, sufficient heat can build up under the canopy to lethally scorch trees.

Historically, ponderosa pine forests of the southwest supported, low severity surface fires. Passive crown fire occurred under some conditions, but active crown fire was rare (Cooper 1960, Covington and Moore 1994, Fulé et al. 2003, Moir and Deterich 1988). Discussions of severity for existing conditions were based on fire type, surface fuel loading, and vegetation type.

Opposing Science

Comments from Chad Hanson, Richard Artley, Arthur Firstenberg cite publications that suggest that crown fire was historically much more prevalent in the project area, even in ponderosa pine, than is concluded in the previous section of this analysis, and in the next section of this report (Williams and Baker 2013, Williams and Baker 2012). One of the assumptions which they use to make this claim is that the science supporting frequent, low severity fires, is based on “small, scattered studies”. In fact, this report cites over 25 studies that are specific to the project area, and about 50 additional studies that specifically include the rest of Arizona and/or the southwest. Included is a 110 page General Technical Report (Dahms and Geils 1997), that completed an assessment of forest ecosystem health in the southwest, and an 85 page report by The Nature Conservancy (Smith 2006) on historical and current landscape conditions for ponderosa pine in the southwest. The preponderance of science does not agree with Williams and Baker, and was soundly refuted by Fulé et al. (2013). Fulé et al. (2013) has 18 co-authors, including many of the leading researchers of fire ecology in southwestern United States. Reconstructions of dry western US forests in the late 19th century in Arizona, Colorado and Oregon based on General Land Office records were used by Williams and Baker (2012) to infer past fire regimes with substantial moderate and high-severity burning. They concluded that present-day large, high-severity fires are not distinguishable from historical patterns. Fulé et al. (2013) and Fulé 2014 describe errors in their study. First, the use of tree size distributions to reconstruct past fire severity and extent is not supported by empirical age–size relationships nor by studies that directly quantified disturbance history in these forests. Second, the fire severity classification of Williams and Baker (2013) is qualitatively different from most modern classification schemes, and is based on different types of data, leading to an inappropriate comparison. Third, while Williams and Baker (2013) asserted ‘surprising’ heterogeneity in their reconstructions of stand density and species composition, their data are not substantially different from many previous studies which reached very different conclusions about subsequent forest and fire behavior changes. Contrary to the conclusions of Williams and Baker (2013), the preponderance of scientific evidence indicates that conservation of dry forest ecosystems in the western United States and their ecological, social and economic value is not consistent with a present-day disturbance regime of large, high severity fires, especially under changing climate (Fulé et al. 2013, Fulé 2014).

Many papers cited by commenters objecting to mechanical treatments attempted to apply the ecology and/or fire regimes of ecosystems other than ponderosa pine (mixed conifer, spruce fir) or ponderosa pine in the northwest. Ponderosa pine has distinct variations within its geographic range (Oliver and Ryker 1990), and the populations of ponderosa pine in northern Arizona have some fundamental genetic differences from pines in other areas within the range of Ponderosa species (Conkle and Critchfield 1988). There are differences in the openness of crown growth, number of needles, and other characteristics. These two populations should not be expected to have identical fire regimes, even if the study was restricted to ponderosa pine.

There were multiple comments from people objecting to ‘fuels treatments’, ‘hazardous fuels treatments’, and/or ‘fuels project/s’ (Richard Artley, Center for Biological Diversity). We include the concept of ‘Strategic placement’ with fuels because treating fuels may not improve ecosystem health. Ecosystem restoration treatment and fuel treatment are not synonymous. Some ecosystem restoration treatments reduce fuel hazard, but not all fuel treatments restore ecosystems. Ecosystem restoration treatments are often designed to recreate presettlement fire regimes, stand structures and species compositions while fuel treatment objectives are primarily to reduce fuels to lessen fire behavior or severity—this is known as ‘’hazard reduction (Reinhardt et al. 2008).

Finney (2001, 2007), and Finney et al. (2007) focused on ‘fuels management’, which is useful for managing fire behavior when that is the primary concern. However, treating only 20% of the landscape, which Finney has shown can be effective in managing fire behavior, would not achieve restoration on a landscape scale. An analysis that focuses on where treatments would best minimize fire behavior, may or may not be support restoration objectives across the landscape (which include conservation of large and old trees, enhancing large oak, enhancing aspen clones, and other treatments).

Of the 586,110 acres proposed for treatment in this EIS, there are about 535 acres of proposed WUI (fuels) treatments. All of the 535 are contiguous and are in RU6. With the exception of these acres, the objectives of the 4FRI are restoration, not hazardous fuels reduction.

More detailed responses to comments on opposing science can be found in Appendix H.

Affected Environment

Existing and Desired Conditions

Existing and desired conditions are discussed as follows:

1. Background and history of the 4FRI area
2. Fire type at the treatment area scale
3. Potential fire type by vegetation type, habitat type, Restoration Unit, and Subunits
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness
5. Fire Return interval/FRCC by treatment area
6. Air Quality

Historic conditions affecting the 4FRI analysis area

In the latter part of the 19th century, unsustainable practices in fire management, grazing, and logging began to change spatial and temporal patterns on the landscape, as well as the structure and composition of landscape components. These practices combined to shift ecosystems within the project area out of their Natural Range of Variability, so that ecological functions are now impaired across the landscape of northern Arizona (Leopold, 1924, Heinlein et al. 2005, Covington and Moore 1994, Fulé et al. 1997b, Covington et al. 2001).

The typical climate of the project area includes an adequate, annual amount of moisture for good vegetative growth and conditions favorable for frequent early summer fires (Harrington and Sackett 1992). Winters are relatively mild, averaging a little above 30° F, and precipitation (as snow) saturates the soil (Schubert 1974). Rainfall minimums occur in May and June, with some areas receiving less than 0.5 inches. The spring dry season is accompanied by increasing air temperatures, low humidity, and persistent winds, and is broken in early to mid-July with development of almost daily thunderstorms; July and August are the wettest, warmest months. A second dry season occurs in the fall. This climatic pattern is particularly conducive for development of a pine-grass savanna maintained by frequent surface fires (Dahms et al. 1997).

Historically, both lightning and human-caused fires, once started, could burn until extinguished by rain, or until they ran out of fuel (typically when they reached an area that had recently burned). Fires could burn for months and cover thousands of acres (Swetnam 1990, Swetnam and Baisan 1996). Effects from these long burning fires would vary as conditions changed over the weeks they burned. As a result, most ponderosa pine in the southwest burned every 2 to 22 years as low-severity, often area-wide fires (Weaver 1951, Cooper 1960, Dieterich 1980, Swetnam et al. 1990, Swetnam 1990, Swetnam and Baison 1996, Fulé et al. 1997a, Fulé et al. 2003, Covington et al. 1997, Heinlein et al. 2005).

The disruption of historical fire regimes by introduced ungulates has been well documented for southwestern ecosystems. Montane grasslands were utilized as summer range for large numbers of sheep and cattle (Leopold 1924). Grazing removed much of the fine fuels that had competed with pine seedlings for water, nutrients and light and had also allowed surface fire to regularly recycle nutrients, scarify seeds, reinvigorate shrubs, and thin seedlings/saplings. This unintentional fire suppression, initiated in the early 19th century through grazing by sheep and cattle, transitioned in the early 1900s to active fire suppression including the construction of fire lines and roads in the mid-20th century. By the early 1900s, fire exclusion had begun to alter ecosystem structure and fire regimes in Northern Arizona (Covington et al. 1994). Settlers saw fire as a threat, and actively suppressed it whenever they could. Fire exclusion was very successful initially, but subsequent accumulation of fuels, through litter-fall and logging debris accumulation, and development of ladder fuels that can initiate crown fire (Covington et al. 1994) made fire suppression more difficult. Initially, fire suppression was very successful because of low fuel loadings, open forests with high canopy base heights, surface fuel loading composed of some needle litter, but mostly grasses/forbs – often overgrazed. Without fires to consume them, pine litter accumulated over time, and the character of the fuels changed from light flashy fuels that supported low severity surface fires, to compact needle litter and duff and dead/down woody debris. This changed the character of the fires as well, allowing less frequent fires that had greater accumulations of fuel to burn, putting more heat into the soil, and increasing crown fire. Fire suppression allowed seedlings and saplings to survive that would have naturally been thinned out by fire. The disruption of fire regimes is an important variable in the composition of vegetative communities. Uncharacteristically long periods without fire may allow species to become established that could not under the historic fire regime (Swetnam 1990).

As Europeans settled into the area, roads and trails broke up the continuity of forest fuels and further contributed to reductions in fire frequency and size (Covington and Moore 1994). Logging removed much of the large tree component across the landscape, allowing younger and smaller trees to survive in unnaturally dense stands. Concerted efforts with fire brigades, ground crews, and air tankers, functioned as the primary mechanisms for excluding fire from southwestern forests (Covington and Moore 1994, Swetnam and Baisan 1996).

Logging, grazing, and fire suppression are the primary factors that, when combined, have allowed landscape patterns to become homogenized, shifting fire regimes across much of the project area from frequent, low-intensity/low severity surface fires to infrequent, high-intensity/high severity crown fires. In addition to being a primary cause of the decline of healthy ponderosa pine forests, woody species have encroached into grasslands and savannas, and conifer encroachment is contributing to the decline of aspen.

Across the treatment area, desired conditions include temporal and spatial landscape patterns, and composition and structure of the components of pine, pine/oak, aspen, pinyon/juniper, and grassland systems that support healthy ecological functions across the landscape. Fires would maintain and enhance, but not degrade habitat for listed, rare, and sensitive species. Fires would recycle nutrients stored in duff, litter, and vegetation, including dead, down woody debris. Aboveground biomass would not be present in amounts that intercept inordinate amounts of precipitation, preventing it from reaching mineral soil. Fires would prevent woody encroachment into grasslands and savannas and contribute to the health of aspen. Smoke and heat from fire would scarify seeds and promote a diverse herbaceous vegetative community and help limit infestations such as mistletoe (Alexander and Hawksworth 1976, Abella 2009).

Across the treatment area, the desired condition would allow the use of prescribed fires to supplement unplanned ignitions, producing an average annual Fire Return Interval (FRI) in the ponderosa pine of no more than 20 years, with an 10 year FRI being preferred unless monitoring indicates a change is warranted. The FRI on the southern end of the project would average less than 10 years because the higher precipitation produces faster regeneration and growth (Puhlick et al. 2012), while the northern, drier portion of the project area could go for 20 – 30 years, depending on environmental conditions affecting fuel accumulations, regeneration, and initial condition (Fulé and Laughlin 2007). Across the treatment area, forest conditions would allow for the use of fire as addressed in the land and resource management plan. Frequent surface fires would rarely move up into tree crowns and, when crown fire did occur, it would be passive crown fire, limited to the tree or the group within which it started. Restored sustainable fire regimes, from a combination of planned and unplanned ignitions, would regulate landscape structure, pattern, and composition, aligning forest changes with climate changes.

Currently, the size and extent of high severity fires are much larger than historic data indicates was typical of ponderosa pine in the southwest (Swetnam 1990, Covington and Moore 1994; Swetnam and Betancourt 1998, Westerling et al. 2006, Climate Central 2012, Miller and Safford 2012) and, while the number of fires reported in and adjacent to the project area has decreased over the last 40 years, the average size has increased (Figure 4). Figure 4 shows the results of a query of reported fires using FireFamilyPlus including those districts of the Coconino and Kaibab National Forests south of the Grand Canyon that burned mostly in ponderosa pine. These fires include some PJ and some mixed conifer, but are primarily ponderosa pine.

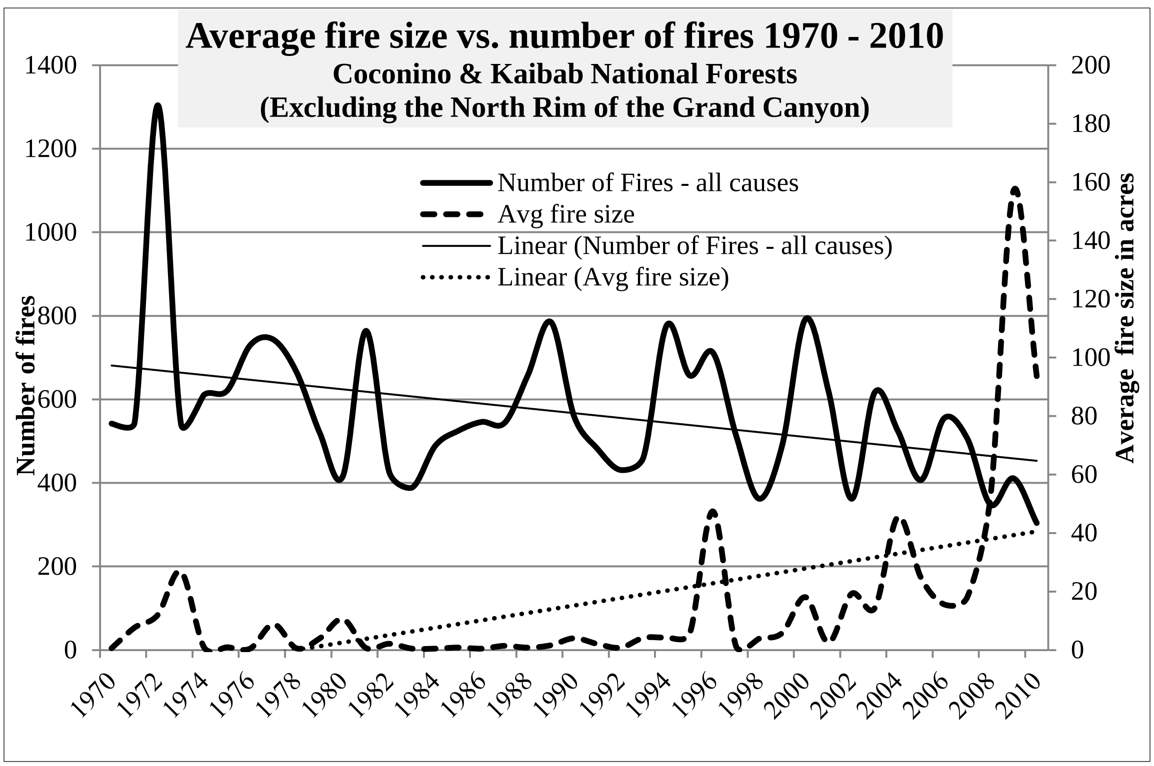


Figure 4 shows the number of wildfires and the associated acres from 1970 - 2010.

Areas of high severity fire have detrimental impacts that extend far out from the actual burn itself both temporally and spatially. The degree of the effects depends on the slope, proximity, and extent of the area of high severity. Such fires can remove the most surface cover all at once, consuming decades of accumulated surface fuels in one fire. Instead of just top-killing vegetation that would normally resprout or scarify seeds, these fires can kill plants and incinerate all or most organic matter in the top inches of soil, including the seed bed and fine roots, affecting the potential for vegetation recovery. These high severity fires can consume enough soil organic matter and nutrients that it becomes difficult for soil-stabilizing plants to take root, leaving the surface soil layers vulnerable to erosion. In addition to the destruction of soil-stabilizing components, hydrophobic soils, and the associated debris flows and floods may permanently change the potential of the source site because of the loss of surface soils, while having severe, long term effects on downstream, downslope, and adjacent areas, regardless of whether or not they burn. These surface layers of soil are essential to natural vegetative communities and, when removed from the site (by erosion), can take hundreds or thousands of years to recover, effectively changing the site potential.

Current conditions inhibit the survival and recruitment of large trees through competition, and threaten the maintenance of ecological systems by fueling increasingly extensive high severity fires. These fires have the potential to alter the successional trajectories of post-burn vegetation, creating entirely different communities than those existing before such events (Savage and Mast 2005, Kuenzi et al. 2008, Strom and Fulé 2007). Figure 5 shows dense forest conditions (numerous trees with dense, contiguous canopy fuels) that occur within the project area and would support high severity fire. Even without crown fire, a surface fire burning though this area could do enough damage to trees to cause widespread mortality (VanWagner 1973).

Figure 5 shows dense, young forest that would support active crown fire in the project area.

In its existing condition, 35% (202,902 acres) would support crown fire, of which 25% (149,362) is active crown fire (Figure 6). “No fire” acres include areas on which there were insufficient fuels to carry fire, including water, rock, cinders, areas of sparse vegetation, etc.

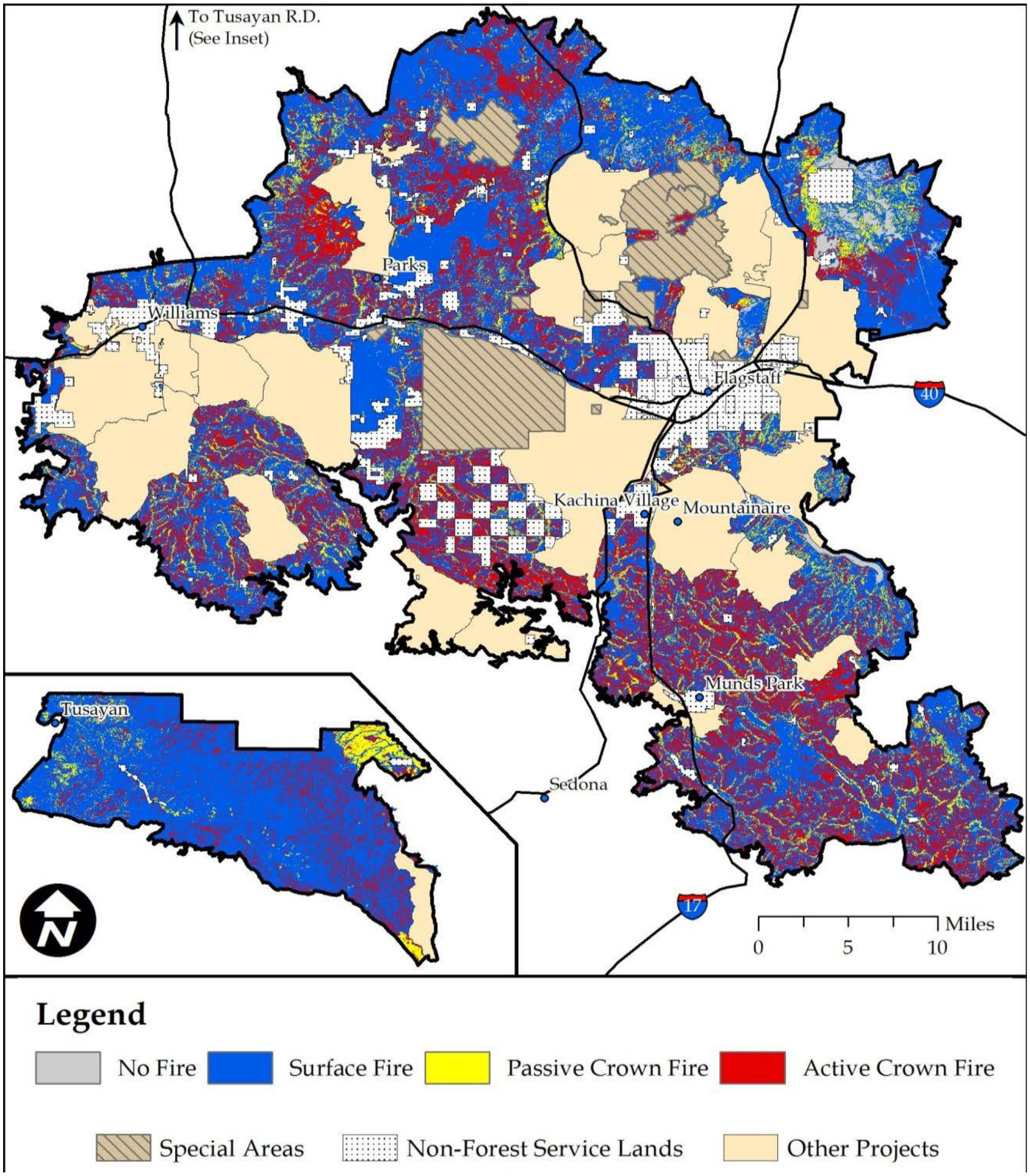


Figure 6. Modeled fire type for existing condition.

The Wildland Urban Interface (WUI) is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels (NWCG 2008). It is that portion of the landscape where structures and vegetation are sufficiently close that a wildland fire could spread to structures, or a structure fire could ignite vegetation. WUI areas are scattered across the project area, though areas of the greatest concern are relatively focused, Flagstaff, Williams, Doney Park, Munds Park, Kachina, Tusayan, Parks, Belmont and scattered developments within or adjacent to the project area (see Cumulative Effects, Figure 7).

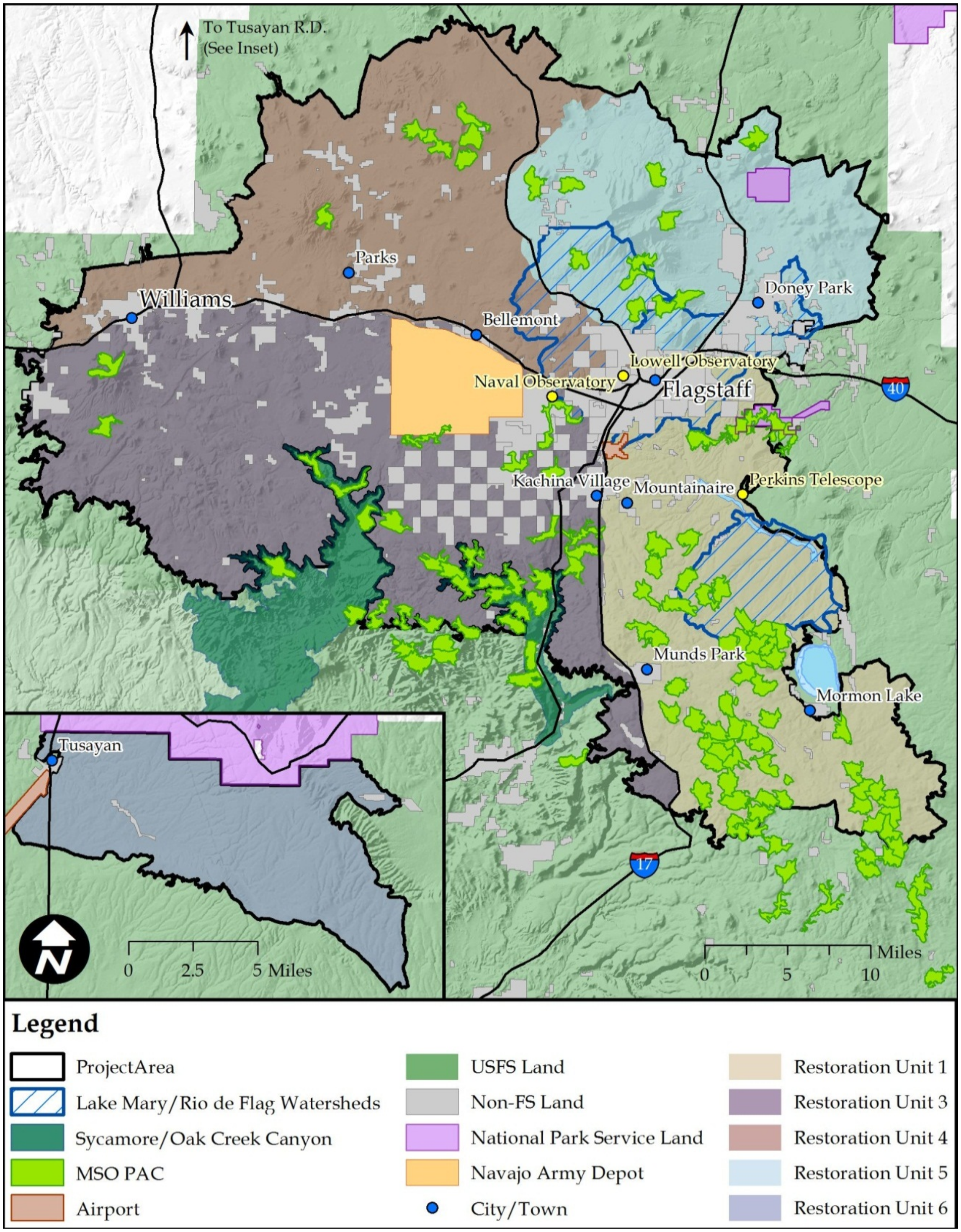


Figure 7 shows a number of the values at risk discussed in this analysis.

Fuel treatments have been, and continue to be implemented in WUI closest to major population centers, but much of the landscape is still vulnerable to undesirable fire behavior and effects, including changes in site productivity, loss of critical habitat, flooding, erosion, weed infestations, damaged infrastructure, and the longer term effects of having thousands of acres of dead trees nearby for decades. Other areas of concern include water resources, such as the Lake Mary watershed and Oak Creek. The Lake Mary watershed includes Upper and Lower Lake Mary, and is a source of water for the city of Flagstaff, as well as being a popular recreation site. Oak Creek itself, though it is mostly outside the project area, is surrounded by Restoration Units 3-4 and 3-5, is a popular recreation site, and there are dozens of homes along Oak Creek (Figure 6 and Figure 7).

Ponderosa Pine

The denser and younger stand structures of the historic ponderosa pine forest were the result of special circumstances in the interaction of climate, site, and disturbances. Even though ponderosa pine reproduction was negligible in some years, there were occasional wet cycles as long as 15 to 20 years without fires when ponderosa pine could regenerate (Swetnam and Dieterich 1985). The regeneration cycle required seed production, establishment, and survival to an age at which the young tree could successfully compete and endure surface fires. In the historic period, most large trees were killed by lightning fires, dwarf mistletoe, bark beetles, windthrow, or senescence. When single or small groups of trees died and fell, they were inevitably consumed by surface fires. This more severe, but localized, fire produced mineral soil seedbeds, reducing grass competition, and creating a favorable microsite for seedling establishment (Cooper 1960). Within these severely burned microsites with little competition and fuel, seedlings could survive, grow, and develop their competitive ability and resistance to fire. Note the lack of crown fire and increased canopy base height (with a corresponding decrease in canopy bulk density) in Figure 8. Open stands of ponderosa pine under a frequent fire regime are capable of supporting a contiguous understory of herbaceous fuels, up to 1,600 pounds per acre in frequently burned stands. These high levels are the result of surface fires which increase nutrient cycling and reduce competition from woody reproduction. Frequent, surface fires kill small trees, but most grasses and forbs survive, and large trees escape damage because of their high crowns and thick barks (Biswell et al. 1973).

Although fires would have burned at higher intensities during drier, warmer, windier conditions, they would have produced primarily low severity effects in the ponderosa pine forests of the southwest (Swetnam and Baison 1996) (refer to page 38 for definitions of intensity and severity). These processes, along with soil types, aspect, topography, and other physical geographic features, contributed to heterogeneous spatial patterns at all scales, with some patterns shifting through time within a natural range of variability (Allen et al. 2002). Numerous documents (e.g. Biswell et al.1973, Brown and Davis 1973 pages 32 - 33, Cooper 1960) refer to historic ponderosa pine stands as open, park-like, and with a vigorous and abundant herbaceous understory. Captain Sitgreaves in 1854 describes an apparently typical ponderosa pine scene where "the ground was covered with fresh grass and well- timbered with tall pines" (in Dahms et al.1997). Photographic and written records of historic forest conditions and archaeological reconstructions suggest that the characteristic vegetation was a grass matrix with individuals, groups, and stringers of large and variously-sized trees of almost exclusively ponderosa pine.

An area now within the Coconino National Forest is described in a U. S. Geological Survey (1904) repot as: “A yellow-pine forest, as nearly pure as the one in this region, nearly always has an open growth, but not necessarily as lightly and insufficiently stocked as in the case in this forest reserve. The open character of the yellow-pine forest is due partly to the fact that the yellow pine flourishes best when a considerable distance separates the different trees or groups of trees. It is very evident that the yellow-pine stands, even where entirely untouched by the ax, do not carry an average crop of more than 40 per cent of the timber they are capable of producing.

Figure 8. Post-Wallow Fire variability in seedling survival. Few survived.

Figure 9. Post-Wallow Fire variability in fire effects to seedlings. Most survived.

The yellow-pine forest in the reserve is, broadly speaking, a forest long since past its prime and now in a state of decadence. Apparently there has been an almost complete cessation of reproduction over very large areas during the past twenty or twenty-five years (due mostly to sheep use), and there is no evidence that previous to that time, it was at any period, very exuberant "(in Dahms et al. 1997).

Although the popular early descriptions of the ponderosa pine forest call attention to the park-like stands, there are also descriptions which refer to dense cover (Woolsey 1911 in Dahms et al. 1997). An accurate picture of the pre-settlement ponderosa pine forest would most likely describe a mosaic not only with an open, grass savanna and clumps of large, yellow-bark ponderosa pine, but also with a few dense patches and stringers of small, blackjack pines (young ponderosa pine). Ponderosa pine naturally regenerates rarely, but then reproduces with an overabundance of seedlings and a high rate of juvenile mortality (Pearson 1931).

Ponderosa pine has many fire-resistant characteristics. Even seedlings and saplings are often able to withstand fire. The development of insulative bark, meristems shielded by enclosing needles, and thick bud scales contribute to the heat resistance of pole-sized and larger trees. Propagation of fire into the crown of trees pole-sized or greater, growing in relatively open stands (dry sites), is unusual because of three factors. First, the tendency of ponderosa pine to self-prune lower branches keeps the foliage separated from burning surface fuels. Second, the open, loosely arranged foliage does not lend itself to combustion or the propagation of flames (compare this with the dense, foliage of spruce or fir). Third, the thick bark does not easily ignite and does not easily carry fire up the bole or support residual burning. Resin accumulations, however, can make the bark more flammable and may occur if trees have been fighting off insects, or sustained damage such as broken branches or deep abrasions on the bole. Understory ponderosa pine may be more susceptible to fire damage where crowded conditions result in slower diameter growth. Such trees do not develop their protective layer of insulative bark as early as do faster growing trees. They remain vulnerable to cambium damage from surface fires longer than their counterparts in open stands. The thick, overcrowded foliage of young stands or thickets also negates the fire-resisting characteristic of open, discontinuous crown foliage commonly found in this species. Ponderosa pine seedling establishment is favored when fire removes the forest floor litter and grass and exposes mineral soil. Fire resistance of open, park-like stands is enhanced by generally light fuel quantities of flashy fuels. Heavy accumulations of litter at the base of trunks increase the intensity and duration of fire, often resulting in a fire scar or "cat face" when a fire does burn through the area and that part of the bole next to the fuel accumulation is subjected to more heat. Flammable resin deposits around wounds can make an individual tree susceptible to fire damage and can enlarge existing fire scars.

Extensive stand-replacing fires are unreported in the documentary records prior to circa 1950 (Cooper 1960, Allen et al. 2002). There are few data available to indicate how much high severity fire was typical across the ponderosa pine in northern Arizona, but simulations suggest that presettlement forest structure would have supported very little crown fire, passive or active (Roccaforte et al. 2008, Covington 2002). Ponderosa pine does not sprout, so crown fire generally produces 100 percent mortality (high severity). Historically, passive crown fire produced only small patches of high severity effects. Extrapolating results from Roccaforte et al. (2008) to those conditions used for modeling 4FRI, patches of high severity, mostly in the form of passive crown fire, would have generally have been less than about 50 acres under those conditions modeled for 4FRI. This could occur in areas with windthrow, disease/insect infestation, area ecotones between ponderosa pine and mixed conifer or PJ, or other site specific situations that would allow crown fire initiation and spread. In a report written in 1910 by Willard M. Drake, Acting Forest Supervisor of the Coconino National Forest wrote: "…Western Yellow Pine, (Pinus ponderosa) is the characteristic species generally forming in this type a nearly pure and often very open stand of mature timber with few young t4rees in the mixture. Only in very scattered areas do the crowns form anything like a continuous cover…" Modeled historic conditions in Southwestern ponderosa pine indicate that up to 17% may have supported active crown fire with windspeeds of 43 mph (Roccaforte et al. 2008), with none under conditions close to those modeled for this analysis. Frequent surface fires, combined with competition from abundant grasses and other understory plants, maintained an open structure.

Ideally, the average Fire Return Interval would average about 10 years (Weaver, 1951, Cooper, 1960; Fulé 2003, Heinlein et al. 2005, Diggins 2010), across the project area with the vast majority of acres burning with low severity surface fire. In the project area, a 20 year maintenance Fire Return Interval (almost doubling the historic Fire Return Interval) should be the maximum, with most areas burning more frequently under current climate conditions. Twenty years would be an average across the ~600,000 acres proposed for treatment. However, differences in soils and precipitation produce much more rapid growth of seedlings and saplings on the southern part of the Coconino National Forest (COF) (Figure 10) than on the Kaibab National Forest (KNF), particularly Restoration Unit 6. Therefore, the maintenance return interval for the southern COF should be shorter than for Restoration Unit 6, and other parts of the KNF. A delay of more than 20 years between fires or treatments, areas currently showing potential for passive crown fire is likely to transition to active crown fire, depending on if it is in the northern or southern part of the treatment area.

Figure 10. Regeneration in the Clear Creek Watershed on the southern Coconino NF

On the south rim of the Grand Canyon (adjacent to Restoration Unit 6), fire has been observed to burn with low severity, thinning regeneration and keeping the system open with significantly more than 20 years between fires where forest conditions are close to historic conditions (Fulé and Laughlin 2007). Diggins et al. (2010) also showed that, under some scenarios, 20 years would be an acceptable fire return. Other evidence shows that an interval of more than 10 years may not be sufficient, if fire is the only tool and mechanical treatments could increase the longevity (Strom and Fulé 2007). The condition of the forest at the start of the maintenance interval is important. Healthier, more open forests in dry areas are able to go longer without fire without supporting extensive high severity fire when it does burn.

In the ponderosa pine across the treatment area, current crown fire potential is shown below in Table 6. Ponderosa pine is a Fire Regime 1 (fire return interval <35 years, and <25% high severity). However, data specific to the project area and ponderosa pine in Arizona indicate a more frequent fire return interval and a lower level of severity is appropriate, particularly under the conditions modeled. In fact, across much of the project area, a Fire Return Interval of 25 years would be too long, and allow canopy and surface fuel loading to increase to a level that could produce undesirable fire behavior and effects if it burned under moderate conditions. Wind is the most critical factor in fire growth in the project area. Roccaforte et al. (2008) modeled historic conditions and determined that, with winds at 6.2 mph, there was no potential for active crown fire, and on 64% of the landscape had potential for passive crown fire with winds over 40 mph and temperatures and fuel moistures in the 97th percentiles. While percentile modeling is extremely useful in evaluating responses to different variables, as discussed in the Methodology section and Appendix D, for the 4FRI effort, we chose to use known fire conditions. We modified the outcomes to include conditional crownfire (not modeled by Flammap), and conditions similar to those of a known large fire (Table 2), and assumed that approximately 10% of the ponderosa pine would have crownfire potential under conditions modeled under desired conditions. Therefore, desired conditions for ponderosa pine in the project area are for no more than 10% of the ponderosa pine (under conditions modeled) in the treatment area to be prone to crown fire or high severity fire, with high severity acres spatially distributed (Cooper 1962, Swetnam and Baison 1996, Roccaforte et al. 2008).

As indicated in Table 6, none of the RUs currently meet the desired condition. Currently, 38% (191,209 acres) of the ponderosa pine in the treatment area currently has potential for crown fire, of which 28% (144,113 acres), would be active crown fire.

Table 6. Modeled fire type in ponderosa pine and savanna by Restoration Unit (RU)

Existing Condition (acres/%)	RU 1	RU 3	RU 4	RU 5	RU 6	Totals
	144,113	**129,226**	**134,278**	**59,034**	**41,189**	**507,839**
No Fire	520/<1	600/<1	426/<1	3,728/6	44/<1	8,217/~1.5
Surface fire	80,257/56	72,776/56	83,499/62	41,109/70	33,673/82	311,313/61
Passive crown fire	15,784/11	12,594/10	10,590/8	6,821/12	2,233/5	48,023/9
Active crown fire	47,553/33	43,256/33	39,763/30	7,376/12	5,238/13	143,186/28
All crown fire	**63,337/44**	**55,851/43**	**50,353/37**	**15,289/24**	**7,471/18**	**191,209/38**

There are no desired conditions for fire type for ponderosa pine habitat classified as Protected, Target/Threshold, Restricted, or PFA/dPFA, however, these areas show crown fire potential of 51% of Target/Threshold across the treatment area having potential for crown fire (Table 7). Crown fire in MSO habitat is unlikely to maintain key habitat components (Noble, 2014).

Table 7. Modeled fire type for ponderosa pine by habitat type for existing conditions

Vegetation Type		Acres of vegetation type	Fire Type	Existing Condition	
				Acres	% of habitat
Ponderosa Pine*	**All Pine**	507,839	Surface	311,313	61
			Passive crown	48,023	9
			Active crown	143,186	28
	Protected	35,262	Surface	17,954	51
			Passive crown	3,034	9
			Active crown	14,106	40
	Target/ Threshold	8,692	Surface	4,275	49
			Passive crown	922	11
			Active crown	3,482	40
	Restricted	66,419	Surface	35,019	53
			Passive crown	6,540	10
			Active crown	24,756	37
	PFA/ dPFA	30,014	Surface	18,400	61
			Passive crown	2,903	10
			Active crown	8,560	29
	LOPFA	367,452	Surface	235,666	64
			Passive crown	34,624	9
			Active crown	92,282	25

*No fire constitutes <1% of the ponderosa pine and <2% of the entire treatment area

Pine/sage

Desired conditions are to maintain and enhance the sage understory and restore the overstory/understory pattern within the pine-sage mosaic. There are few sources that describe this association. One that does is the Terrestrial Ecological Survey (Brewer et al. 1991). According to the survey, there are about 16,064 acres in RU6 with potential vegetation that could include both ponderosa pine and big sagebrush. Monitoring on the KNF identified *Artemisia tridentata* var. (big sage), and monitoring at the adjacent Grand Canyon National Park identified *A. nova* (black sage), though it was far less common than big sage (USDI 2011).

There are no baseline data available that represent current conditions within the project area though, based on the ecology of the species present and a 1991 survey (Brewer et al. 1991), some assumptions can be made. The desired condition for the sage component of the pine/sage community is a shifting mosaic of sagebrush with a mix of age classes which is regulated primarily by fire. Fire scar analysis that included ponderosa pine on one of the four soil types that support pine and sage indicated an average fire return interval of roughly seven years for surface fires (Huffman et al. 2006). The study suggested that ponderosa pine density has increased substantially since 1887 on an area within RU6 that included one of these soil types. As far as we have knowledge of the system, we can assume that frequent fire probably suppresses big sagebrush establishment, while long fire return intervals allow too many trees to mature, shading out and competing with the big sage and other surface vegetation.

Data from the Grand Canyon (USDI 2011) show that populations of big sage respond better to fires that occur from July through December, and average stem counts from burns at all times of the year may recover to pre-burn levels within 5 - 10 years Figure 11 summarizes data from the south rim of the Grand Canyon. Out of 41 plots, 5 were unknown severity, 2 were moderate/low severity, 1 was moderate/high severity, and 33 were low severity (USDI 2011).

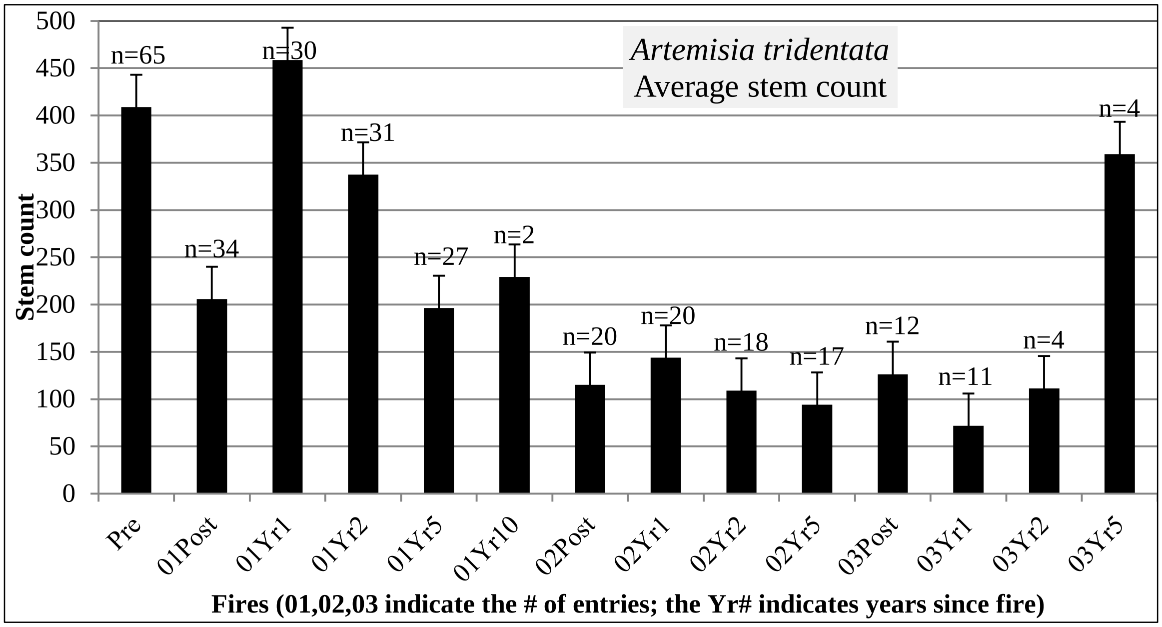


Figure 11. *Artemisia tridentata* pre- and post-burn average stem counts, all age classes.

It should be noted that 'n' for 03YR2 and 03Yr5 n is only 4. Time between 1st and 2nd entry burns averaged 6.5 years, and time between 2nd and 3rd entry burns was 7.9 years. As with many plants, survival appears to be highly dependent on other factors such as pre/post precipitation, temperature, and humidity. Pine-sage provides valuable habitat for several species of wildlife including migratory birds. Shrub species that co-occur with sage, providing further diversity include Fendler's ceanothus, snakeweed, and Gambel Oak, as well as three species that are rare in this PPC, including mountain mahogany, bitter brush, and Oregon boxleaf.

Currently, sage cover under ponderosa pine varies from ~2 % cover[1] where it burned with high severity, or where it has been shaded out by pine to over 35% cover in areas where fire has been excluded (Figure 12, Figure 13). Figure 12 displays a condition that is sustainable about 6 years after a low severity prescribed fire. Sagebrush and pine are both present in various age classes, along with a diversity of other vegetation and an herbaceous layer. This image shows the scarcity of fine, herbaceous fuels within the sagebrush clumps, allowing only minimal fire to impact the sage under most conditions (Tisdale and Hironaka 1981 in McArthur and Taylor 2004).

In the context of the TES Survey Brewer et al. (1991) used 'canopy cover' as criterion describing the relative dominance of each species, of potential productivity, of the influence of plants on precipitation interception and soil temperatures, and of the value of vegetation to animals.

Figure 12. Six years post-prescribed fire in pine/sage east of Tusayan (RU6).

Figure **13** shows a current condition that is either out of the Historic Range of Variability, or a late seral stage for this pine/sage association. If it is within the HRV, this would represent a late seral stage, with sage outcompeting other shrubs, and ponderosa pine saplings not yet shading it out. The primary contiguous fuel is needle litter, which would do minimal damage to sage unless there was a wind. A moderate to high intensity fire burning with a moderate to strong wind at the right time of the year would be required to kill enough trees for fire alone to reset the area in to an earlier seral stage. There are insufficient data to determine if this is a late seral stage, or if this is out of the historic range of variability.

Figure 13. Pine/sage at either a late seral stage, or out of the Historic Range of Variability.

Large and/or old trees

Large and/or old trees in the project area increase structural diversity, improving habitat for birds, insects, and other animals. Old trees have greater genetic diversity than even-aged groups of young trees, and provide forests a better chance of adapting to changing climate conditions and other environmental stressors (Minard 2002). Large and/or old ponderosa pines within the project area are threatened by the increasing size and severity of wildfires. Across the west, the increasing severity of wildfires and the ensuing death of large and/or old ponderosa pines has been linked to fuel accumulation resulting from a century of fire exclusion (Covington et al.1997, Sackett et al. 1996). Some of these fuels are deep duff and organic soil layers at the surface. When they burn, they burn by smoldering combustion and, although temperatures are lower than in flaming combustion, residence times are much longer so more heat is transferred (Hartford and Frandsen 1992). These low intensity fires can cause root and basal stem injury by consuming fine roots growing in the duff layer and through long-term heating of the soil and cambium at the tree base (Hood 2010, Ryan and Frandsen 1991).

Crown damage (scorch) is an important factor in the mortality of old trees that are attributed to fire (Fowler and Sieg 2004, Haase and Sackett 2008, Hood 2010). The proximity of dense young trees and ladder fuels is problematic because it is so wide spread. Figure **14** shows a large ponderosa pine that was killed because it was at the head of a deep draw that was choked with dense young pines. When the fire came up the draw, it wasn't all crown fire (as can be seen by the red needles remaining on the trees on the right side of the photo), but the heat was sufficient to **cause the large tree to 'torch'.**

Figure 14 shows a large tree near the top of a drainage that burned in the Schultz Fire in 2010.

The desired condition for large and/or old trees would be low levels of surface fuels (litter, duff, organic soil, CWD) in the immediate vicinity of old trees, and no ladder fuels sufficiently close for flame impingement should the ladder fuels ignite.

This would decrease potential fire-caused mortality in large and/or old trees. Currently, across much of the project area, fuel loads of all kinds in the immediate vicinity of large and/or old trees are such that mortality would be high in the event of a wildfire burning under undesirable conditions.

Aspen

The desired condition for aspen is to maintain and/or regenerate existing aspen stands or clumps. Fire has been a fundamental, necessary, beneficial disturbance in aspen of the western US for hundreds of years (DeByle 1985, Amacher et al. 2001, Strand et al. 2009, Margolis et al. 2011).

The unique fire ecology of aspen (i.e. its' high sensitivity to fire and its ability to vigorously re-sprout following even high severity fire) supports this theory, and aspen is highly competitive on burned sites, with multiple adaptations for fire. Thin bark with little heat resistance means it is easily top-killed by fire but, fire triggers physiological changes that initiate sprouting for several years following fire, while removing canopy shading (aspen is not shade tolerant). Combined with profuse sprouting for several years after a fire that topkills an aspen tree, this strategy is effective. Following fire, the decrease in surface albedo increases soil temperature and effectively increases the length of the growing season, and the rate of growth (Hungerford 1988). Combined with a flush of nutrients, suckers are stimulated to grow quickly following a fire. This allows them to quickly reach a height which makes them competitive for sunlight, furthering the survival of suckers, and allowing them to out-compete most other woody species (Amacher et al. 2001).

Aspen fire regimes vary somewhat from site to site, so there is no desired condition specifically based on percent crown fire. The fire regime in aspen varies from ~10 to ~150 years (Jones and DeByle 1985, DeByle et al.1987; Strand et al. 2009, Margolis et al. 2011), with fire limiting conifer encroachment and rejuvenating decadent stands. It is the effects of the fires that do occur that would determine the trajectory of the aspen. Fire in aspen stands varies from low severity surface fire to mixed or high severity, with vigorous suckering a common response of the species (DeByle et al. 1987). Aspen can appear in dense thickets after infrequent moderate to high severity fire, even if only a little aspen was apparent before a fire (Jones and DeByle 1985) (Figure 15).

Some of the crown fire modeled in aspen could be attributed to encroaching conifers, which would move the aspen towards the desired condition. Extensive crown fire would topkill the aspen (as well as encroaching conifers) where there is crown fire, but most aspen stands could be expected to sprout vigorously following even high severity fire. Small, and/or highly stressed clones may take longer to recover or, particularly in the presences of browsing ungulates, may disappear. In the absence of browsing, the short term effect would be an exchange of large trees, healthy or decadent, for multiple young sprouts. In the absence of browsing, the longer term effect would be healthier aspen stand in most cases or, in the presence of browsing, much weakened stands.

Stable aspen is considered to be "properly functioning" and "self-replacing" (Bartos 2001). In many instances, these clones exist with a "skirt" or "fairy ring" of young regeneration around the edge and numerous larger stems in the interior. The stems are a various ages resulting from pulses of regeneration that occurred at various times in the past. Increased shading towards the center of such clones would decrease the flammability of the center, so the outer ring would continue to sucker and resprout as it periodically burned. Aspen succeeding to conifers are responding to natural forces. Some of these forces (primarily fire) have been altered by human intervention, which has given shade-tolerant conifers a marked advantage (Bartos 2001). In most aspen stands ladder fuels are absent or only moderately present, in the form of conifers or shrubs. Fuels generally consist of herbaceous material, fallen leaves, downed timber, and any shrubs or conifers that may be present. These fuels are not in a condition to burn as frequently as those in adjacent grasslands or ponderosa forest. When conditions are dry enough in aspen stands with ladder fuels of conifers or shrubs, the abundance, chemistry, and vertical distribution of the fuel may favor a hot fire with rapid spread. Aspen are the most flammable in the fall.

Figure 15. Aspen and bracken fern in a high severity area one year after the Wallow Fire

Based on evidence of repeated surface fire in aspen on south aspects of the San Francisco Peaks, it is likely that the present stand structure for some clones, dominated by >20 m tall, mature aspen stems (>120 years old) may be in part an artifact of fire exclusion. These fire-sensitive aspen stems would have been historically exposed to frequent fires, thus the same stands likely looked very different in the nineteenth century. One hypothesis is that they were smaller diameter aspen “thickets” that were top-killed and regenerated after each fire (Allen 1989 in Margolis et al. 2011). Alternatively, some larger diameter stems at the center of the stand may have been protected from being girdled by fire, creating a multi-cohort age and stand structure.

Aspen in the entire area have been declining since at least the late 1990’s. The decline has been attributed in part, to changes in the frequency and severity of both fire and ungulate grazing (DeByle 1985, Amacher et al. 2001, Fairweather et al. 2007). Many stands now have decadent stems and conifer encroachment (Figure 16). Fire would have been the dominant disturbance, along with some ungulate browsing and some blow-down of decadent stems. Moderate browsing has some, but not all, of the same effects as fire but, as with fire, when it is too frequent, it is detrimental to the health of the stand (Amacher et al. 2001, Fairweather et al. 2007).


Figure 16. Aspen northwest of San Francisco Peaks with pine encroachment beginning.

Currently, aspen stands, as delineated in the FVS data (McCusker et al. 2014) have some of the highest surface fuel loadings of CWD in the area proposed for treatment so that, in the event of a wildfire mature stems would be top-killed and, though in most areas aspen would be expected to sucker quickly following fire, in small, highly stressed stands, fires could be more detrimental than beneficial.

In Figure 16 note the decadent stems on the right of the photo. A fire would have killed most of the encroaching pine, consumed some of the decadent aspen (snags and dead/down stems), and stimulated suckering. Management strategies include mechanically cutting encroaching conifers, and implementing prescribed fire at intensity levels that would be site-specific, depending on the condition of the stand/s being burned.

Gambel Oak

Within the project area, Gambel oak occurs as the dominant component of a woodland and as a component of Pine/Oak.

The oak woodlands community consists of Gambel oak thickets containing various diameter stems, and low-growing, shrubby oak. Some areas contain oak trees with relatively large hollow boles or limbs. When present, coniferous trees are widely scattered and are frequently mature or old. Within the project area, oak woodlands generally occur at elevations between 6,000 and 8,500 feet. There are no desired conditions for Oak Woodlands that are specific to fire.

Where Gambel oak is a component of Pine/Oak, it is likely to be the only deciduous tree in otherwise pure southwestern ponderosa pine forests, adding diversity to these forests. Some of the stands have a large enough component of Gambel oak to be considered pine-oak habitat for the Mexican Spotted Owl (as described in the forest plan and MSO Recovery Plan). As with pure ponderosa pine forests, pine-oak forests have become altered since Euro-American settlement in the late 1800s, so that current conditions are outside of the historic range of variability (Abella 2008a, Abella and Fulé, 2008a). Frequent fire was part of the historic environment, with historic fire return intervals averaging less than 10 years (Abella and Fulé 2008b). Fire exclusion has contributed to a shift in oak densities, with multiple studies indicating there have been increases in small-diameter oak and basal area since Euro-American settlement in the late 1800's (Abella 2008a, Fulé et al 1997a). The majority of this increase, however, is from small and medium-sized stems, and a more simplified forest structure (Abella 2008b).

Pre-settlement conditions may not be realistic to try to replicate, but densities of small-diameter oak could be reduced and surface fire eventually reestablished for restoring oak to within a range of historical variability (Abella 2008a). Oak management strategies within this project includes conservation of all existing large, old oaks, maintaining a variety of growth forms and managing for densities similar to the range of variability of oak's evolutionary environment.

In the project area, Gambel oak generally occurs as a tree or a large, open shrub (Figure 17). In most situations, Gambel oak resprouts vigorously the 1st growing season following fire (Ffolliott and Gottfried 1991, Kunzler and Harper 1980, Brown 1958). If successive fires occur at this stage, Gambel oak stands may be reduced to a grass-forb stage (Crane 1982). As sprouts continue to grow, natural thinning occurs, adding dead stems to the fuel. Fire occurring at this stage may send Gambel oak stands back to a seral grass-forb stage. In the absence of high to moderate severity fire, sprouts form young poles. Pole-sized growth forms may be self-thinning in younger clumps (Abella 2008b). At this stage fires are stand replacing, either creating openings within stands for colonization by resprouts or a complete recycling back to a grass-forb stage.

Figure 17. Pole-sized clone of Gambel oak on Restoration Unit 6

In the absence of high severity fire, Gambel oak stands reach maturity in 60 to 80 years. Fire response in mature stands is similar to that in young poles. A severe fire would recycle the stand;

low-severity fires would create openings for resprouts. Under extreme burning conditions, dense understories of Gambel oak could serve as ladder fuels that carry fire to overstory tree crowns, increasing fire risk to ponderosa pine, but this is not common. The form of Gambel oak that dominates the oak of the Mogollon Rim is rarely the shrubby type that is found further east, but is most often of a small tree form and rarely produces crown fire. Differences in litter, soil, and species composition beneath Gambel oak as compared with ponderosa pine are well documented. Compared to pine litter, oak litter is looser, less resinous and with moisture, potentially resulting in lower fire intensity near boles (Abella and Fulé 2008a). Large oaks have high ecological and aesthetic value (Abella and Fulé 2008a) but were often cut because they were highly prized as firewood and building. In Figure 17, the stump to the left of center, and the absence of other stumps or large trees in the immediate vicinity indicates open conditions probably existed when this clone became established.

There are no data specific for crown fire in Gambel oak, and mortality is often likely from surface fire effects, but there are insufficient data available to determine how much fire is detrimental. Therefore, the effectiveness of treatments to oak was evaluated on the same severity scale as for ponderosa pine, assuming that oak should have less than 10% crown fire. Fire modeling shows crown fire in Gambel oak woodlands across the proposed treatment area at 22% (Table 8).

Table 8. Modeled fire type for Existing Conditions for oak woodland

Vegetation type	Current fire type	% veg type
Oak Woodland	No fire	<1
	Surface	77
	Passive crown	8
	Active crown	14

Grasslands

Desired conditions for grasslands are to restore grassland conditions where there is potential, and to enhance historic grassland inclusions within greater forested areas. Little is known about the pre-settlement condition of grasslands within the project area (Smith and Schusman 2007). Ecological processes were disrupted by domestic grazing years before anyone began to study the flora of the area (Leiberg et al.1904, Allen 1984 in Smith and Schusman 2007).

Frequent fires were the primary disturbance that maintained grasslands, killing young woody encroachment, such as conifer seedlings (Finch 2004). Fire exclusion promotes this encroachment, and grassland acreage has decreased (Arno 1985, Gruell 1985). Most grasslands in the project area are subject to invasion by woody vegetation, (Figure 18) and fire is acknowledged to be the most influential force in checking tree invasion or encroachment (Bond and Keeley 2005, Kozolwski and Ahlgren 1974 pgs.164 – 168, Moore et al. 2004, Archer et al. 2000, Allen 1984 in Smith et al. 2007).

It is difficult to reconstruct specific fire regimes in the grasslands themselves because there is little hard evidence left, such as tree rings. However, reasonable extrapolation can be made by observing the rate of encroachment, the response of the grassland to fire, and by extrapolating from fire studies on adjacent lands. Over the years, airborne particles deposited leaves are washed to the surface below trees, increasing nutrients. Needle litter also affects soil properties, influencing what can grow there. Droppings from birds and other critters may carry seeds into the area, attracted by trees. Multiple studies have been done on fire return intervals in ponderosa pine sites that are near or immediately adjacent to these montane grasslands (Weaver 1951, Cooper 1960, Swetnam 1990, Swetnam and Baison 1990, Fulé et al.1997a, Fulé et al.1997b, Heinlein et al. 2005, Diggins 2010). These grasslands, have drier microclimates than forested areas and, with an annual accumulation of highly flammable fuels, it can be assumed that they burned as frequently as surrounding forest types. These fires would have killed most young seedlings, and top-killed most shrubs and aspen (Allen 1984 in Smith et al. 2007).

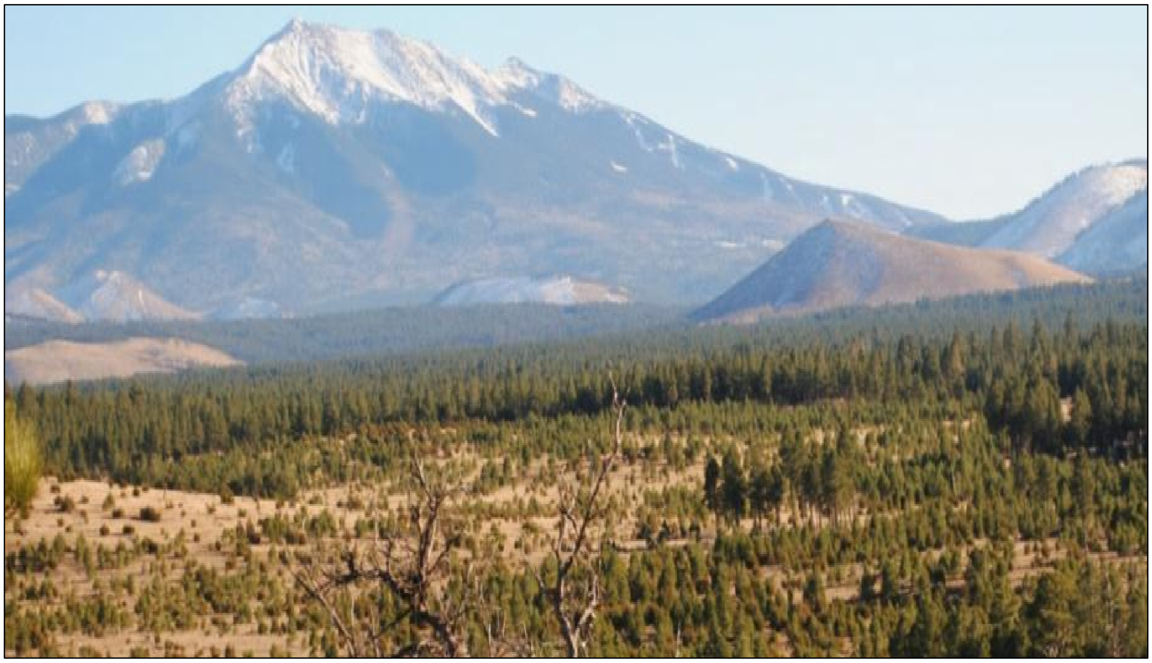


Figure 18. Woody encroachment in grassland opening northwest of Mt. Humpheys, 2011

Soil types can be used as a surrogate to estimate what tree densities and dominant vegetation was historically (Abella et al. 2011). Mollisols and mollic intergrade soils indicate grasses and herbaceous vegetation were present for hundreds to thousands of years, although tree cover may have been present as well, generally less than 10% on mollisols and 10 – 30% on some mollic intergrades (Steinke 2007, USDA 2006). Soil surveys indicate that over 50% of the treatment area is dominated by soils that would have supported grassland vegetation or very open forests with less than <30% tree cover (Stienke 2012).

Soil conditions eventually shift with woody encroachment. Once established, woody plants alter soils and microclimate in their immediate vicinity, affecting both pool sizes and flux rates of nutrients. The result is the formation of ‘islands of fertility’. Archer et al. (2001) described three general mechanisms have been proposed to account for this: (1) woody plants act as nutrient pumps, drawing nutrients from deep soil horizons and laterally from areas beyond the canopy, depositing them beneath the canopy via stem flow, litter fall and canopy leaching; (2) tall, aerodynamically-rough woody plant canopies trap nutrient-laden atmospheric dust which rain washes off the leaves and into the soil beneath the canopy; and (3) woody plants serve as focal points attracting roosting birds, insects and mammals seeking food, shade or cover. These animals may enrich the soil via defecation and burrowing. For these reasons, soil carbon and nitrogen pools increase subsequent to woody plant colonization in grazed grasslands (Archer et al. 2000). Fire suppression activities likely became effective in montane grasslands around 1930, judging by the success of tree invasions (Figure 19 and Figure 20) (Allen 1984, Moore and Huffman 2004).

Figure 19. West side of San Francisco Peaks with encroachment in grasslands, circa 1870.

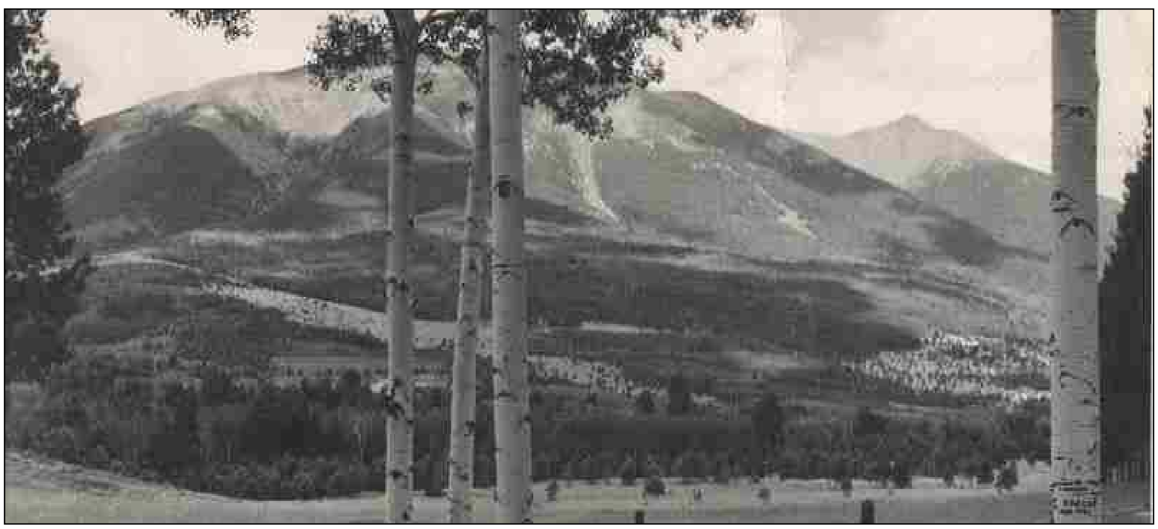


Figure 20**. West side of San Francisco Peaks with complete closure of openings.**

USFS definitions for grasslands suggest that there should be less than 10% tree cover. It can be assumed that in healthy grasslands, the trees representing the 10% cover would not all burn at once, having withstood multiple fires so that crown fire would not readily initiate. They would have matured only after becoming somewhat fire resistant by having surface fires kill off the lower branches and developing thick bark. However, because there can be some trees in a grassland, there could sometimes be some crown fire in trees. This could occur in areas where there has been no fire for several years and seedlings became established, providing ladder fuels that allowed fire to climb into the crown/s of some of the trees representing the <10% tree cover, though it is unlikely that all the trees would burn at once. Therefore, desired conditions include potential crown fire in only a small portion of the 10% tree cover in grasslands. This analysis uses a number of 3% as a maximum for crown fire in grassland vegetation for desired conditions. Fire modeling currently shows 9% of grassland areas have potential for crown fire (Table 9).

Controlling woody species encroachment into grasslands and savanna is most effectively done with fire, as it was historically. However, because fire has been absent so long, there are many trees that are too large to kill with fire and mechanical treatments would be necessary to move the grasslands back to a condition where they could be managed with fire alone.

Table 9. Modeled fire type for grasslands (existing condition).

Vegetation	Fire Type (existing condition)	%
Grassland	No fire	<6
	Surface	86
	Passive crown	6
	Active crown	2

Pinyon/Juniper Woodland

Pinyon/Juniper (PJ) ecosystems intergrade with ponderosa pine on an elevational gradient, with PJ becoming the dominant ecosystem as elevation decreases. On the higher elevation, PJ is bounded mostly by ponderosa pine, on the lower elevation, by shrublands and grasslands. The treatment area includes 26,223 acres of PJ, the majority of which are included only to facilitate prescribed fire in adjacent ponderosa pine or grasslands. The one exception is a 535 acre unit in the WUI immediately east of the town of Tusayan for which the objectives are primarily fuel reduction rather than restoration.

Scarred trees and charcoal evidence from research on the Tusayan Ranger District indicated that fire was ubiquitous over the last 500 years. Little evidence has been found, however, to indicate that high severity fires were extensive (Huffman et al. 2008). This suggested that fires were often small in extent and probably occurred as patchy surface fires to mixed-severity fires that killed groups of trees or small stands (Huffman et al. 2006).

Pinyon/Juniper fires do not carry well unless there is a high wind, though they may creep around and cause occasional torching where there is sufficient litter or surface fuel. The productivity of understory vegetation decreases as stands mature, the canopy closes, and litter becomes the primary contiguous surface fuel. Typically, in a mature PJ stand, canopy base height is low, but surface fuel is usually insufficient to produce surface fire of high intensity, and PJ foliage is often too moist to ignite easily. Pinyon-juniper stands most likely to burn by wildfire have small scattered trees with abundant herbaceous fuel between the trees, or have dense, mature trees capable of carrying crown fire during dry, windy conditions. Such stands are often located just below the ponderosa pine type. Stands of moderate tree density where overstory competition reduces the herbaceous fuel, and the trees themselves are more widely spaced, are very unlikely to burn (Gori et al. 2007). Closed pinyon-juniper stands do not have understory shrubs to carry a surface fire, and do not burn until conditions are met to carry a crown fire.

Fire records from the Coconino NF show several large fires (>1,000 acres) in PJ over the last 20 years. It should be noted, however, that pinyon-juniper ecosystems range from PJ savanna/ grasslands to dense woodlands, with the fire regimes also varying from frequent to infrequent and low to high severity depending largely on the canopy cover and surface vegetation.

A study that included part of Restoration Unit 6 showed juniper (*Juniperus spp.*) was generally confined to upland sites and pinyon pine was found in relatively greater amounts along with ponderosa in the canyons. This suggests that the fire regime in that area is of surface fires burning with relative regularity through ponderosa and pinyon pine communities and less frequently spreading onto upland areas where pinyon and Utah juniper were more important (Huffman et al. 2006). Ponderosa and pinyon pine fire intervals were similar and less than <50 years, whereas juniper intervals tended to be longer than these species with means up to 100 years (Figure 21).

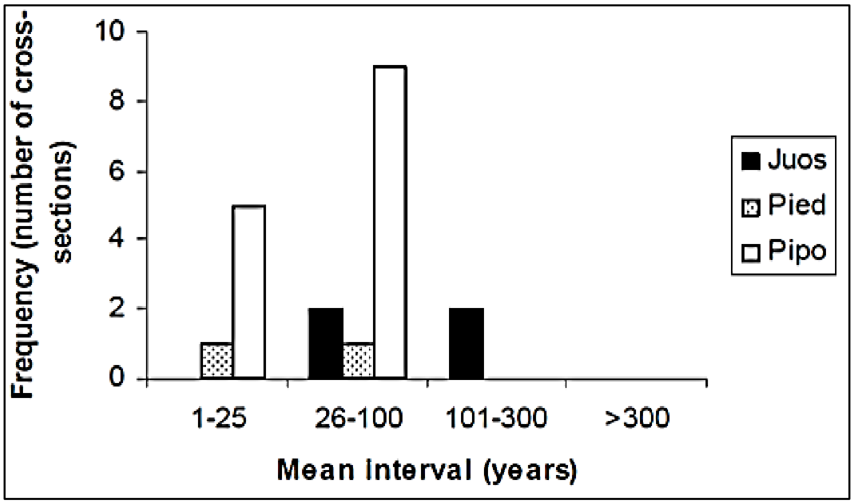


Figure 21. Fire mean intervals by frequency and species (Huffman 2006).

Figure 21 displays fire mean intervals from cross-sections collected at a study site on the Tusayan Ranger District. Means of 1-25, 26-100, 101-300, and >300 represent fire regimes characterized as frequent-low severity, moderate frequency-moderate severity, low frequency-moderate to high severity, and low frequency-high serverity, respectively. Species shown are Utah juniper (Juos), pinyon pine (Pied), and ponderosa pine (Pipo).

On a study site at Tusayan, data collected by Huffman et al. (2006) suggested fires in PJ occurred at a mean frequency of 41.6 years. In that area, there is no evidence of extensive stand replacing fire over the last 400 years and it can be assumed that the historical pattern has been one of frequent surface fires in ponderosa pine communities and small severe fires on pinyon-juniper uplands. The exclusion of these patchy, mixed severity fires at Tusayan has allowed stands to become more dense and homogenous, possibly increasing the site's susceptibility to severe fire of large extent (Huffman et al. 2006).

Historically, PJ fires in the treatment area probably carried into upland pinyon-juniper as patchy low severity surface to mixed-severity fires that did not result in large patches of tree mortality (Huffman et al. 2006, Huffman et al. 2008). Pinyons are poorer recorders of fire than ponderosa pine (e.g. lower post-fire survivorship, more unrecorded fires) and junipers, which appear to scar well, are difficult to age, so fire history reconstructions in some PJ types are difficult. Evidence for low severity surface fires comes from direct observations of fire type in pinyon-juniper savanna-woodland settings in central New Mexico, southern and northern Arizona, and western Colorado while evidence for mixed-severity fires come from fire-history and stand reconstruction studies in pinyon-juniper shrub woodlands settings in northern Arizona, northern New Mexico and southwestern Utah (Gori 2007). Pre-settlement high-severity fires that were largely or entirely stand-replacing have been reported in pinyon-juniper shrub and persistent woodlands in northern Arizona, but are rare, with one study suggesting a return interval of 400 years (Huffman et al. 2006).

Post-treatment conditions in the PJ area east of Tusayan to be treated mechanically are likely to be outside the natural range of variability (in terms of structure and fire behavior) in order to adequately decrease potential fire behavior (Huffman et al 2009). However, in that area of PJ proposed for thinning, the desired condition is for fuels reduction rather than restoration, so the resulting stand structure would be moved towards the desired condition. Table 10 shows modeled fire type for all PJ in the areas proposed for treatment.

Table 10. Modeled fire type for pinyon/juniper under existing conditions

Vegetation Type	Fire Type (existing condition)	% veg type
Pinyon/Juniper	No fire	<1
	Surface	83
	Passive crown	7
	Active crown	9

Restoration Units

When evaluated at the Restoration Unit scale, none of the RUs meet desired conditions for fire type (<10% crown fire), with crown fire potential ranging from 42% in RU1 to 19 % in RU6 (Table 11). ”No fire” includes water, rock, roads, cinders, areas of sparse vegetation, and other acres on which there were insufficient fuels to carry fire under the conditions modeled. These acres range from 45 acres (<1%) in RU6 to 5,733 acres (8%) in RU5.

Table 11. Modeled fire type for Existing Condition by Restoration Units.

		Fire Acres			Fire Percent		
	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	Surface Fire	Passive Crown Fire	Active Crown Fire
Existing Condition	RU 1	87,958	17,352	48,091	57%	11%	31%
	RU 3	90,781	13,639	44,449	61%	9%	30%
	RU 4	111,574	11,956	41,503	67%	7%	25%
	RU 5	52,182	7,370	7,918	71%	10%	11%
	RU 6	35,253	2,763	5,469	81%	6%	13%
	Total	**377,748**	**53,080**	**147,432**	**64%**	**9%**	**25%**

Restoration Unit 1

Restoration Unit 1 is currently of the most at risk of all the RUs in regards to crown fire and its effects in its existing condition. Values at risk in or adjacent to RU1 include: Lake Mary, a source watershed for Flagstaff, and a popular recreation site for locals and visitors to the area (Subunit 1-1); Pulliam Airport, the commercial airport that serves Flagstaff and surrounding communities (Subunit 1-1); eastern and southern portions of the city of Flagstaff, the Perkins Telescope (managed by the Lowell Observatory) just north of Lower Lake Mary (Subunit 1-1); more PACs than any other RU, and Walnut Canyon National Monument (Subunit 1-1) (Figure 22).

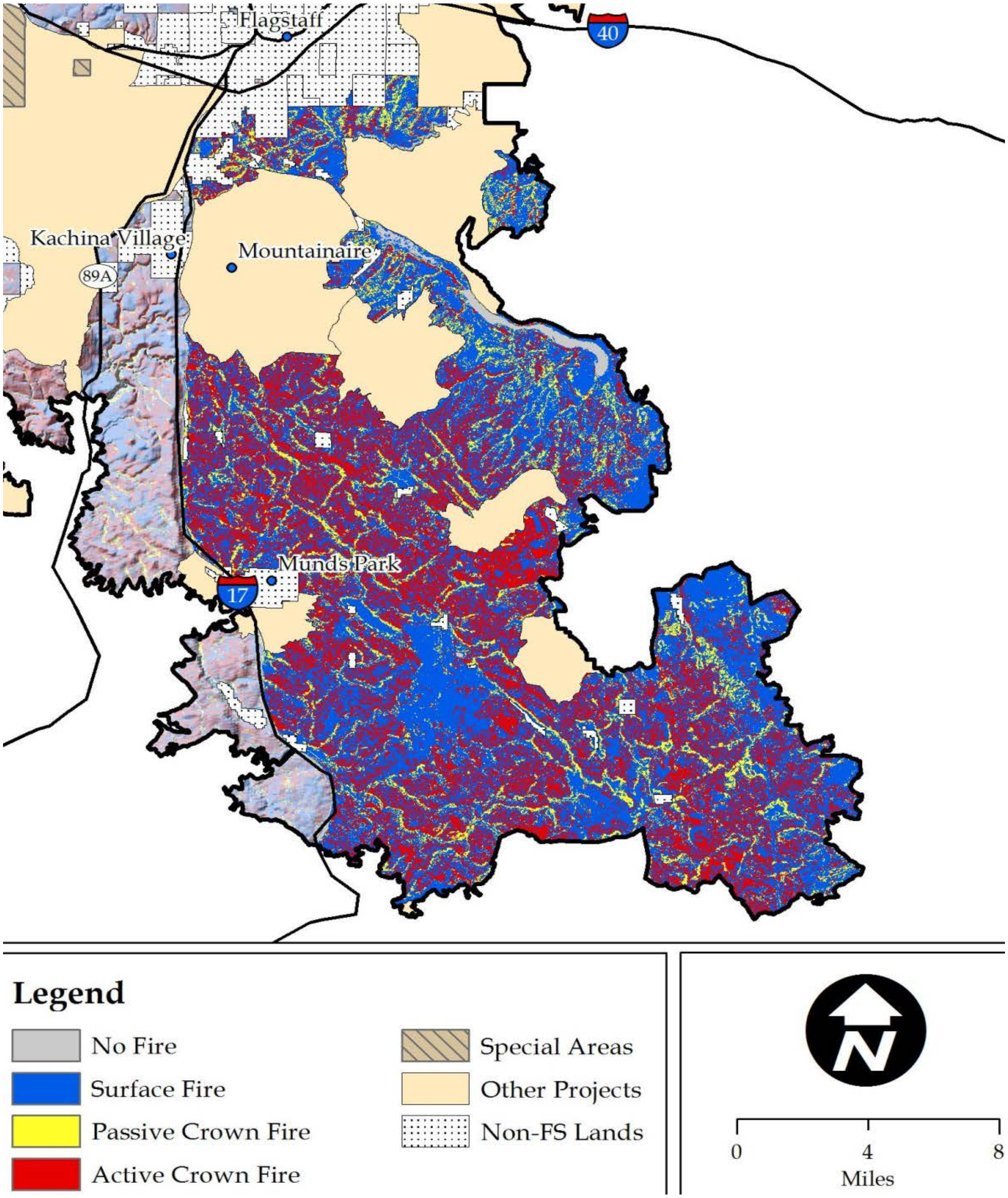


Figure 22. Modeled fire behavior for RU1, Existing Condition.

With 42% of RU1 having potential for crown fire, of which 31% would be active crown fire, there is a need to restore the ecosystems in RU1 to a condition where fire, when it occurs, is beneficial and does not support undesirable fire behavior or effects. There are concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer adjacent to the proposed treatment area, as well as the city of Flagstaff to the northwest. Active crown fire would be expected on the steep slopes to the west, south, and east of Mormon Mountain. Wildfires in those locations would move into untreated fuels upslope of the area modeled below. Second order effects from high severity fire on the slopes of Mormon Mountain would include flooding and debris flows downslope of the areas of high severity fire, including Mormon Lake.

If 31% of the RU burned with active crown fire (Table 11) and another 11% burned with passive crown fire, the ability of Upper and Lower Lake Mary to continue to function as a water source for the city of Flagstaff could be diminished as sediment coming off areas of high burn severity is deposited in the lakes.

There are no desired conditions for fire type within the habitat types, but the potential for undesirable fire behavior and effects within these areas could have negative effects to adjacent areas (Table 12).

Table 12. Fire type by vegetation/habitat types for existing conditions in RU1.

RU 1 acres =		154,383	Veg type acres	2010	
Vegetation Type		Type		Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**144,113**	**80,257**	**56%**
		Passive		**15,784**	**11%**
		Active		**47,553**	**33%**
	Protected	Surface	29,052	15,020	52%
		Passive		2,246	8%
		Active		11,728	40%
	Target/ Threshold	Surface	4,793	2,236	47%
		Passive		504	11%
		Active		2,042	43%
	Restricted	Surface	25,710	12,731	50%
		Passive		2,601	10%
		Active		10,348	40%
	PFA/ dPFA	Surface	4,670	2,594	56%
		Passive		518	11%
		Active		1,558	33%
	LOPFA	Surface	79,889	47,676	60%
		Passive		9,915	12%
		Active		21,877	27%
Other Vegetation*	Aspen	Surface	420	241	57%
		Passive		40	9%
		Active		140	33%
	Grassland	Surface	8,135	6,131	75%
		Passive		1,340	16%
		Active		236	3%
	Juniper Woodland	Surface	286	236	83%
		Passive		12	4%
		Active		38	13%
	Oak	Surface	287	195	68%

	Woodland	Passive		62	21%
		Active		30	11%
	Pinyon/ Juniper	Surface	1,141	897	79%
		Passive		115	10%
		Active		95	8%

*Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area in RU1

Areas downhill from active crown fire would be in the path of runoff and debris flows; areas uphill from those areas would be subjected to crown fire moving into them. It would be expected that some of the ponderosa habitat that burns with high severity would have potential to go through a type conversion, becoming non-forested (Savage and Mast 2005).

Aspen fire regimes vary somewhat from site to site, so there is no desired condition specifically based on percent crown fire. In RU1, there would be potential for 42% (180 acres) of aspen to burn with a crown fire, of which 33% (140 acres) would be active crown fire. Additional effects are described on page 59.

Grasslands within the treatment areas currently have sufficient encroachment by trees that 19% of grassland acres have potential for crown fire. The majority of the crown fire (14%) is passive and is likely to be beneficial to the grasslands. Additional effects are described on page 63.

Oak Woodlands currently have potential for 31% to burn with crown fire, of which 11% would be active crown fire. Additional effects are described on page 60.

Pinyon-juniper fire regimes vary from site to site, so there is no desired condition specifically based on the percent of crown fire, though the effects of fires that do occur would affect the desired condition. About 30% (266 acres) of the pinyon/juniper woodland in RU1 has potential for crown fire.

Subunits

Values currently at risk in Subunit 1-1are described on page 67. Subunit 1-1 includes the Pulliam Airport. Currently, there is potential for several acres of active crown, and several more of passive crown fire within ½ mile of the runway. Subunit 1-3 includes the Lake Mary basin, a source watershed for the town of Flagstaff. Current conditions show 42% of Subunit 1-3 to have potential for crown fire, 29% of which would be active crown fire (Table 13). There is potential for a significant amount of active crown fire within 0.3 miles along a ~3.5 mile stretch of Interstate 17. All or parts of, 10 PACS are within SU1-3, accounting for ~4,700 acres.

Table 13. Modeled fire type in Restoration Unit 1 by subunit and vegetation type

		Fire Type (acres)				Fire Type (%)			
Existing Condition	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
1-1	**10,170**	**164**	**6,383**	**2,047**	**1,576**	**2%**	**63%**	**20%**	**15%**
Ponderosa Pine	8,914	115	5,602	1,714	1,483	1%	63%	19%	17%
Grassland	567	14	307	198	48	3%	54%	35%	8%
Oak Woodland	173	0	120	52	0	0%	70%	30%	0%
Pinyon-Juniper	515	34	354	83	45	6%	69%	16%	9%
1-2	**8,054**	**61**	**5,899**	**827**	**1,267**	**1%**	**73%**	**10%**	**16%**
Ponderosa Pine	6,517	23	4,508	738	1,249	<1%	69%	11%	19%

Grassland	1,537	38	1,391	90	18	<3%	90%	6%	1%
1-3	**39,791**	**426**	**22,869**	**5,056**	**11,440**	**1%**	**57%**	**13%**	**29%**
Ponderosa Pine	36,461	110	20,497	4,526	11,328	<1%	56%	12%	31%
Aspen	88	0	54	13	22	0%	61%	15%	24%
Grassland	3,241	316	2,318	517	90	10%	71%	16%	3%
1-4	**18,250**	**16**	**10,877**	**1,985**	**5,372**	**0%**	**60%**	**11%**	**29%**
Ponderosa Pine	17,285	7	10,082	1,868	5,328	<1%	58%	11%	31%
Grassland	519	10	409	92	8	2%	79%	18%	1%
Oak Woodland	83	0	54	9	20	0%	65%	11%	24%
Pinyon-Juniper	363	0	331	16	16	0%	91%	4%	4%
1-5	**78,119**	**315**	**41,931**	**7,436**	**28,436**	**0%**	**54%**	**10%**	**36%**
Ponderosa Pine	74,936	265	39,568	6,938	28,165	0%	53%	9%	38%
Aspen	332	0	187	27	118	0%	56%	8%	36%
Grassland	2,270	50	1,706	443	71	2%	75%	20%	3%
Juniper Woodland	286	0	236	12	38	0%	83%	4%	13%
Oak Woodland	32	0	21	0	10	0%	67%	1%	32%
Pinyon-Juniper	262	0	212	16	34	0%	81%	6%	13%

Restoration Unit 3

Restoration Unit 3 currently has the second greatest potential for undesirable fire effects and fire behavior based on crown fire potential. There is potential for crown fire across 39% of RU3, of which 30% would be active crown fire (Figure 23).

Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to wildfire potential for Interstate 17 and Interstate 40, as well as the communities of Flagstaff, Munds Park, Williams, Belmont, Kachina Village, and Parks. Sycamore Canyon and Oak Creek Canyon are within or adjacent to this RU as well. The north and east borders are Interstates 10 and 17 respectively.

Adjacency concerns for fire behavior include Flagstaff in the northeast of the RU, and Oak Creek and Sycamore Canyons. Oak Creek Canyon is a popular recreation area, and includes Slide Rock State Park in addition to homes and businesses. Highway 89A runs though RU3 from Flagstaff to Sedona via Oak Creek Canyon. It is a scenic, heavily used highway which would be at high risk should there be extensive flooding and/or debris flows from a high severity fire in or upslope from it. While most of the canyon itself is not within the proposed treatment areas, second order effects (indirect) would be unavoidable within much of the canyon and Oak Creek should there be high severity fires along the rim. The severity of second order fire effects would depend on the slope and extent of a burn. The same concerns apply to Sycamore Canyon, because, although there are no roads, homes, or businesses in the canyon, there are some downstream that could be affected. There are also popular trails in and around Sycamore Canyon that would be affected.

Ponderosa pine does not meet desired conditions for fire type (Table 14). Winds are generally out of the southwest, so fires starting in RU3 would be pushed toward these communities and Interstate 17. With 43% (55,000+ acres) of the pine habitat at risk of crownfire, it is likely that a wildfire in this area would destroy much of the MSO and goshawk habitat in RU3.

Aspen in RU3 occupy 201 acres. The existing fire behavior is not likely to be detrimental because there is only potential for 8% active crown fire and 20% passive. Some of this crown fire can usually be attributed to encroaching conifers. Additional effects are described on page 59.

Grasslands within RU3 do not currently meet the desired condition for crown fire of less than 3% crown fire. Passive crown fire is possible on 6% (706 acres) which would mostly be beneficial. The 167 acres with potential active crown fire would have potential to damage surface and soil resources, as well as being a potential control risk. Additional effects are described on page 63.

Oak Woodlands currently have potential for crown fire in 16% (344 acres) of the vegetation type, of which 13% (269 acres) would be active crown fire. Additional effects are described on page 60.

Pinyon/Juniper woodlands have potential for crownfire in 16% (965 acres) of the vegetation type, of which 8% (701 acres) would be active crown fire.

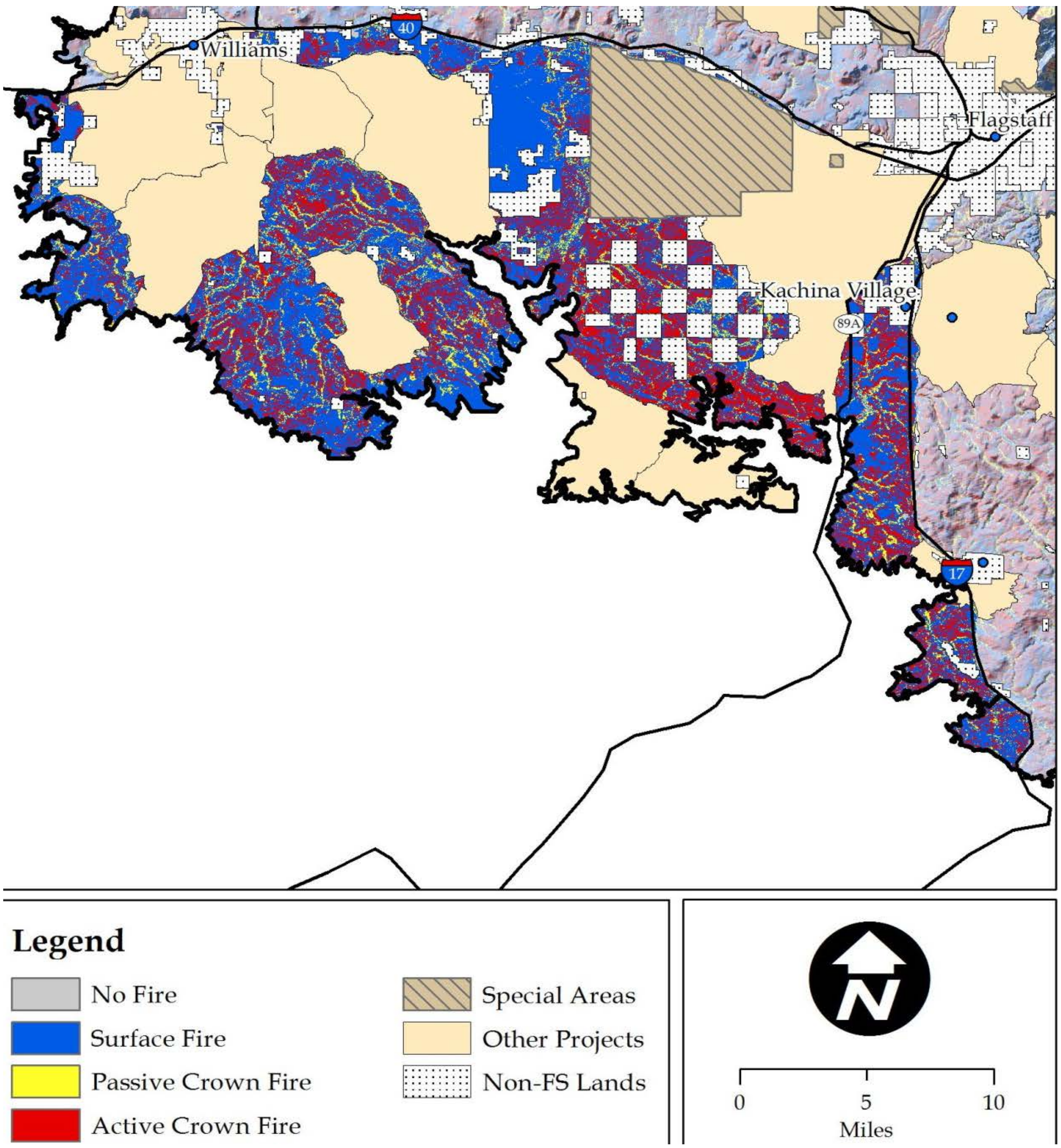


Figure 23. Modeled fire type for Restoration Unit 3, existing condition.

Table 14. Modeled fire type by vegetation/habitat type for Existing Condition for RU3

RU 3 acres =		149,715		2010	
Vegetation Type		Type	Veg type acres	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**129,226**	**72,776**	**56%**
		Passive		**12,594**	**10%**
		Active		**43,256**	**33%**
	Protected	Surface	4,793	2,020	42%
		Passive		611	13%
		Active		2,076	43%
	Target/ Threshold	Surface	3,899	2,039	52%
		Passive		481	11%
		Active		1,440	37%
	Restricted	Surface	38,527	21,085	55%
		Passive		3,672	10%
		Active		13,704	36%
	PFA/ dPFA	Surface	5,582	2,948	53%
		Passive		605	11%
		Active		2,026	36%
	LOPFA	Surface	76,424	44,683	58%
		Passive		7,288	10%
		Active		24,010	31%
Other Vegetation*	Aspen	Surface	201	144	72%
		Passive		40	20%
		Active		16	8%
	Grassland	Surface	12,772	11,670	91%
		Passive		706	6%
		Active		167	1%
	Juniper Woodland	Surface	1,851	1,559	84%
		Passive		49	3%
		Active		240	13%
	Oak Woodland	Surface	1,633	1,282	79%
		Passive		75	5%
		Active		269	16%
	Pinyon/ Juniper	Surface	4,033	3,351	83%
		Passive		175	4%
		Active		501	12%

*Nonburnable substrate constitutes <1% of ponderosa pine and <15% of the treatment area in RU3

Subunits

Ponderosa pine within RU3 does not meet desired conditions in any of the subunits (Table 15). Subunit 3-2 includes an area along Interstate 40 from the outskirts of Flagstaff to Williams, and currently has potential for over 9,000 acres of crown fire (Table 15). Subunit 3-3 encompasses Sycamore Canyon, and includes Rogers Lake. With potential for almost 20,000 acres of crown fire, potential effects to the Sycamore Canyon Wilderness area from flooding and/or debris flows following high severity fire could compromise the functioning of the water resources and adjacent riparian areas. Subunit 3-4 is strategically important for the communities of Flagstaff, Kachina Village, and Munds Park, as well as Interstate 17. Unplanned ignitions starting in or near Pumphouse Wash and Munds Canyon would be likely to funnel wildfires towards or even into, Kachina Village and Munds Park. Additionally, water resources and riparian areas in these areas would be compromised by flooding and/or debris flows. Although SU3-4 is small, with 40% of the area currently having potential for crown fire, there is a need to restore the historic fire regime. At the subunit scale, it is clear that some areas have more encroachment than others, with SU3-5 having potential for crownfire on 324 acres (28% of the grasslands in SU3-5).

Table 15. Modeled fire type in RU3 subunits by vegetation type for existing conditions

Existing Condition	Acres	Fire Type (acres) No Fire	Surface	Passive	Active	Fire Type (%) No Fire	Surface	Passive	Active
3-1	**23,145**	**66**	**15,307**	**2,177**	**5,596**	**<1%**	**66%**	**9%**	**24%**
Ponderosa Pine	18,805	40	11,606	1,943	5,216	0%	62%	10%	28%
Aspen	91	0	64	25	2	<1%	70%	27%	2%
Grassland	590	19	503	56	11	3%	85%	10%	2%
Juniper Woodland	907	1	779	32	96	0%	86%	3%	11%
Oak Woodland	845	1	704	40	100	0%	83%	5%	12%
Pinyon-Juniper	1,908	4	1,652	81	171	0%	87%	4%	9%
3-2	**32,726**	**283**	**23,091**	**2,790**	**6,561**	**<1%**	**71%**	**9%**	**20%**
Ponderosa Pine	22,885	135	13,753	2,601	6,397	1%	60%	11%	28%
Aspen	59	0	39	8	12	<1%	66%	13%	20%
Grassland	9,611	149	9,233	180	49	<2%	96%	2%	1%
Oak Woodland	172	0	67	2	103	0%	39%	1%	60%
3-3	**48,434**	**80**	**28,920**	**4,510**	**14,924**	**0%**	**60%**	**9%**	**31%**
Ponderosa Pine	44,426	62	25,598	4,244	14,522	<1%	58%	9%	33%
Aspen	50	0	41	7	2	0%	82%	15%	3%
Grassland	1,353	7	1,135	166	45	<1%	84%	12%	3%
Juniper Woodland	873	2	713	17	140	0%	82%	2%	16%
Oak Woodland	232	6	208	11	7	<3%	90%	5%	3%
Pinyon-Juniper	1,500	3	1,224	65	208	0%	82%	4%	14%
3-4	**9,019**	**200**	**5,164**	**834**	**2,821**	**<3%**	**57%**	**9%**	**31%**
Ponderosa Pine	8,920	187	5,119	805	2,809	2%	57%	9%	32%
Grassland	99	13	44	29	12	14%	45%	30%	12%
Oak Woodland	0	0	0	0	0	0%	100%	0%	0%
3-5	**36,392**	**217**	**18,299**	**3,327**	**14,547**	**1%**	**50%**	**9%**	**40%**
Ponderosa Pine	34,190	177	16,699	3,002	14,312	<1%	49%	9%	42%
Aspen	2	0	1	0	0	0%	50%	25%	25%
Grassland	1,120	40	756	274	50	4%	68%	24%	4%
Juniper Woodland	70	0	67	0	4	0%	95%	0%	5%
Oak Woodland	384	0	302	22	60	0%	79%	6%	16%
Pinyon-Juniper	626	0	475	29	122	0%	76%	5%	19%

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 40, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds are fire away from these communities. There is also potential to impact the Fort Valley

Experimental Station northwest of Flagstaff. Over the last 20 years, RU4 has been impacted by some large fires, including the Hochderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. Areas of potential active crown fire currently exist adjacent to heavy fuel loading in mixed conifer on Kendrick and Sitgreaves mountains, and the San Francisco Peaks (Figure 24). Areas of active crown fire show on the slopes of Kendrick and Sitgreaves mountains. In these locations, flooding and debris flows could damage infrastructure and homes scattered downslope. Additionally, potential for high severity fire in areas north and west of Flagstaff could be affected by flooding and debris flows. With 32% of RU4 having potential for crown fire, of which 25% would be active crown fire, there is a need to restore the ecosystems in RU4 to a condition where fire is beneficial and does not produce undesirable fire behavior and effects.

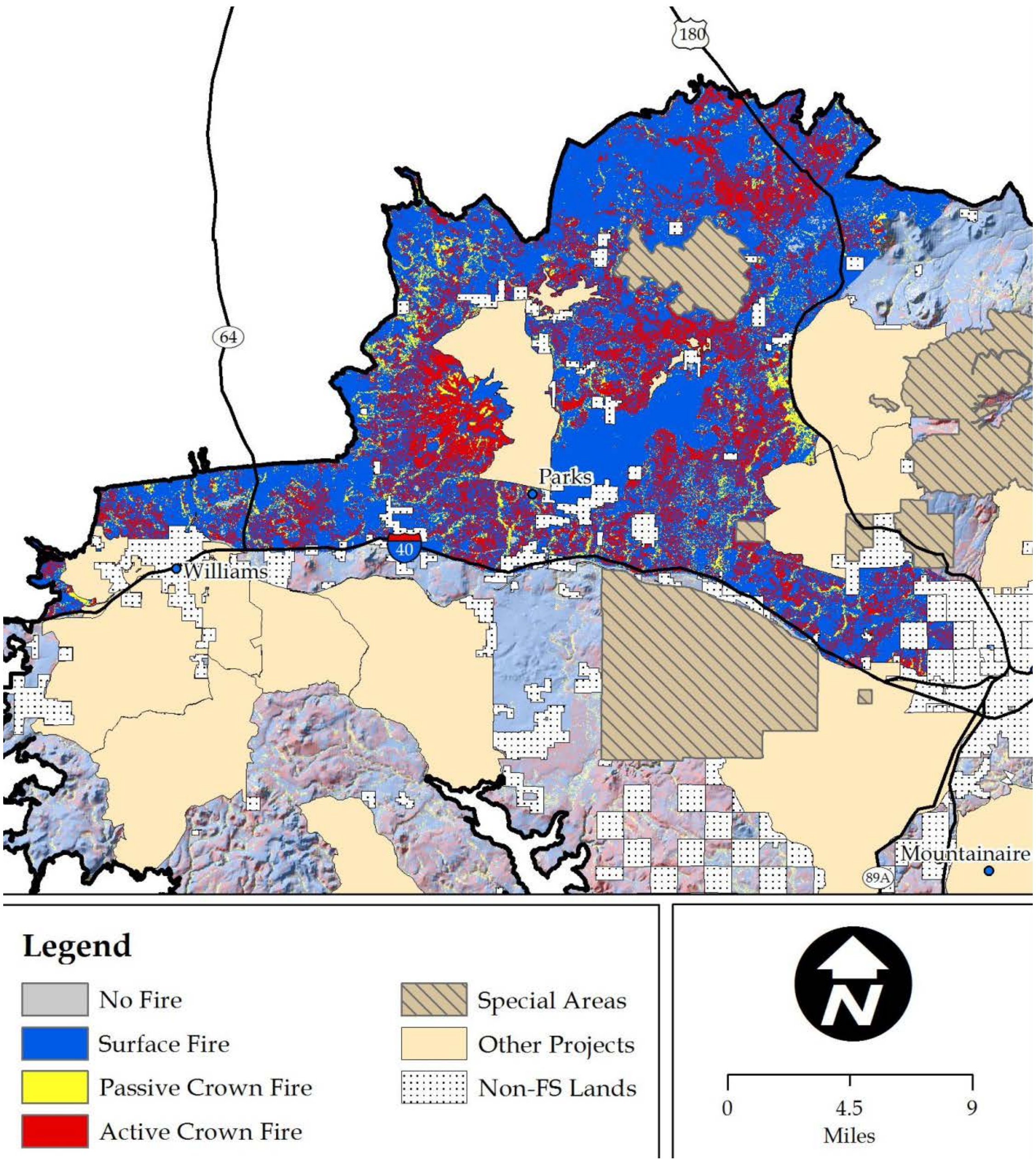


Figure 24. Modeled fire type for Restoration Unit 4, Existing Condition

Ponderosa pine occupies over 134,000 acres in RU4. As described for RUs 1 and 3 above, high severity fire in ponderosa pine can lead to type conversion to a non-forested type. RU4 has potential for over 47,000 acres of crown fire in ponderosa pine (Table 16). Even without including passive crown fire, none of the ponderosa pine habitat types meet desired conditions. Over half of the restricted habitat is indicated as being at risk of crown fire.

Table 16. Modeled fire type by vegetation/habitat type for Existing Condition in RU4.

RU 4 acres =		165,645	Veg type acres	2010	
Vegetation Type		Type		Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**134,278**	**83,499**	**62%**
		Passive		**10,590**	**8%**
		Active		**39,763**	**30%**
	Protected	Surface	558	379	68%
		Passive		45	8%
		Active		134	24%
	Restricted	Surface	1,576	751	48%
		Passive		196	12%
		Active		621	39%
	PFA/ dPFA	Surface	13,484	8,008	59%
		Passive		1,250	9%
		Active		4,221	31%
	LOPFA	Surface	118,659	74,361	63%
		Passive		9,100	8%
		Active		34,786	29%
Other Vegetation*	Aspen	Surface	497	403	81%
		Passive		31	6%
		Active		59	12%
	Grassland	Surface	22,661	21,080	93%
		Passive		788	3%
		Active		645	3%
	Juniper Woodland	Surface	118	69	59%
		Passive		4	3%
		Active		43	36%
	Oak Woodland	Surface	926	669	72%
		Passive		90	10%
		Active		165	18%
	Pinyon/ Juniper	Surface	7,165	5,855	82%
		Passive		453	6%
		Active		829	12%

* Nonburnable substrate constitutes <1% of ponderosa pine and >1% of the treatment area in RU4

Aspen could benefit from the type of fire that shows up in the modeled fire behavior. With 81% surface fire, most of the mortality would come from high surface fuel loads, but the indirect post-fire effects in most cases would be likely to include vigorous sprouting. Additional effects are described on page 59.

Grasslands occupy over 22,000 acres of grasslands in RU4, which include Government Prairie. Under existing conditions, 6% (1,433 acres) have the potential for crown fire. There are more acres of grassland in this RU than any of the others so, although there is potential for only 3% active crown fire, that represents the potential for over 600 acres of active crown fire in grasslands, with potential to damage surface vegetation and soils. The 788 acres of passive crown fire would be mostly beneficial to the grasslands. Additional effects are described on page 63.

Oak Woodlands in RU4 would have potential for 28% (255 acres) to burn with crown fire, of which 18% (165 acres) would be active crown fire. Additional effects are described on page 60.

Pinyon/Juniper woodlands in RU4 would have potential for 17% (1,326 acres) to burn with crown fire, of which 12% (833 acres), would be active crown fire. Additional effects are described on page 65.

Subunits

At the subunit level (Table 17) SU 4-5, though the smallest of all the Subunits at 6,919 acres, is adjacent to the city of Flagstaff, and has steep topography, so that indirect fire effects of high severity fires could impact neighborhoods, schools, and infrastructure in west Flagstaff. Currently, 33% of SU 4-5 has potential for crown fire, with 28% being active crown fire, some of it in Dry Lake Hills, and areas just west of Lowell Observatory. Fires that started southwest of this area would have potential to burn into housing developments on the west side of Flagstaff.

In subunit 4-2, grasslands meet desired conditions for fire type. In the other three they do not, with potential crownfire ranging from 14% in SU4-5 to 5% in SU4-4. However, much of the fire that did occur in these areas would be beneficial to the grasslands, as described above.

Table 17. Fire type in RU4 subunits by major vegetation type, Existing Condition.

Existing Condition	Acres	Fire Type (acres)				Fire Type (percent)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
4-2	**10,227**	**89**	**6,997**	**927**	**2,214**	**1%**	**68%**	**9%**	**22%**
Ponderosa Pine	7,381	33	4,744	772	1,833	<1%	64%	10%	25%
Aspen	1	0	1	0	0	29%	71%	0%	0%
Grassland	328	27	291	8	1	8%	89%	2%	>1%
Juniper Woodland	8	0	7	1	0	0%	89%	8%	3%
Oak Woodland	567	2	378	58	129	0%	67%	10%	23%
Pinyon-Juniper	1,941	26	1,576	88	250	1%	81%	5%	13%
4-3	**67,012**	**324**	**48,122**	**4,399**	**14,166**	**0%**	**72%**	**7%**	**21%**
Ponderosa Pine	55,312	308	37,879	3,791	13,333	1%	68%	7%	24%
Aspen	230	3	214	5	9	1%	93%	2%	4%
Grassland	6,951	11	6,403	239	298	<1%	92%	3%	4%
Juniper Woodland	31	0	30	0	1	0%	97%	0%	3%
Oak Woodland	325	0	273	29	24	0%	84%	9%	7%
Pinyon-Juniper	4,162	2	3,323	336	501	0%	80%	8%	12%
4-4	**81,487**	**194**	**51,809**	**6,269**	**23,214**	**0%**	**64%**	**8%**	**28%**
Ponderosa Pine	65,003	83	36,515	5,701	22,704	0%	56%	9%	35%
Aspen	255	0	182	26	46	<1%	71%	10%	18%
Grassland	15,055	108	14,107	507	332	1%	94%	3%	2%
Juniper Woodland	78	2	31	3	42	3%	40%	4%	53%
Oak Woodland	35	0	19	3	12	0%	55%	9%	36%
Pinyon-Juniper	1,062	0	955	29	78	0%	90%	3%	7%
4-5	**6,919**	**3**	**4,645**	**361**	**1,910**	**0%**	**67%**	**5%**	**28%**

Ponderosa Pine	6,581	1	4,361	326	1,893	0%	66%	5%	29%
Aspen	11	0	6	1	4	0%	54%	6%	40%
Grassland	327	2	278	34	13	1%	85%	10%	4%

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz Fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 acres) mostly on Mount Elden, immediately upslope and adjacent to northern Flagstaff). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. Figure 25 shows areas of passive crown fire in the northwest, much of which is in Gambel oak and scattered juniper and shrubs.

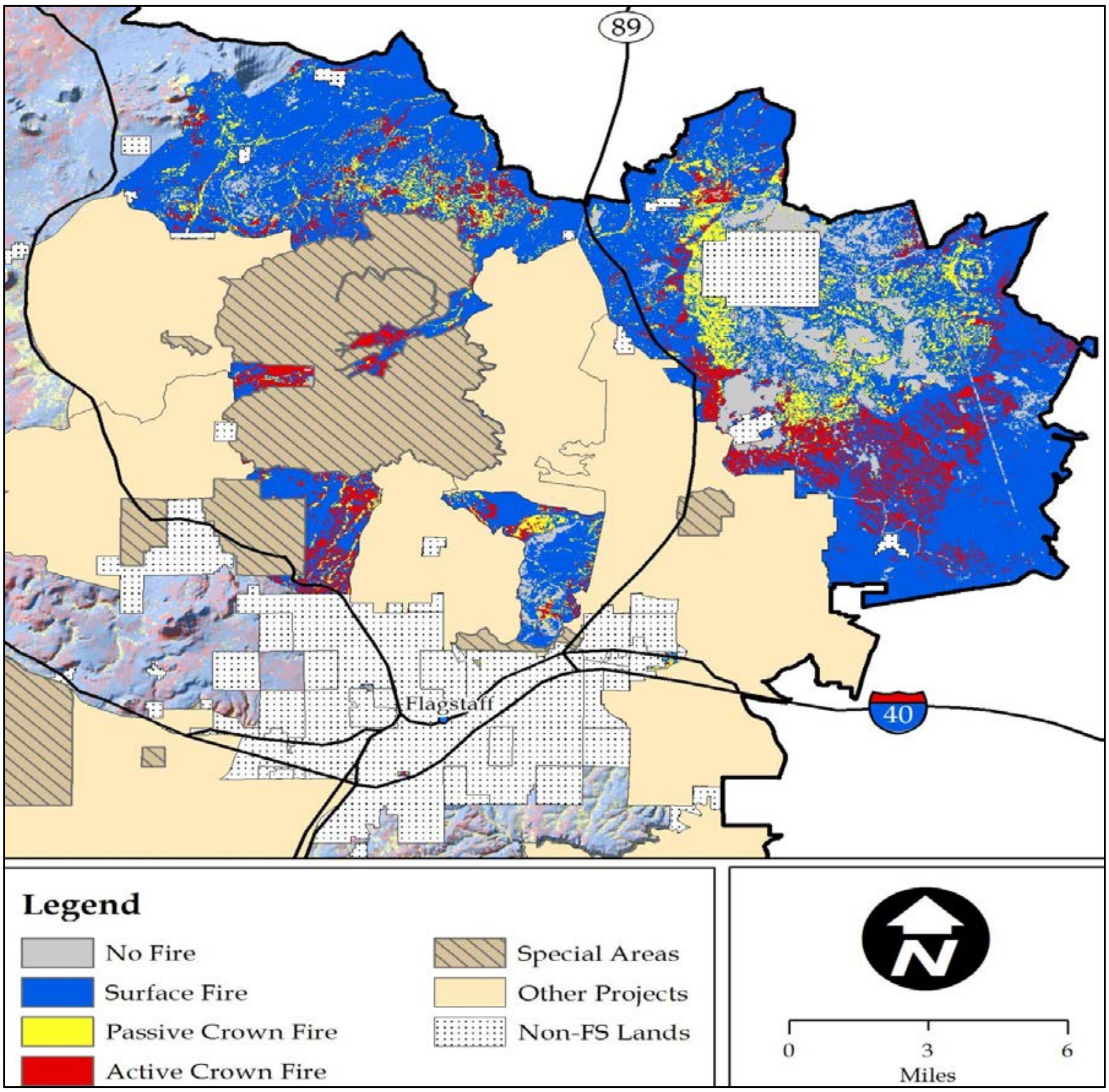


Figure 25. Modeled fire type for Restoration Unit 5, Existing Condition

In the east center of RU5 are some large contiguous areas of passive crown fire. These would be of particular concern under more extreme conditions than are modeled, because of the potential to become active crown fire. The grey areas represent areas of low to no fuel in the cinder substrate northeast of Flagstaff. These areas, have little fuel, but have been reported to attract lightning, increasing the potential for lightning starts in the vicinity (see Appendix D), though there are areas in the cinder hills of over 500 acres have insufficient vegetation to carry a fire. With 21% of RU5 having potential for crown fire, of which 11% would be active crown fire, there is a need to restore the ecosystems in RU5 to a condition where the risk of undesirable fire behavior and effects is minimized.

Ponderosa pine in RU5 does not meet desired conditions for fire type (Table 18). The pine vegetation type has potential for 24% crown fire, of which 12% would be active crown fire. About 5,733 acres are non-burnable (water, cinders, etc.). Effects from the Shultz Fire were beneficial where low severity fire dominated, and there were no/few effects from the flooding and debris flows that followed the fire. Downslope of areas with high severity effects, flooding and debris flows choked streams and riparian areas, and eroded stream banks (Figure 26). In Figure 27 notice the lack of surface vegetation, litter, or duff to hold the soil in place. Subunit 5-2 includes much of the youngest, most sparsely vegetated cinder cones, as well as areas that were affected by the second order fire effects resulting from the Schultz Fire.

Figure 26. Erosion and deposition from flooding and debris flows downstream of a high severity burned area on the Schultz Fire (2010).

Aspen in RU5 is mostly on the west side of Highway 89A. In RU5, aspen occupies about 403 acres, of which 17% (67 acres) would have potential for crown fire, 11% (43 acres) would be active crown fire. Some of the crown fire modeled in aspen can be attributed to encroaching conifers. Additional effects are described on page 59.

Grasslands occupy 4,536 acres in RU5. On these acres, there is potential for undesirable fire effects to soil and surface vegetation. Currently, there is potential for 7% of the grassland areas (327 acres) to support crown fire. About 2% (105 acres), would be active crown fire. Passive crown fire (222 acres) in these areas would be beneficial to the grasslands, decreasing woody encroachment and indirect effects would include removing immediate seed sources for future encroachment. Additional effects are described on page 63.

Oak Woodlands make up just 21 acres of RU5. There would be potential for <1% active crown fire, and about 5% (20 acres) of passive crown fire. Additional effects are described on page 60.

Pinyon/Juniper woodlands make up 8,845 acres of RU5; 8% (677 acres) of it would have potential for crown fire, of which 393 acres would be active crown fire. In Pinyon/Juniper, this may be within the historic fire regime. Additional effects are described on page 65.

Figure 27. Forest Service Road 418 two months after the Schultz Fire.

Table 18. Fire type by vegetation and habitat type for Restoration Unit 5.

RU 5 acres =		73,203	Veg type acres	2010	
Vegetation Type		Fire Type		Acres	%VT
Ponderosa Pine*	**All Pine**	**Surface**	**59,034**	**41,109**	**70%**
		Passive		**6,821**	**12%**
		Active		**7,376**	**12%**
	Protected	Surface	859	535	62%
		Passive		132	15%
		Active		167	19%
	Restricted	Surface	606	451	74%
		Passive		71	12%
		Active		83	14%
	PFA/ dPFA	Surface	2,227	1,343	60%
		Passive		419	19%
		Active		325	15%

	LOPFA	Surface	55,341	38,780	70%
		Passive		6,199	11%
		Active		6,801	12%
Other Vegetation*	Aspen	Surface	403	332	82%
		Passive		24	6%
		Active		43	11%
	Grassland	Surface	4,536	2,521	56%
		Passive		222	5%
		Active		105	2%
	Juniper Woodland	Surface	74	67	90%
		Passive		7	9%
		Active		0	1%
	Oak Woodland	Surface	386	349	91%
		Passive		20	5%
		Active		1	0%
	Pinyon/ Juniper	Surface	8,771	7,804	89%
		Passive		277	3%
		Active		393	4%

* Nonburnable substrate constitutes <1% of ponderosa pine and ~8% of the treatment area in RU5

Subunits

Subunit 5-2 includes areas that were burned over by the Schultz Fire. A direct effect across part of the fire area was to remove the potential for crown fire in the short term. Table 19 shows mostly surface fire, with grasslands in Subunit 5-1 meeting desired conditions for fire type.

Table 19. Modeled fire in subunits of RU5 for Existing condition 5 by vegetation type

		Fire Type (acres)				Fire Type (%)			
Existing Condition	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
5-1	**21,341**	**791**	**16,641**	**1,630**	**2,278**	**<4%**	**78%**	**8%**	**11%**
Ponderosa Pine	18,040	742	13,591	1,500	2,207	4%	76%	8%	12%
Aspen	392	5	325	21	42	1%	83%	5%	11%
Grassland	1,239	19	1,118	84	17	2%	90%	7%	1%
Oak Woodland	95	0	85	10	0	<1%	89%	10%	0%
Pinyon-Juniper	1,574	25	1,522	15	12	<2%	97%	1%	1%
5-2	**51,863**	**4,942**	**35,540**	**5,740**	**5,641**	**<10%**	**69%**	**11%**	**11%**
Ponderosa Pine	40,994	2,985	27,518	5,322	5,169	7%	67%	13%	13%
Aspen	10	0	7	3	1	0%	67%	26%	7%
Grassland	3,297	1,668	1,403	138	88	51%	42%	4%	3%
Juniper Woodland	74	0	67	7	0	0%	90%	9%	1%
Oak Woodland	291	16	264	10	1	5%	91%	3%	<1%
Pinyon-Juniper	7,196	272	6,281	261	381	4%	87%	4%	5%

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and adjacent to the south unit of Grand Canyon National Park. Proposed treatments in RU6 are all within the Tusayan Ranger District of the Kaibab National Forest. With 19% of RU6 having potential for crown fire, of which 13% would be active crown fire, there is a need to restore the ecosystems in RU6 to a condition where fire is beneficial and does not produce undesirable fire behavior or effects. In some of these areas, ponderosa pine, Gambel oak, and pinyon/juniper co-occur. These areas are likely to have frequent ladder fuels, accounting for the widespread and scattered crown fire (Figure 28).

Continuous areas of passive crow fire show in the northeast and southeast areas where pinyon and juniper are more frequent. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area, with over half of it having had fire in the last 10 years. In the westernmost area, near where highway 183 goes though the town of Tusayan, there is pinyon/juniper for which fire behavior is a concern for the town of Tusayan. This is in the area where there are 535 acres of fuels treatments. The active crown fire shown in Figure 29 is largely dispersed, with only a few areas of contiguous crown fire.

Figure 28. Ladder fuels in RU 6 where oak, ponderosa pine, and juniper co-occur

The Tusayan Ranger District, which includes all of Restoration Unit 6, currently has a shorter fire return interval overall, than the rest of the project area. Of ~55,000 acres of fire documented in between 1989 and 2009, less than 2% burned with high severity. The majority of the acres burned were within the ponderosa pine, in areas proposed for treatment in 4FRI. In its existing condition, 18% of the ponderosa pine has potential to sustain crown fire (Table 20), with 13% of it being active crown fire.

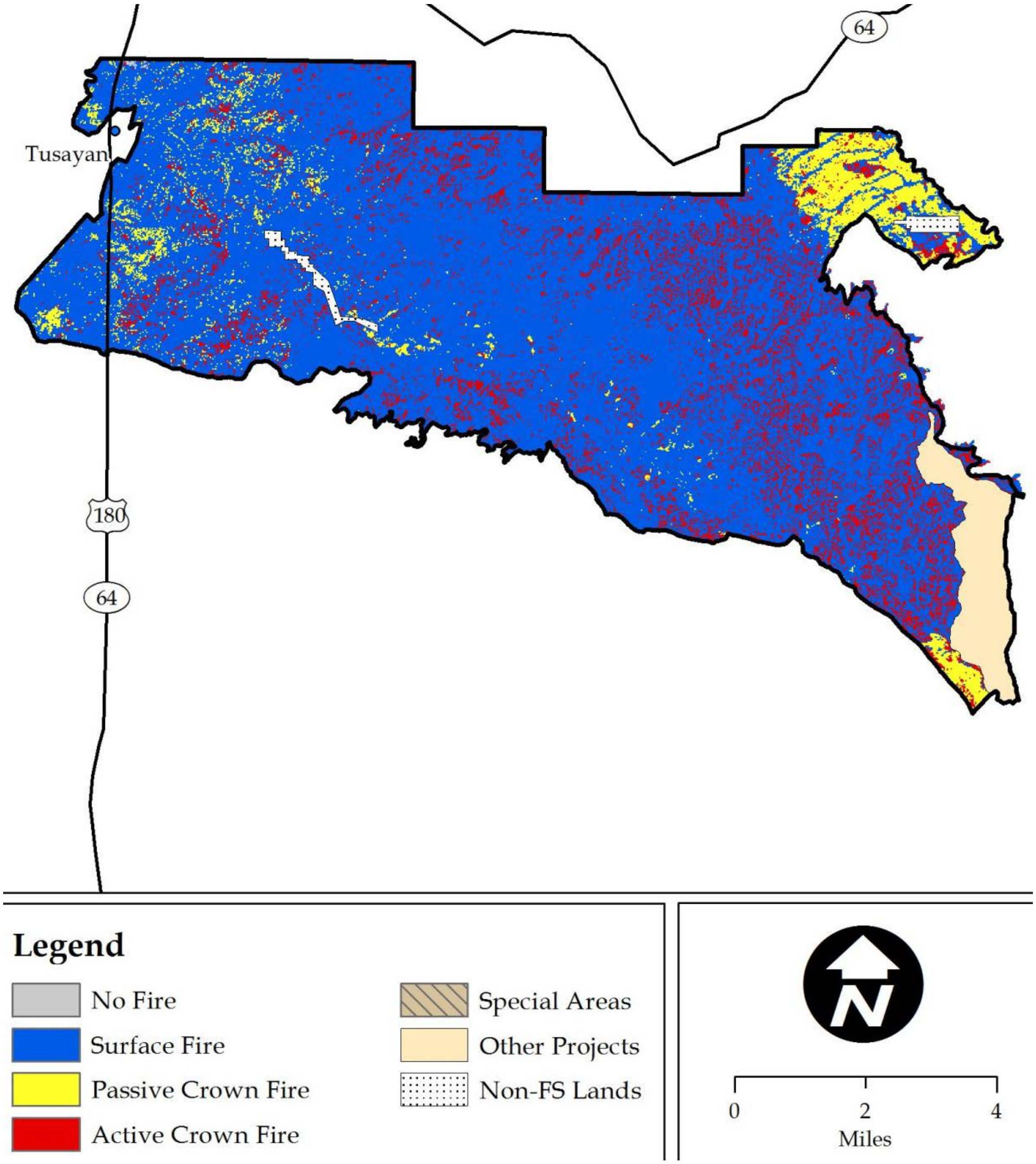


Figure 29. Modeled fire type on RU6, Existing Condition.

Ponderosa pine, in its existing condition does not meet desired conditions for fire type (Table 20), with about 7,400 acres of crown fire potential. However, only about 5,200 acres of this is active crown fire, and none if it occurs in contiguous areas of greater than 50 acres. With 82% of the ponderosa pine in RU6 modeled as surface fire, it isn't too far off of desired conditions.

Grasslands currently meet desired conditions in RU6. Effects are described on page 63.

Oak Woodlands constitute only 30acres of RU6. Of these, 70% have potential for crown fire, of which 68% of it (20 acres) would be passive crown fire. This area is in the ecotone that has ponderosa pine, juniper, and oak, so there are plentiful ladder fuels (Figure 28). Additional effects are described on page 60.

Pinyon/Juniper woodland currently has potential for 1,533 acres of passive crown fire, with an additional 227 of active crown fire. There is no desired condition for those acres included as operational burn only (1,701 acres). For the remaining 535 acres proposed for fuels reduction, the desired condition is for 0% of the area to support crown fire. Additional effects are described on page 65.

Table 20. Fire type by vegetation/habitat type for Restoration Unit 6, Existing Condition

RU 6 acres =		43,530	Vegetation type acres	2010	
Vegetation Type		Type		Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**41,189**	**33,673**	**82%**
		Passive		**2,233**	**5%**
		Active		**5,238**	**13%**
	PFA/ dPFA	Surface	4,050	3,506	87%
		Passive		111	3%
		Active		430	11%
	LOPFA	Surface	37,139	30,167	81%
		Passive		2,123	6%
		Active		4,808	13%
Other Vegetation*	Grassland	Surface	93	89	96%
		Passive		2	2%
		Active		1	1%
	Juniper Woodland	Surface	13	10	79%
		Passive		3	21%
		Active		0	0%
	Oak Woodland	Surface	30	9	30%
		Passive		20	68%
		Active		1	2%
	Pinyon/ Juniper	Surface	2,206	1,472	67%
		Passive		504	23%
		Active		229	10%

* Nonburnable substrate constitutes <1% of the ponderosa pine and <1% of the entire treatment area in RU6

Subunits

The majority of ponderosa pine in RU6 is in SU6-3, of which 15% currently could support crown fire, 13% of which would be active crown fire. There are only 8,553 acres of ponderosa pine proposed for treatment in Subunits 6-2 and 6-4 combined. There are only a total of 92 acres of grasslands in RU6 and, which currently meets desired conditions for fire type (Table 21). Fires that occur in the grassland area would continue to maintain the grasslands by keeping woody encroachment at bay, recycling nutrients, rejuvenating fire adapted shrubs, and maintaining fuel loads at desirable levels. The 38% passive crownfire in SU6-4 can be attributed to the presence of juniper, and the ecotone between the PJ and ponderosa pine, where fire type is trending towards the passive crownfire that dominates this kind of PJ under the modeled conditions (Figure 28).

Some of the pine within these subunits are on the edge of the core area of ponderosa pine, and have a component of juniper and/or oak (Figure 28). Figure 28 shows an area in the northwestern corner of Subunit 6-4 where oak, ponderosa pine, an juniper co-occur. Although the canopies are not always contiguous, there are copious ladder fuels, illustrating why modeled fire type in this area showed up as almost contiguous passive crown fire. Gambel oak is present in most of the pine in all subunits, but is most prevalent in subunit 6-4 where there are areas of pure oak woodland. Oak is being overtopped in many of these areas by ponderosa pine.

Table 21. Fire type in subunits of Restoration Unit 6 by vegetation type, Existing Condition

Existing Condition	Acres	Fire Type (acres)				Fire Type (%)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
6-2	**5,551**	**7**	**4,663**	**410**	**470**	**<1%**	**84%**	**7%**	**8%**
Ponderosa Pine	5,069	7	4,303	297	462	0%	85%	6%	9%
Pinyon-Juniper	483	0	361	114	8	<1%	75%	24%	<2%
6-3	**34,109**	**33**	**28,730**	**888**	**4,458**	**0%**	**84%**	**3%**	**13%**
Ponderosa Pine	32,635	33	27,587	724	4,290	0%	85%	2%	13%
Grassland	85	0	82	2	1	0%	96%	3%	1%
Juniper Woodland	13	0	10	3	0	0%	79%	21%	0%
Pinyon-Juniper	1,375	0	1,050	158	167	0%	76%	12%	12%
6-4	**3,870**	**4**	**1,860**	**1,465**	**541**	**0%**	**48%**	**38%**	**14%**
Ponderosa Pine	3,484	4	1,783	1,212	485	0%	51%	35%	14%
Grassland	7	0	7	0	0	0%	100%	0%	0%
Oak Woodland	30	0	9	20	1	0%	30%	68%	2%
Pinyon-Juniper	348	0	61	232	55	0%	<18%	67%	16%

Surface fuels and canopy characteristics affecting fire behavior and effects

The ability of a forest to maintain its resilience to fire depends, in part, on how close it is to threshold conditions that would support crown fire. Canopy characteristics and surface fuel loading combine to produce combinations of surface fire intensity (flame length is a good proxy for fireline intensity – the higher the intensity, the longer the flame length) and physical structure (the height, density, and horizontal and vertical continuity of canopy fuels) that can produce crown fire under a given set of conditions. For ponderosa pine, the closer conditions are to the threshold, the faster they would deteriorate to a point where crown fire is possible.

Canopy characteristics

Existing conditions for Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are shown in Table 22. The following figures and tables classify canopy characteristics by desired openness which represents the openness of an area, as well as how well it can maintain a trajectory towards the desired condition. The areas with lower desired openness are primarily those associated with MSO habitat currently have the highest fuel loading (Table 23), as well as the lowest Canopy Base Heights (CBH), the higher Canopy Bulk Density (CBD), and the highest Canopy Cover (CC). Across the landscape, a mosaic at all scales would be well adapted to fire for southwestern ponderosa pine, and would be maintainable by fire alone should that be desired.

Table 22 shows modeled canopy characteristics for Existing Conditions. Desired conditions are for Canopy Base Height (CBH) to average greater than 18 feet (affects the initiation of crown fire) and for Canopy Bulk Density (CBD) to be less than 0.05 (affects the ability of crown fire to be sustained from one tree crown to the next) (Nicolet 2011). It is important to note that the average CBH, in particular, is only an indicator of potential. Fire only needs one access point to the canopy to initiate crown fire so, if there is one tree with a low CBH and sufficient CBD to initiate crown fire. However, averages are an indicator that can be a useful part of an assessment when used with other indicators and as baseline data to judge trends. Currently, at the stand level, average canopy bulk density in the ponderosa pine of the treatment area averages around 0.059 kg/m3, with about 82% of the pine having a canopy bulk density greater than .05 kg/m3. Currently the canopy base height in the treatment area average is about 15 feet.

Table 22. Modeled canopy characteristics for Existing Conditions. Shaded cells do not meet desired condition.

Desired openness	Existing Conditions			% of Ponderosa Pine
	CBH (feet)	CBD (kg/m3)	CC (%)	
High	15.36	0.061	41	41
Moderate	14.74	0.061	43	24
Low (Mechanical)	16.44	0.063	42	6
Low (Burn-Only)	13.99	0.046	33	18
Very Low (Burn-Only)	14.54	0.063	41	2
Very Low (Mechanical)	15.54	0.062	48	4
Very Low (PAC Burn-Only)	14.42	0.067	49	4
Very Low/No Proposed treatment (MSO Core Areas)	14.18	0.070	51	1
No Proposed Treatments	14.48	0.049	41	0.4
Weighted Average[2]	14.98	0.059		

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Wildland fuels are composed of various categories of fuels, including live and dead, small and large, and so on. Each plays a different role in fire behavior and effects. Litter, duff, and Coarse Woody Debris greater than 3 inches in diameter (CWD>3 inches) affect fire behavior and effects, including emissions. CWD and duff contribute more than other fuels to total emissions in prescribed fires because prescribed fires are almost exclusively surface fires, and very little of the canopy fuels are generally consumed. Litter is a necessary component of fires that get very large, because it is usually what allows the fire to spread at the surface. With a crown fire, large amounts of canopy fuels are consumed over a relatively short duration. Both wildfire and

[2] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive. For the Existing Condition, acres used are

prescribed fire consume surface fuels. The heat produced by smaller woody debris (<3 inches in diameter) and some litter mostly goes upwards, having less of an effect on surface fire effects than duff, or larger woody fuels. When areas with heavy fuel loading burn under the wrong conditions, particularly fuels that smolder in place for extended periods, enough heat can transfer to the soil that it can consume or kill soil biota and other organic matter in soil that is critical to soil function and productivity (Lata 2006, Neary et al. 2005, Valette et al. 1994). Additionally, small woody fuels generally burn quickly, contributing less to emissions, than litter, duff and CWD. These three fuel components also tend to represent the majority of surface fuels by weight. These surface fuels are far more likely to cause high severity effects to soil than other fuels because they can smolder in place for long periods, transferring more heat into the soil, cambiums, and other surface and soil components of an ecosystem than aerial fuels (fuels that are not in contact with the surface) and produce troublesome emissions. Mechanical thinning alone can contribute significantly to decreasing the potential for crown fire by breaking up vertical and horizontal canopy fuel continuity, but does little, in the long run, to decrease surface fuel loading. Initial thinning impacts may include temporary fire 'breaks' where there are skid trails, or other surface disturbances, but surface fuels are generally not removed from the treatment area, and remain a potential source of heat and emissions. Post mechanical thinning often increases surface fuel loading by small amounts (Fulé et al. 2012). Effects may be spottier but, where fuels have been pushed into piles or furrows (intentionally or otherwise), they may smolder for a long time.

Surface fuel loading by treatment ability to maintain desired openness

When averaged by desired openness (Table 23), CWD is lower than recommended levels of 5-7 tons/acre (see shaded areas), in all but the two lowest levels of openness. Duff levels exceed historic levels in all categories.

Table 23. Existing Condition of litter, duff, and CWD > 3" (in tons/acre). Shaded cells are not within 3 - 10 tons/acre.

Existing Conditions					% of ponderosa pine
Desired openness	CWD	Litter	Duff	Total	
High	3.7	3.1	3.1	9.9	41
Moderate	3.7	3.9	3.1	10.7	24
Low (Mechanical)	3.8	3.2	3.3	10.3	6
Low (Burn Only)	3.2	2.5	2.9	8.6	18
Very Low (Burn Only)	3.8	3.2	3.2	10.2	2
Very Low (Mechanical)	5.0	5.0	3.9	13.9	4
Very Low (PAC Burn Only)	6.0	4.8	5.1	15.9	4
Very Low/ No Proposed Treatments (Core Areas)	5.8	5.1	4.7	15.6	1
No Proposed Treatments	3.0	3.8	2.4	9.3	<1
Weighted Average[2]	3.7	3.5	3.2	10.7	

Figure 30 shows heavy fuel loading within the project area in a PAC on Mormon Mountain in 2011. In this location, litter was 8-12 inches deep, with several inches of duff beneath it and large logs scattered about. This location probably has around 15 tons of CWD, and more than 10 tons of litter and duff per acre. While this is one end of the extremes for fuel loading, it is an extremely hazardous condition from the perspective of fire behavior and effects. If a wildfire burned though this area, even under moderate conditions, the effect to the area could be devastating, with high tree mortality, loss of soil productivity, and total loss of habitat. This condition is not a large portion of the project area, but much of it is an important component of the landscape, and critical for wildlife.

In the existing condition, shown in Figure 31, the majority of the area that currently exceeds recommended levels for surface fuel loading is near, or associated with MSO habitat.

Figure 30. Very high surface fuel loading in a PAC on Mormon Mountain in 2011

The likelihood of undesirable fire behavior and effects increases with increased surface fuel loading. Undesirable fire behavior and effects could be expected in areas where fuel loading is >20 tons/acre, though there would be variations from site to site based on the conditions under which a fire burns.

Surface fuel loading by stands

Figure 31 displays surface fuel loading of duff, litter, and coarse woody debris (>3 inches diameter) for existing conditions. The darkest blue represents areas where fuel loadings are on the high end of what is recommended from the combined perspectives of soil productivity, historic levels, soil heating, wildlife, and fire hazard (Brown et al. 2003). Yellow though red show where surface fuel loads exceed levels recommended.

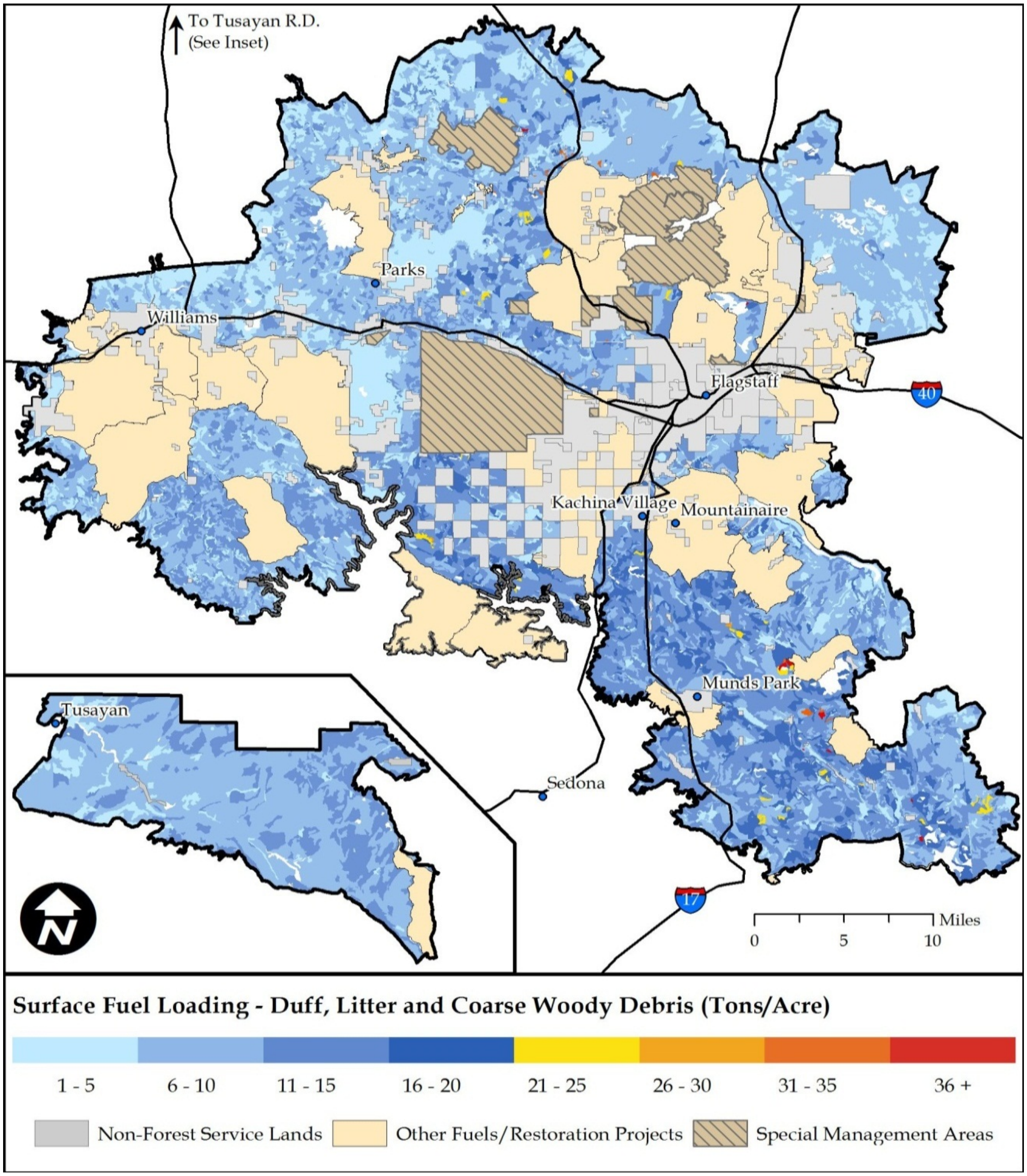


Figure 31. Surface fuel loading for Existing Conditions.

When averaged by the stand, there are currently ~2,953 acres, mostly in PACs, that have surface fuel loading greater than 20 tons/acre. There are also almost 64,000 acres on which surface fuel loading is between 15 and 20 tons/acre. These 64,000 acres do not currently exceed recommended fuel loadings, but are on the high end of recommended fuel loading. Conditions that would affect the severity of direct and indirect fire effects include environmental factors at the time of the burn such as fuel moisture, wind speed, and those factors that affect fireline intensity (page 38).

Fire Regime/Condition Class (FRCC)

Figure 32 shows a landscape within the project area that was mostly in a FRCC1 around 1880. The photographs show evidence of grazing in the foreground, and wide open meadows with scattered individual trees in background. Figure 33 shows the same area around 1980 in FRCC3. Note the conifer encroachment in the meadows. Fern Mountain can be seen in the background. The desired condition is to have all of the area currently assessed as FRCC3 move to FRCC2, and some of the area currently assessed as FRCC2 move to FRCC1.

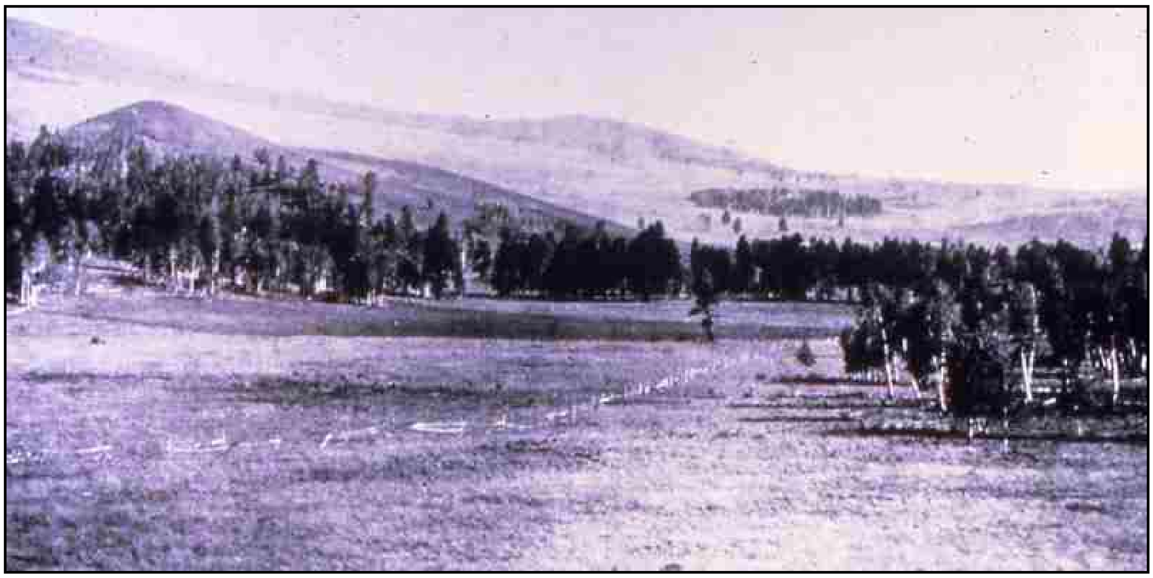


Figure 32. Grasslands on west side of San Francisco Peaks, near Flagstaff, AZ ca 1880.

Figure 33. Same area as above. Circa 1980

It is difficult to ascertain FRCC for the grasslands on the Mogollon Rim because of insufficient data for seral stages (based on changes in dominant vegetation and cover), fire return intervals, fire severity. However, as illustrated by the photos (and Figure 33), and soil data, native grasslands have been encroached with conifers, and additional changes in vegetation are likely from fire suppression, though details are lacking. High frequency fire in the adjacent pine forests makes it likely that grasslands, which are highly flammable when they are cured, also had a fairly high fire frequency. It is reasonable to assume that a significant portion of the grasslands would currently be classified as FRCC3, based on likely changes in vegetation dominance and woody encroachment

Table 24 shows 61% of ponderosa pine (309,782 acres) are currently classified as VCC3, indicating the ecosystem is highly departed from its historical range, and an additional 25% (126,960 acres) are in an VCC2, indicating the ecosystem is moderately departed from its historical range. The 4FRI area proposed for treatment is classified as an FRCC3.

Table 24. Vegetation Condition Class (VCC) - Existing Condition

	2010	
	Acres	**%**
VCC1	71,097	14%
VCC2	126,960	25%
VCC3	309,782	61%
Vegetation departure =	66%	
Fire Severity Departure =	74%	
Fire Return Interval Departure =	80%	
FRCC of treatment area =	**3**	

Fire Return Interval

Fire Return Interval is one of the variables used to calculate Fire Regime/Condition Class (pg. 33). It can be used as a coarse indicator of the status of an area. As calculated for this analysis, it does not take into account seasonality, severity, average size, spatial complexity, or other important characteristics of a fire regime. The average, however, can be a useful indicator of how close or far an area is from a sustainable fire regime that can create and maintain the temporal and spatial disturbance patterns produced by the ecological functions of fire.

Fire Return Interval is closely related to fire history. The Mogollon Rim has a high density of ignitions, both lightning and human, and a large percent of the area burned with wildfire in the last 10 years (Figure 34). About 30% of the area burned by fires greater than 1,000 acres in the last 25 years (not counting WFU) produced high severity effects. Many of these areas have been slow to regenerate and remain open areas with excessive CWD in an area dominated by herbaceous vegetation. Prescribed fire has focused in a ‘donut’ around the Flagstaff area, and near other high risk areas. In Figure 34, the spatial layers are translucent to show areas with multiple burns.

For ponderosa pine in the project area, the historic fire return interval ranged from 2 to 22 years (Weaver 1951, Cooper 1960, Dieterich 1980, Swetnam et al. 1990, Swetnam 1990, Swetnam and Baison 1996, Fulé et al. 1997a, Fulé et al. 2003, Covington et al. 1997, Heinlein et al. 2005).

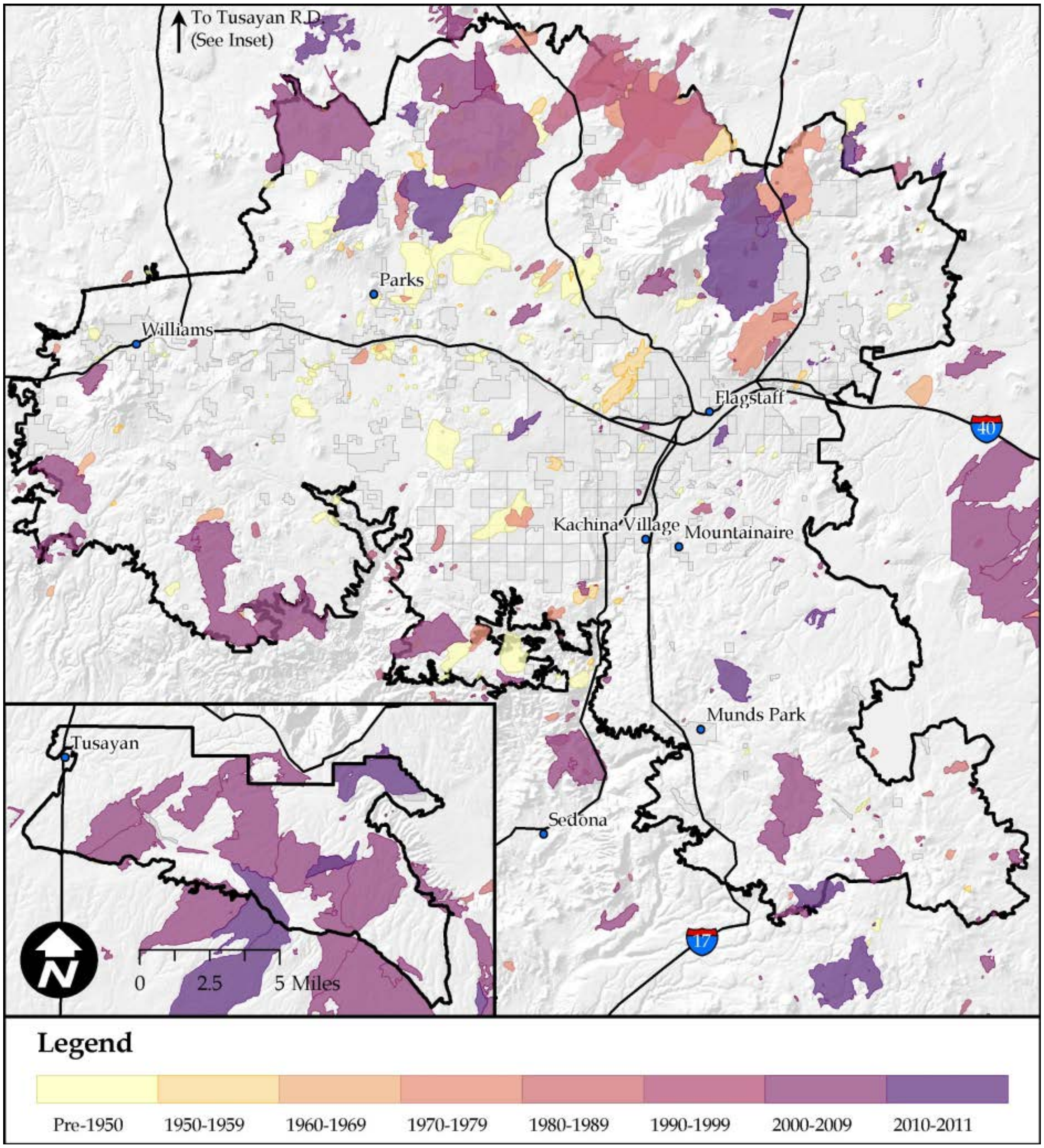


Figure 34. Wildfire history of the 4FRI area pre-1950 through 2011

The average fire return interval from 2001 to 2010, was calculated to be 43 years for the ponderosa pine and grassland in the project area. These calculations included planned and unplanned ignitions, indicates a current fire return interval of ~43 years with ~34,000 acres burning annually from 2001 to 2010. This FRI is an average that includes both areas that have burned much more frequently than every 43 years, and areas that have burned at a much longer frequency. It was only calculated from 2001 to 2010 because the consistency of the data between forests was less dependable before 2001, and this work was done in the winter of 2010 - 2011. This is double the desired maximum average for maintenance burning in ponderosa pine on the Mogollon Rim. This fire return interval of 40 years, has contributed to the degree of departure from historic conditions that puts over 34% of the area proposed for treatment area at risk of high severity fire effects based on crown fire alone. From 2001 through September of 2013, average acres burned over the project area, including both wildfire and prescribed fire were about 15,000.

Emissions: Air Quality and Ecological Effects

Wildland fire emissions, can cause adverse health effects and/or become a nuisance, but are fundamental to the disturbance ecology associated with healthy ecosystems in the project area. Because fire is a necessary part of the equation, air quality impacts are part of all action alternatives in one form or another. All action alternatives propose using prescribed fire extensively, and all are expected to achieve the desired conditions for air quality. Air quality within the project area currently meets EPA air quality standards.

Desired conditions do not currently exist for Air Quality on both the Kaibab and Coconino National Forests, but the desired conditions in this analysis are:

- Air quality meets all State and Federal ambient air quality standards.
- Visibility in Grand Canyon National Park, and Sycamore Canyon, Class 1 areas, makes reasonable progress towards, or meets national visibility goals established in the Clean Air Act, the Regional Haze Rule, and the Arizona State Implementation Plan.

The management action that has the greatest potential effect on air quality is prescribed burning. All prescribed fires are expected to achieve the desired conditions for air quality under all alternatives, and hence, Air Quality is not expected to be a primary driver in selecting one alternative over another.

Some comparison between alternatives can be made by looking at the indirect effects of management activities that reduce the likelihood of high severity fires. High severity active crown fires produce large quantities of emissions that are often heavily concentrated. The alternatives that best alter stand structure to promote surface fire over active crown fire and decrease surface fuel loading would have the least negative environmental consequences to Air Quality, and are the focus of comparison between alternatives regarding Air Quality in this report.

Wildfire vs. Prescribed Fire

National Forests are increasingly using prescribed fire, and wildfire to achieve resource objectives, and to reduce the risk of undesirable fire behavior and effects (see Appendix A). Federal land managers have conflicting roles when it comes to protecting visibility in Class I areas, or managing nuisance smoke. On the one hand, they are given the responsibility of protecting and meeting visibility standards and being responsive to public tolerances. On the other hand they are tasked to allow fire, as nearly as possible, to function in its natural role in the ecosystem (USDA and USDOI 1995). This puts the land manager in the awkward position of contributing to emissions, and needing to explain why smoke from wildland fires may be acceptable, while other types of pollution (i.e. Auto emissions, industrial emissions) are not. In this context, smoke and visibility impairment from wildland fire that closely mimics what would occur naturally may generally be viewed as acceptable (Peterson 2001).

Wildfires contribute to air quality impacts, and their emissions are monitored in the same manner as emissions sources that can be controlled (such as dust, vehicle emissions, smoke from wood-burning stoves, industrial emissions, prescribed fire, etc.), and included in air quality assessments used to approve burn plans. Smoke impacts from wildfire are less easily mitigated than prescribed fire, whether the expected effects of the fire are desirable or not. Among the many factors fire managers and line officers must carefully weigh when deciding whether to suppress a wildfire, manage it to perform its natural role as in the ecosystem, or to ignite a prescribed fire is whether the potential benefits of the wildfire outweigh the smoke impacts to the airshed, affected communities, and rural residents. Prescribed fires and wildfires both create smoke, but differ in the amount, timing, and predictability of these events (Table 25). Most wildfires occur during the summer months.

Table 25. Generalized comparison of options for managing fire on federal land

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

Fire managers are able to manage smoke impacts to some degree by timing prescribed fire and, to some degree burn out operations on wildfires, to occur when ventilation conditions are favorable. It may be possible to check a fire's edge on days when reduced emissions are needed, or blackline burn units days or even weeks in advance of burning the main units of a prescribed fire in order to best take advantage of burn windows with good ventilation. Various Emissions Reductions Techniques are utilized and documented as a standard part of implementing prescribed fires. (ERTs are listed in Appendix E). A 'Daily Burn Accomplishment Form' is completed and submitted for each day a burn is being implemented (see Appendix E). Activities on prescribed fires and wildfires in an airshed are coordinated between fire managers, in conjunction with ADEQ, to either spread high emission producing events from multiple wildfires 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 duration of smoke impacts.

In the last ten years, acres of prescribed fire have increased across both forests, though the actual amount fluctuates from year to year (Figure 35). Actual smoke impacts are dependent on numerous unforeseeable factors such as ventilation parameters, live and dead fuel moisture, wind direction and speed, firing techniques, timing and duration of ignition, fuel arrangements and loading, atmospheric stability, and more. Air quality impacts are related much more closely to these factors than the 4FRI Alternatives.

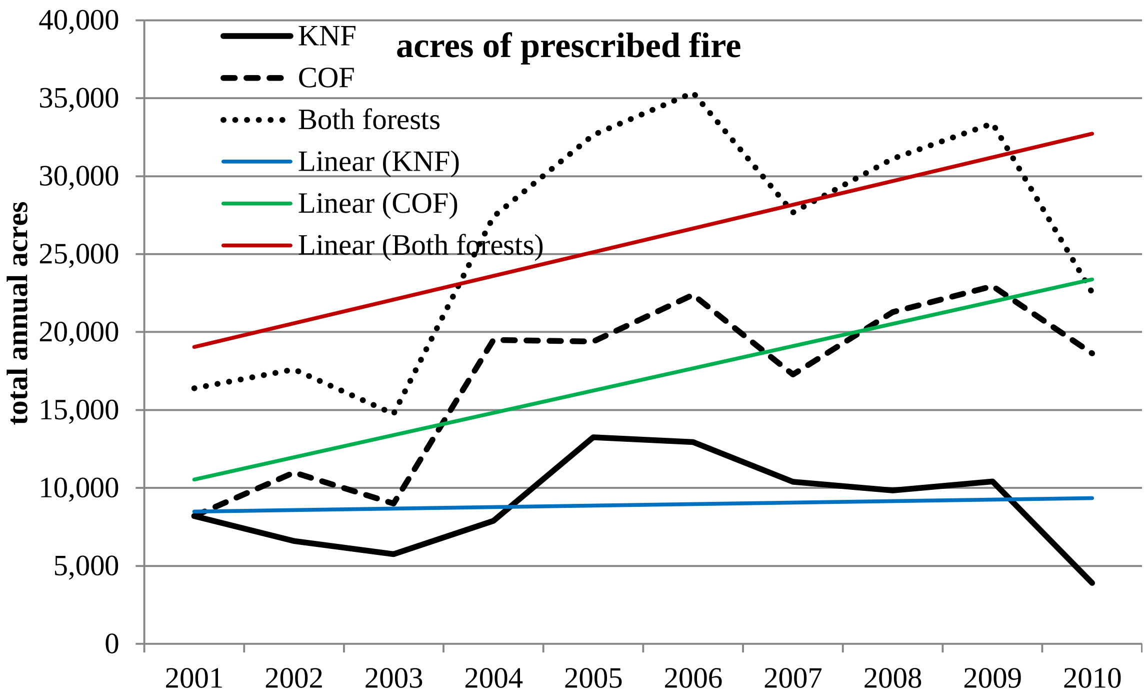


Figure 35. Acres of prescribed fire and trends for both forests from 2001 through 2010

Smoke is inevitable in the airsheds of northern Arizona, whether from wildfire, or prescribed fire. 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 (wildfire or prescribed fire) produce behavior and effects that are low to moderate. Fires that burn under more extreme conditions (most/all fires in this category are wildfires) produce behavior and effects that are moderate to severe. Air quality effects from large, high severity fires usually creates more emissions over a longer time than prescribed burning, because of differences in the size and duration of the fires (Hardy et al. 2001c pg. 93) 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 Arizona Department of Environmental Quality standards and regulations, including the legal limits to smoke emissions from prescribed burns as imposed by Federal and State Law. The Arizona Department of Environmental Quality ADEQ) enforces these laws by regulating acres that are treated based on expected air impacts. These regulations 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 impacts). Figure 35 charts acres of prescribed fire in the last 10 years and the trends for both forests. The red line is the average for both forests; green is average for the Coconino National Forest (COF); and the blue line is the average for the Kaibab National Forest (KNF).

Meteorological, Climatological and Topographical effects on Air Quality

Climatological limits are set by weather and fuel moisture, which profoundly affect fire behavior, fire effects, and the behavior and effects of emissions. As weather varies from year to year, so does the risk of high severity fires and the ability to use prescribed burns and wildfires to achieve resource objectives. Large fluctuations in the number of days of opportunity vary widely from year to year, creating large fluctuations in the number of acres treated with wildland fire. Running averages over many years must be used in order to view trends in fire use or fire effects (Kleindienst 2012).

Topography and weather patterns determine the extent to which airborne particulate matter accumulates within local airsheds. Diurnal temperature changes affect how pollutants in the region are dispersed. Meteorological conditions also limit how much smoke the airshed can absorb at any point in time without violating NAAQS (details on page 18) or visibility thresholds. 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, southwest, and west (figure 36) and, as such, during daytime hours, fire activities within the 4FRI treatment area are most likely to affect smoke sensitive receptors to the north, northeast, and east of fire locations. 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 smoldering fuels (duff, dead/down wood), which often 'pools' in low lying areas until the air warms again the next day. Nighttime settling of residual smoke from fires generates as many concerns and complaints of nuisance smoke as daytime smoke. "Nuisance Smoke" is defined in the State Implementation Plan (page 19) 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)

Figure 36 shows the prevailing wind direction for each of three Remote Automated Weather Stations (RAWS) that are used to determine overall weather patterns in the area. Flagstaff (left), Mormon Lake (middle), and Tusayan (right). For each RAWS, a wind rose shows the average wind speed and direction for a year; from November through April, and from April through October. Prevailing winds are from the west, southwest, and south during the day. Night-time winds are calm most of the time, allowing topography to be the main control on the movement of emissions so, for multiple consecutive burn days, there are likely to be smoke impacts in low area and, for most prescribed burns during the day, there is some potential for smoke impacts to locations north, northeast, and/or east of the burn unit.

During the winter, weather conditions can trap emissions in a layer of cold surface air (inversion). Under these conditions, particulates can be trapped close the surface in local airsheds, including Flagstaff, Williams, and the Verde Valley. Visibility is also an air quality consideration. Visibility tends to be lowest in the summer due to regional haze and smoke from fires.

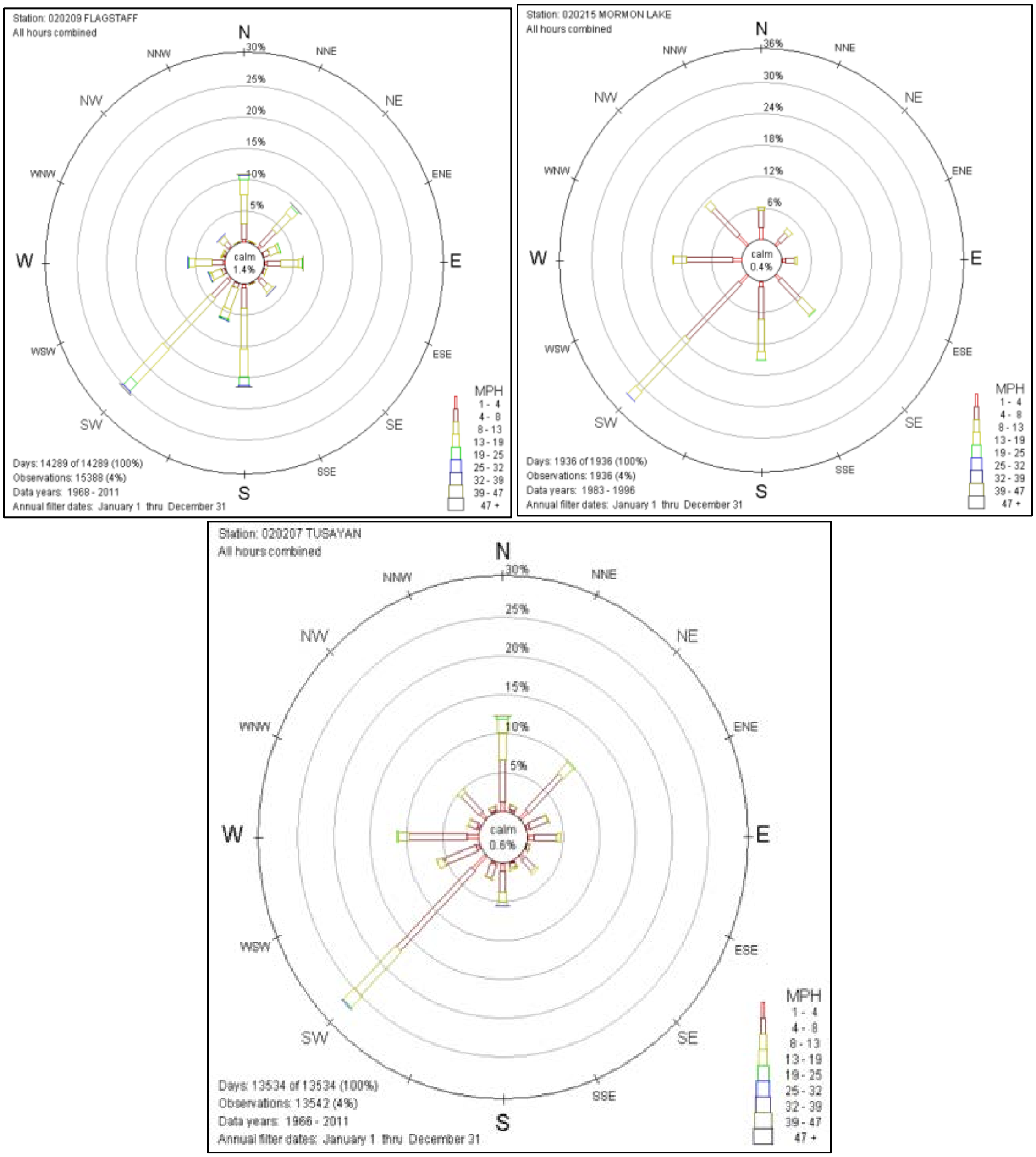


Figure 36. Wind roses from the three Remote Automated Weather Stations (RAWS) showing average winds in the project area.

Emissions and Public Health

Air pollutants called particulate matter include dust, dirt, soot, smoke and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires and natural windblown dust. The Clean Air Act establishes National Ambient Air Quality Standards (NAAQS) for six principal pollutants that pose health hazards: carbon monoxide (CO), lead, nitrogen dioxide, particulate matter less than 10 microns in size (PM 10), particulate matter less than 2.5 microns in size (PM 2.5), ozone, and sulfur dioxide.

Particulate Matter (PM)

The pollutant form of greatest concern from wildland fire, including both prescribed fires and wildfires is particulate matter (PM), (Ottmar 2001, Graham 2012), although fire also creates other criteria pollutants and visibility impacts. Particulate matter is defined as tiny particles of solid or semi-solid material suspended in the air. Particles may range in size from less than 0.1 microns to 50 microns. Particles larger than 10 microns tend to settle out of the air quickly and are not likely to affect public health; smaller particles remain airborne, are considered inhalable, and have the greatest health effects.

Total suspended particulate (TSP) was the first indicator used to represent suspended particles in the ambient air. EPA used the indicator PM10 starting in 1987, which included only those PM-10 particles in the ambient air. In July of 1997, however, EPA adopted the indicator PM2.5, which includes only those particles with aerodynamic diameter smaller than 2.5 micrometers.

Fine particulate matter is the major pollutant of concern in smoke from wildland fire, including prescribed burns and wildfires (Ottmar 2001). Studies indicate that 90% of smoke particles emitted during wildland fires are PM 10, and about 90% of PM10 is PM2.5 (Ward and Hardy 1991). Human health studies on the effects of particulate matter indicate that it is PM2.5 that is largely responsible for health effects (Dockery et al. 1993). Because of its small size PM2.5 has an especially long residence time in the atmosphere, penetrating deeply into lungs (Ottmar 2001).

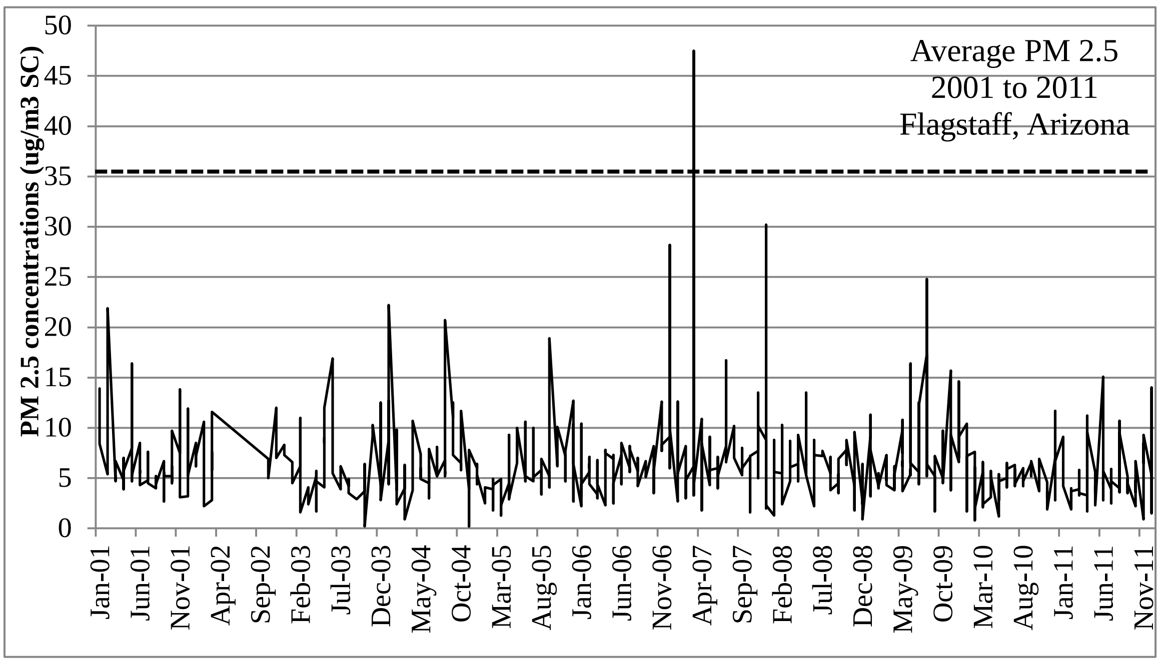
The Clean Air Act defines the NAAQS for PM 2.5 as an annual mean of 15µg/m3, and a 24 hour average of 35µg/m3. At this concentration or above, PM 2.5 is considered to have a detrimental effect on public health. It is important to note that it is not the total amount of emissions from a fire that have effects on human health, but rather how concentrated pollutants in ambient air are for a period of time.

Atmospheric conditions during a fire have a considerable influence on how particulate matter is distributed though the ambient air, and its potential to affect public health. Wind speed and direction, mixing layer height, atmospheric temperature profile upward in the atmosphere, and atmospheric stability all impact where and how well smoke will disperse. Particles from 2.5 microns to 10 microns in diameter come from many sources. In many cases windblown dust and dust kicked up on unpaved roads by vehicle traffic account for much of this fine particulate matter (Kleindienst 2012).

Studies of human populations exposed to high concentrations of particles (sometimes in the presence of SO2) and laboratory studies of animals and humans, indicate there is potential for detrimental effects on human health. These include effects on respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body’s defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The major subgroups of the population that appear to be most sensitive to the effect of particulate matter include individuals with chronic obstructive pulmonary or cardiovascular disease of influenza, asthmatics, the elderly and children. Particulate matter also soils and damages materials and is a major cause of visibility impairment. The same particulate matter that poses health risks is also largely responsible for these impairments to visibility. “The combination of light absorption by elemental carbon and light scattering caused by the very small particles that make up wildland fire smoke explains why emissions from wildland fire play such an important role in visibility impairment (Core 2001a).”

Management activities with the largest direct impact on Air Quality are prescribed fires. Road dust has not been demonstrated to be a measureable contributor on a regional level to visibility in the 16 Class I areas located on the Colorado Plateau (ADEQ 2003). The Kaibab National Forest has burned about 8,000 acres/ year with prescribed fire in ponderosa pine since 2000. When wildfire acres are added, the Kaibab averaged about 17,000 acres a year (in ponderosa pine) from 2001 through fall of 2010. From 2001 through fall of 2010, the Coconino NF averaged a little over 13,000 acres of prescribed fire in ponderosa pine. When wildfire acres are added, the Coconino averaged about 20,000 acres in ponderosa pine for that same period. No notice of violation of NAAQS standards has ever been issued to the Kaibab NF. Over the same period of time, one exceedence occurred on the Coconino National Forest. It occurred on one monitor for one day for an exceedence in $PM_{2.5}$ in Flagstaff in 2007 (Figure 37 and Figure 38). Figure 37 charts PM 2.5 levels from January 2001 through November of 2011. The dotted line indicates the NAAQS for PM 2.5, which is 35 ug/m3*). NAAQS for PM 10 (Figure 38) is 150.

Figure 37. PM 2.5 levels from January 2001 through November 2011 in Flagstaff, AZ. (*ug/m^3 = micrograms per square meter)



Fugitive dust

Heavy equipment used on paved and unpaved roads during the implementation of projects has the potential to create localized impacts from fugitive dust. With high wind events, this fugitive dust has the potential to be carried for several kilometers. Control measures developed for site specific projects can reduce these localized particulate matter emissions, such as reducing travel speeds on unpaved surfaces, ceasing work activities during periods of high winds, applying gravel or soil stabilizers on dust problem areas, covering loads, and covering ground surfaces with water during earth moving activities (BLM 2011). There would be dust abatement measures on about 7 miles of roads in areas of concern.

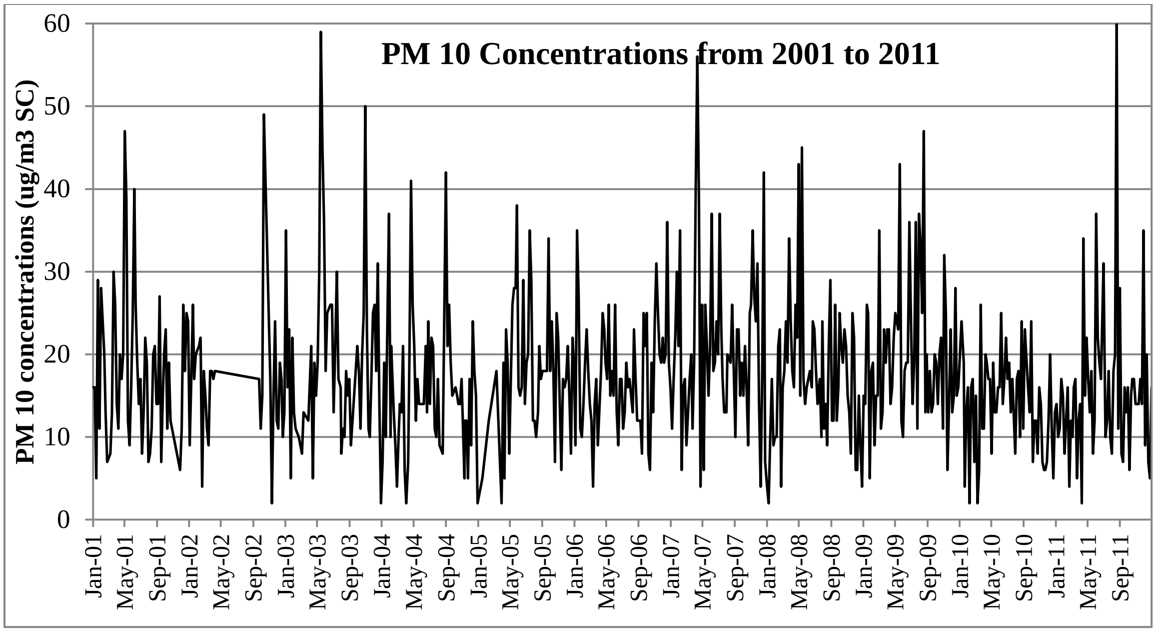


Figure 38. PM 10 levels from January 2001 through November 2011

Radioactive emissions

Concerns have been raised about the potential for smoke from prescribed fire treatments proposed in 4FRI to contain radioactive substances. During the Cerro Grand fire of 2000, there was also considerable public concern regarding the potential release of radionuclides from the Los Alamos National Laboratory (LANL). The following risk summary is from “2002 Fact Sheet: Cerro Grand Fire Releases to Air” which may be viewed at:

http://www.nmenv.state.nm.us/OOTS/PR/2011/NMED_Monitoring_Air_Quality_in_Los_Alamos.pdf

> “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 radioactive 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.”

Following the Cerro Grande fire that burned 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 (http://www.nmenv.state.nm.us/nmrcb/documents/LasConchasFireAirMonitoring.html).

A study that included Lockett Meadow, within the project area, 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, Graham 2012a).

Communication with the EPA (Gerdes 2012, Graham 2012a), and studies that addressed these emissions (Schollnberger et al. 2002) indicate that radioactive isotopes and other undesirable chemicals are present in wildfire emissions. 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. At the level of exposure the public is subjected to, 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 (NMED 2002, Graham 2012a) and the greatest health risk is from breathing high concentrations of particulate matter in the smoke.

Mercury

Mercury is present at some background level around the world, and is sometimes present in emissions from wildland fires (Selin 2009, Obrist et al. 2008, Biswas et al. 2007, Wiedinmyer and Friedli 2007, Friedli et al. 2003). However, there is insufficient science to support conclusions about specific effects from the 4FRI. General conclusions may be possible, but no valid effects could be presented. Even if we did have the means of providing an estimate of mercury emissions, we would still not know the effects. We were not able to find any information on levels of mercury in the biomass in or near the project area, or in emissions from wildfires or prescribed fires in, or close to the project area. The amount and impact of mercury that is in emissions from a specific fire depends on how much mercury is present in the biomass that is burning; how intensely the fire burns, moisture content of the fuel, how complete the burn is, and wind for the duration of the time there are emissions in the air. There is little question that there would be more mercury in emissions from high intensity wildfires than from the low intensity fires that would typify the prescribed fires proposed by the 4FRI (Obrist et al. 2008, Biswas et al. 2007, Friedli et al. 2003, Lahm 2014). Mercury is not a Criteria Pollutant, that is, it is not one of the six substances for which there are National Ambient Air Quality Standards, because it is not considered an ‘ambient’ substance. Mercury is regulated as a “point source”, meaning emissions are regulated by the specific sources which discharge pollutants into the air from a specific and clearly discernable discharge point, such as a power plant. When a high intensity wildfire burns through an area, it is likely to release more mercury than a low or moderate intensity prescribed fire would. Additionally, prescribed fires help reduce the intensity of ensuing wildfires for several years, depending on the pre-burn condition of the burn unit.

Smoke Sensitive Areas and Sensitive Receptors

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, etc. where smoke and air pollutants can adversely affect public health, safety, and welfare" (State Implementation Plan, Appendix A-10 page 36). Several smoke sensitive areas lay within the airsheds of the areas proposed for treatment (Table 26). The list is not inclusive, and we recognize that there are a number of communities within, adjacent, or sometimes downwind of the project that are likely to have some impacts of smoke from 4FRI activities and are not listed. While these areas do not necessarily meet the official definition of smoke sensitive, we are aware of smoke-sensitive populations in airsheds that could be impacted by prescribed fire, and experience has shown that these areas need to be considered when planning and executing prescribed fires.

Table 26. Smoke sensitive areas and sensitive receptors

Area	Proximity to implementation area	Concerns
Flagstaff	Within boundaries or directly adjacent in all directions	Hospital, schools, human habitation, visibility, young children, Interstate visibility
Williams	Within boundaries or directly adjacent in all directions	Hospital, schools, human habitation, visibility, young children, Interstate visibility
Verde Valley	Less than 10 miles downslope south and southwest.	Hospital, schools, human habitation, visibility, young children.
Grand Canyon National Park	Adjacent to the northern boundary of project area	Class I airshed, school, human habitation, campgrounds
Havasupai Reservation	About 55 miles Northwest of the EIS project area	Hospital, schools, human habitation, visibility, young children, elders.
Navajo Reservation	Northeast and east of the project area	Hospital, schools, human habitation, visibility, young children, elders.
Hualapai Reservation	About 55 miles west of the project area	Hospital, schools, human habitation, visibility, young children, elders.
Hopi Reservation	Northeast of the project	Hospital, schools, human habitation, visibility, young children, elders.

A Class I area is an area classification that requires the highest level of protection under the Clean Air Act of 1963. Projects which may potentially impact Class I areas must address efforts to minimize smoke impacts on visibility. Class I areas most likely to be impacted by activities in the 4FRI project area are the Grand Canyon National Park and Sycamore Canyon Wilderness Area. The national visibility goal of the Clean Air Act is, "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I areas in which impairment results from manmade air pollution." Wildfires are considered to be natural sources of visibility impairment, and generally outside state control or prevention.

Coconino County enjoys good air quality most of the time. Less than 1% of days per year rated in the Unhealthy for Sensitive Groups category, and no days were rated Unhealthy, Very Unhealthy or Hazardous (US EPA 2010).

Non-attainment areas are where air quality has violated one or more of the National Ambient Air Quality Standards (page 18). If a project area is within attainment, no additional requirements of the Regional Haze Rule State Implementation Plan administered by the ADEQ apply. The State Implementation Plan (40 CFR 51.309(d) (7)) for Arizona from December 23, 2003 states that "road dust is not a measurable contributor on a regional level to visibility impairment in the 16 Class I areas. There are no non-attainment zones that are expected to be affected by any of the alternatives in this project."

No NAAQS are in non-attainment over the project area. On rare occasions, pollution from distant large population centers in California affects the air quality in the area. Huge 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 is also a NAAQS pollutant. Levels are increasing, and are trending up in northern Arizona (Kleindienst, 2012). Natural background ozone concentrations are naturally high in the West; transport from industry and large urban areas in California and other non-local sources also contributes significantly (Koo et al. 2010, Tong and Mauzerall 2008). Under current regulations, ozone levels in northern Arizona are largely outside of the regulatory control of the State of Arizona. Spikes seen in ozone levels do not correlate with fire activity although, under certain weather conditions, smoke from fires has the potential to create ozone. As yet, data on how much ozone is created from wildland fire, or prescriptive criteria to deter ozone creation are not available. The airsheds 1, 3, and 5 (Figure **39**) can be expected to experience the majority of the smoke impacts originating from the proposed treatment area, with rare instances of mild impacts in Airshed 6.

Permits are issued by the Arizona Department of Environmental Quality (ADEQ), who help to monitor/manage potential smoke impacts by tracking what is burning at any given time. The ADEQ currently has air quality monitors in Campe Verde, Sedona, Flagstaff, Prescott, Show Low, and Springerville, with additional monitors that can be set up if when there are specific concerns. Outputs of these monitors are available online at:

http://www. phoenixvis.net/PPMmain.aspx

umulative effects from prescribed fires and from wildfires that are not being actively suppressed on Federal, State, and Tribal lands are largely mitigated through implementation of the Enhanced Smoke Management Program in the Arizona Smoke Implementation Plan (SIP) by the Smoke Management Group. When the Federal land managers actively began prescribed burn programs in the 1970s, they became rapidly aware that a pro-active program for the coordination of prescribed burns would be vital to obtain and continue support of prescribed burning programs by ADEQ and the public. An interagency Smoke Management Group was developed in partnership with the State, and housed in the ADEQ offices in Phoenix. The personnel in the group are funded largely by the Federal agencies, demonstrating the initiative of the agencies to, in some degree, self-regulate emissions production from prescribed burns, across Federal and State boundaries. This group assists land managers in not exceeding NAAQS or visibility thresholds through the following services:

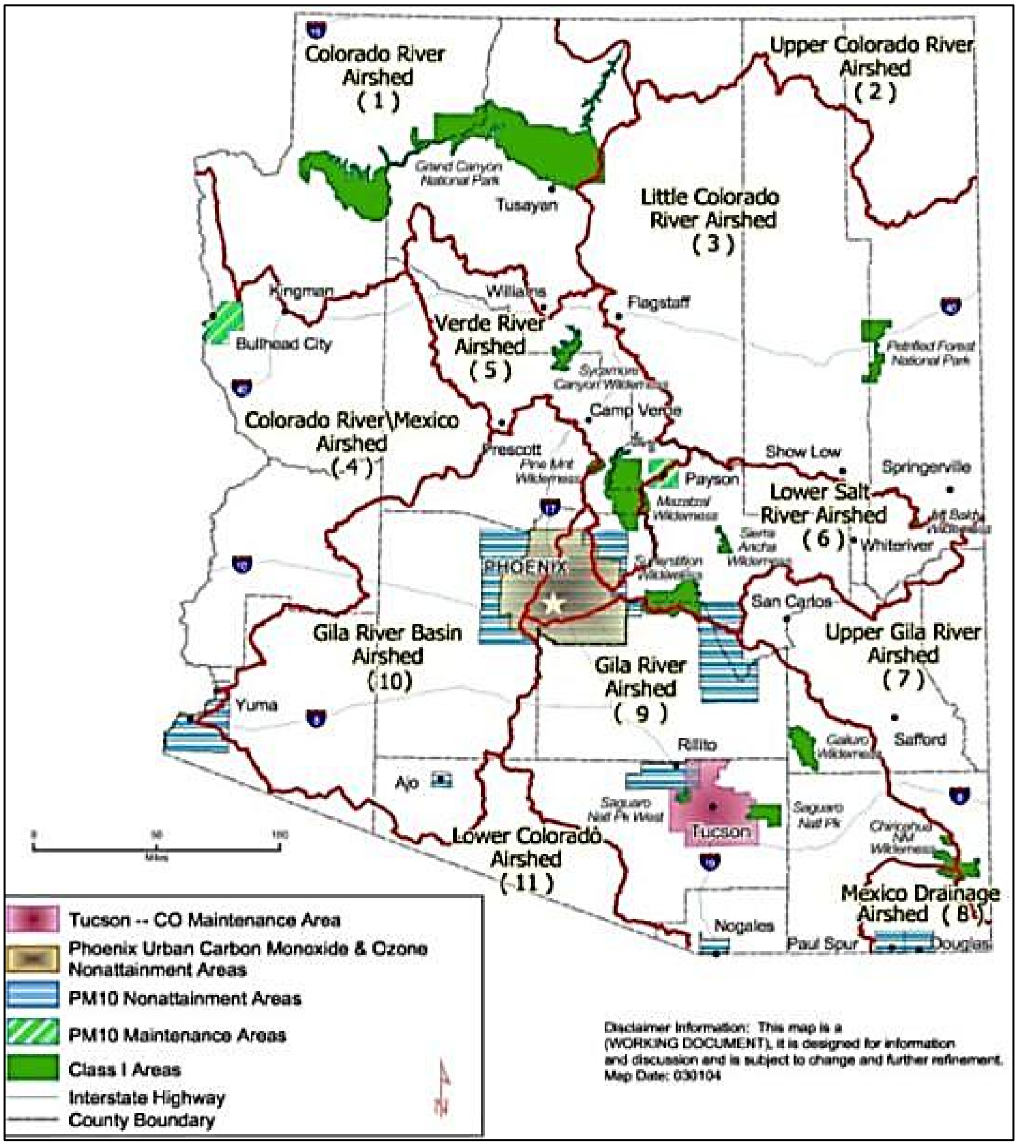


Figure 39. Arizona airsheds.

- Serves as a central collection point for all burn requests from the numerous Federal, State, and Tribal land managers who are all competing to produce smoke that will impact the same airsheds during limited windows of opportunity.
- Evaluates potential emissions from individual and multiple, and determines how meteorological forecasts will affect smoke concentrations both during the burn, and during diurnal settling. The Group considers cross-boundary impacts; and weighs burning decisions against possible health, visibility, and nuisance effects.
- Assists in coordinating activities within and between agencies when potential emissions would likely exceed desired conditions.
- Makes recommendations on the approval or disapproval of each burn request to ADEQ officials.

- Tracks the use of Best Management Practices and Emission Reduction Techniques used by land managers, to document efforts by land managers to minimize impacts to Air Quality. This information is used promote support from both ADEQ and the public.
- Monitors data gathered from the IMPROVE network to assess visibility impacts in Class I areas, and track progress towards Arizona SIP goals.

While emissions from wildfires are not regulated, Federal, State, and Tribal land managers understand their responsibility to balance the ecological benefits of wildfires with the social impacts of the smoke they produce. The Smoke Management Group also assists land managers in this area through:

- Limiting prescribed burn approvals during periods when wildfires are already impacting an airshed.
- Making recommendations on the timing, or assisting in the coordination between units, of tactical operations such as burn outs, that will produce large amounts of emissions, so that they are done, when possible, when ventilation conditions are most favorable, or spread out over several burning periods to reduce total emissions when ventilation is not as good.
- Assisting land managers in determining the strategy to take on new wildfires. There may be enough fires burning that suppression on a new start is recommended to reduce cumulative smoke impacts even though all other fire effects would be desirable, and move the area towards desired conditions in the Forest Plan.
- Acting as a sounding board for public complaints. In keeping tabs on the type and number of complaints, the Group is able to provide land managers feedback from beyond their local publics on the state of public smoke tolerance. This is vital in maintaining general public support of allowing wildfires to perform their natural role in the ecosystem under the right circumstances in future windows of opportunity.
- Through the services of the Smoke Management Group, cumulative effects from wildland fire that are within the control of Federal and State Land Managers, are thus managed to keep Air Quality across Arizona within desired conditions, including not exceeding NAAQS, protecting visibility in Class I Areas, and additionally promoting general public support of prescribed burn and wildfire management programs.

Over 280 million people visit our nation’s national parks and wildernesses areas every year. Visitors expect to view the scenery through clean fresh air. To protect visibility in these areas of high scenic value, Congress designated all wilderness areas over 5,000 acres and all national parks over 6,000 acres as mandatory federal Class I areas in 1977, subject to the visibility protection requirements in the Clean Air Act.

Baseline visibility conditions have been established for the Grand Canyon National Park and Sycamore Canyon Wilderness which are the two Class I areas potentially affected by activities and wildfires in the 4FRI implementation area (Table 27). The Forest Service will continue to adhere to requirements in the Arizona State Implementation Plan to meet natural condition visibility goals. Data from Table 28 is from Fitch and Truman 2007.

The most sensitive smoke receptor in the State of Arizona is the Verde Valley, which is easily impacted with nuisance smoke from the cumulative burning on the southern part of the KNF, the eastern side of the COF, and the Western side of the Prescott National Forest, as diurnal drainage of smoke from fires settles into this valley. Considerable coordination between Forests takes place when burns and wildfires that can affect the Verde Valley take place, facilitated by the interagency Smoke Management Group housed at ADEQ.

Table 27. Areas expected to be impacted by proposed prescribed fire treatments

Camp Verde	Highway 180	Interstate 17
Cornville	Wupatki/Sunset Crater National	Co. Rd. 65
Cottonwood	Lake Mary Road (Co. Rd. 209)	Highway 89A
Flagstaff	Grand Canyon National Park	Interstate 40
Flagstaff Airport	Walnut Canyon National	Hopi Reservation
Mormon Lake	Highway89	Williams
Parks and	Grand Canyon Airport	Navajo Reservation
Sedona	Highway 64	Town of Tusayan
Strawberry and	Village of Oak Creek	

Smoke monitors in the Verde Valley (Sedona, and Camp Verde) track emissions concentrations, as well as equipment that captures images of visibility conditions. Spikes are found in particulate matter concentrations as smoke from fire activity on the surrounding forests settles into the valley at night, although levels have not, as yet, exceeded NAAQS thresholds in the Verde Valley. Many complaints of nuisance smoke in the Sedona area are primarily concerned with the reduced quality of highly valued scenic views of the Red Rocks. Visibility in the Class I area of Sycamore Canyon Wilderness can also be affected by smoke from fires in the southeast portion of the KNF. Table 28 lists most of the areas that are expected to be impacted to some degree by implementation of prescribed fires in the 4FRI treatment area.

Table 28. Baseline and 2064 goal in 2003 Arizona State Implementation Plan for Natural Conditions

Class I Area	Baseline Data Years	Baseline	2064 Goal in 2003 AZ SIP
Grand Canyon NP	1999-2000, 2002-2004	11.6 dv	6.95 dv
Sycamore Canyon Wilderness	2001-2004	15.2 dv	6.96 dv

Visibility is measured in deciviews (dv). A deciviews is a metric of visibility proportional to the logarithm of the atmospheric condition. The deciview haze index corresponds to incremental changes in visual perception from pristine to highly impaired conditions. Visibility conditions are monitored and tracked through the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. The data can be accessed at http://vista.cira.colostate.edu/tss/. This includes data for all Class I areas that have monitors, including the Grand Canyon National Park.

The number of days (duration) of smoke impacts is of concern to the public as well as concentrations. While the variability from year to year would be large, the average number of acres proposed for treatment in the 4FRI differs somewhat between alternatives. The desired Fire Return Interval is between 2 and 22, with different FRIs being appropriate for different areas of the proposed treatment area at different stages of restoration. Overall, however, to produce a 10 year fire return interval, the following number of acres would need to be burned annually on average (**this assumes no wildfire**). Table 29 displays the average number of acres by alternative that need to burn annually (prescribed fire or wildfire) for a 10 year fire return interval on those acres proposed for prescribed fire.

All acres are not equal when it comes to emissions. 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 40** shows differences in emissions from wildfire or prescribed fires that burn at different stages in burn only and mechanical plus burn treatment cycles.

Table 29. Average annual acres needed to produce a 10 year fire return interval

	Alt. A	Alt. B	Alt. C	Alt. D	Alt. E
Average annual acres	0	58,330	58,611	17,844	58,611
Current average acres burned	17,000	17,000	17,000	17,000	17,000
Additional acres needed to implement alternative	0	41,333	41,611	1,688	41,611

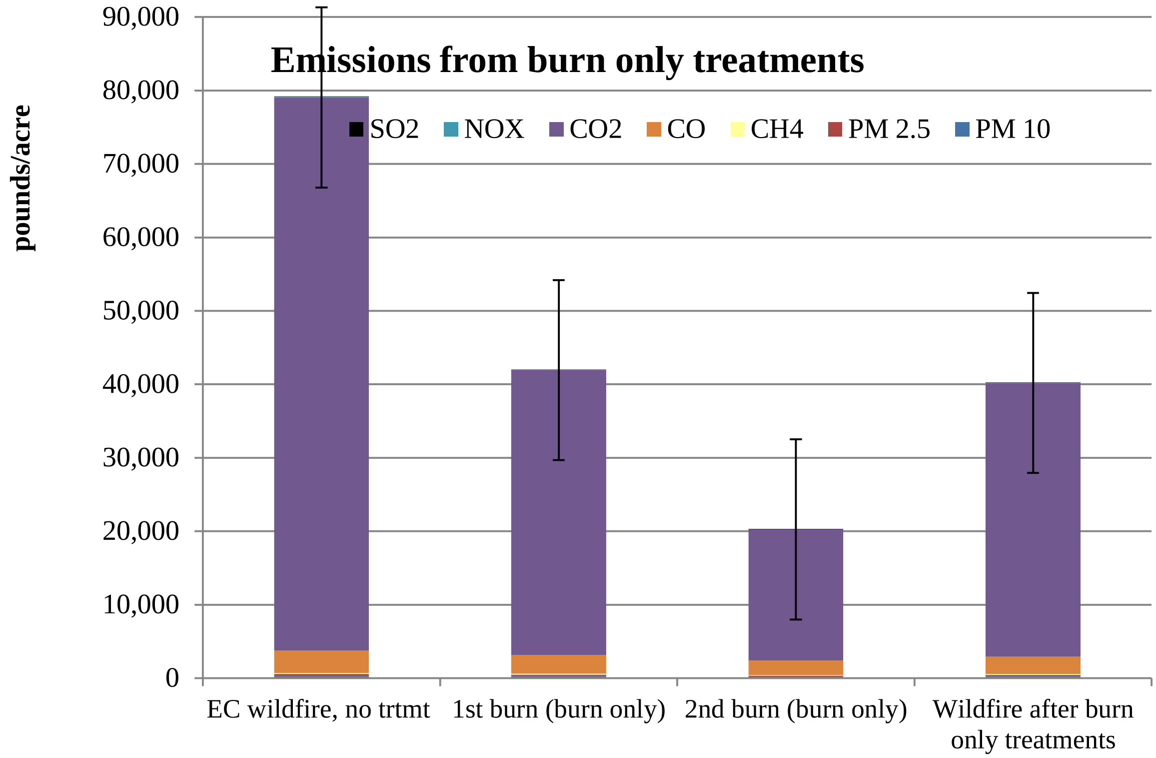
Modeling results show very little difference in wildfire emissions between no treatment and a mechanical only treatment (Figure 40). While this excludes emissions from canopy fuels, it is a good indicator of surface fire intensity, is worth noting when considering the potential fire effects of a wildfire burning in those acres proposed for mechanical treatment only in Alternative D.

The initial difference in fuel loading was 11 tons/acre, and the difference in emissions between the treatments stays roughly the same, with no statistical difference and can be attributed the initial difference in fuel loading with one exception. The first prescribed fire following a mechanical treatment produced a little over 30,000 pounds/acre of emissions. The first prescribed fire without thinning produced a little over 40,000 pounds/acre of emissions. Since the mechanical plus fire stands started out with more fuel, this shows a difference that can be produced by removing some fuels prior to burning.

Public Influence

Public tolerance for smoke, rather than law, regulation, or policy, effectively sets a social limit to how many acres are treated with wildland fire. 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 (Kleindiest 2012). In order 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 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 reference conditions (Klindiest 2012).



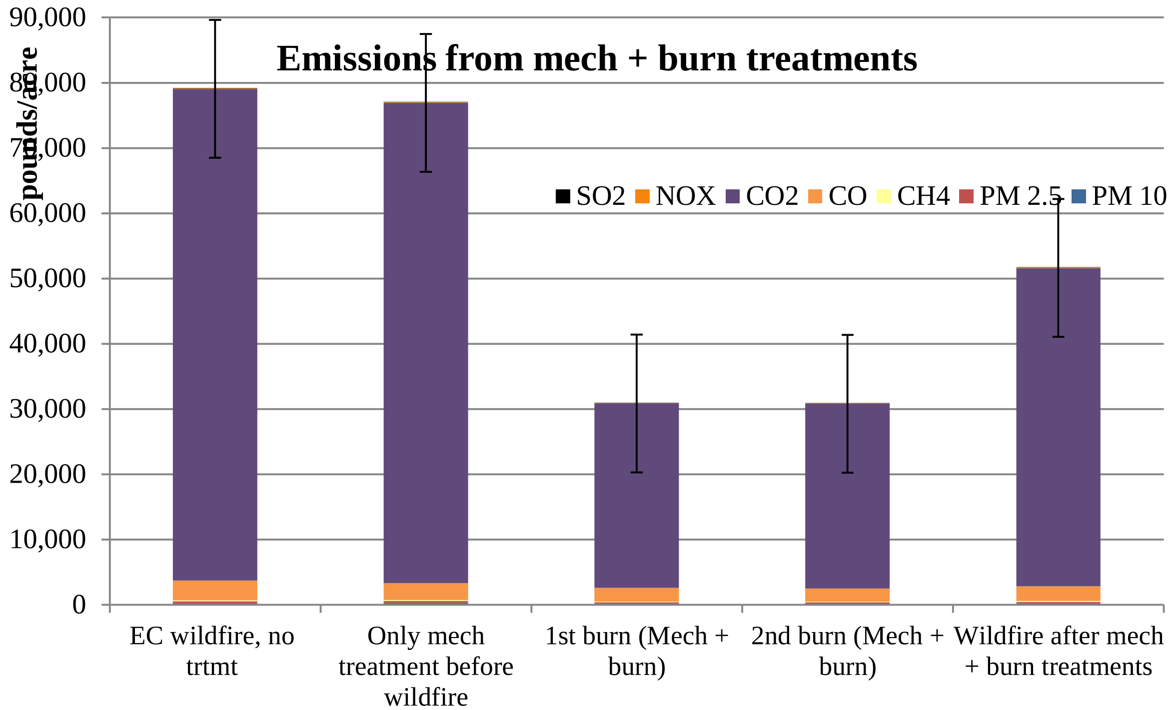


Figure 40. Modeled emissions for various treatment types.

Ecological effects of smoke

From an ecological perspective, smoke effects are important to the germination of many native plants, and in some cases appears to be more important than heat (Abella 2006, Abella et al. 2007, Abella 2009, Keeley and Fotheringham 2002, Schwilk and Zavala, 2012). Many of these occur in the treatment area, including *Nama dichotomum, Heliomersis longifolia, Penstemon spp. Artemisia ludoviciana, Erigeron speciosus, and Symphyotrichum falcatum.* Smoke may also be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1975, Alexander and Hawksworth 1976, Zimmerman et al. 1987).

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 could be attributed to the lack of effects from smoke, as smoke has been shown to affect the richness of seedbanks, and germination of many local species (Abella 2009). Pine needles smoke specifically, may reduce or prevent the growth of fungi (Parmeter and Uhrenholdt 1974), and be more effective at increasing germination than pine wood smoke.

Environmental Consequences

Throughout this section, changes directly attributable to proposed actions, such as thinning or prescribed fire, are direct effects. These include changes to canopy bulk density, canopy base height, consumption of surface fuel, etc. Changes to the potential behavior and effects of future wildfires that result from the direct effects are considered indirect effects.

Alternative A No Action

Under Alternative A, there would be no changes to current management. Alternative A would not meet the purpose and need of this project because the ecosystems and natural resources within the treatment area would continue to degrade. The treatment area would not move towards desired conditions. This alternative would not reduce the risk to human lives nor would it result in safe, cost-effective fire management that would protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreements. As required by FSM 5100 (page 9).

This Alternative would not meet direction in Forest Service Manual 5100 (page 9), which includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. The objectives of fire management on lands managed by the USFS are:

1. Forest Service fire management activities shall always put human life as the single, overriding priority. This Alternative would not fully support incorporation of the highest standards for firefighter and public safety and would not be expected to improve and enhance the safety of the public as it relates to wildland fire.

2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement. This Alternative would not achieve restoration in project area. Under this Alternative fire, when it occurs, would be detrimental to the ecosystems in which it burns as well as areas outside of the burned area. Wildfire in untreated areas is more costly and less efficient to manage in untreated areas than prescribed fire, or wildfire that is managed in areas that have had restoration treatments.

Direct and Indirect Effects

Effects resulting from Alternative A are indirect because there would be no management actions. The effects of implementing Alternative A are discussed in the following order.

1. Fire behavior at the treatment area scale

2. Potential fire type by vegetation type

3. Within Restoration Units/Subunits, fire type is broken out by vegetation/habitat types

4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

5. Fire Return interval/FRCC by treatment area

6. Air Quality

This alternative would not meet the purpose and need of 4FRI. Under Alternative A, both forest plans would continue to be implemented, but there would be no effective decrease in crown fire potential. Fire Regime/Condition Class and Vegetative Condition Class would continue to move away from desired conditions. The direct and indirect effects of Alternative A relate to the effects of the continued degradation of surface and canopy fuel conditions, and the effects of the lack of low severity fire. These include the potential for the direct effects of wildfires of increasing size and severity occurring within the project area. Increasing loads of surface fuels would transfer sufficient heat to the soil when it burned, to produce high severity effects, consuming and killing roots, seeds, biota, and other organic matter in the top layer/s of soil, and decreasing soil productivity. Trees would be damaged or killed as increasing canopy fuels and ladder fuels would allow crown fire to initiate more readily. Mortality rates would increase for large/old trees because of decades of built up fuel around their boles and over their roots, and ladder fuels within or close to their driplines. The indirect effects of such burns could compromise water resources (such as Oak Creek, Mormon Lake, or Lake Mary) from indirect fire effects such as flooding and debris flows. Indirect effects could also include impacts to air quality downwind and downslope of fires. The most likely impacts to air quality being locations northeast of the project area, and in low areas, such as the Verde Valley, Williams, or Flagstaff.

In the short term (<20 years) effects of Alternative A would include an increased risk of undesirable behavior and effects. Wildfire behavior would threaten lives, resources, and infrastructure. It would be expected that 65 – 80% of the area burned in wildfires larger than 1,000 acres would burn with low severity effects that would beneficial. In the absence of wildfire, air quality would remain at current levels. In the short term, there would be no impacts on air quality from prescribed fires. Average annual acres burned with high severity wildfire would increase, along the associated air quality impacts. This alternative would not move the areas proposed for treatment towards the desired condition of less than 10% crown fire potential under conditions that produced the Schultz Fire (Table 30, Figure 41). ”No fire” includes acres on which there were insufficient fuels to carry fire, including water, rock, cinders, areas of sparse vegetation, etc.

In the long term (>20 years), tens of thousands of acres (the actual amount would be a subset of the 200,000+ acres in the treatment area that would likely burn with high severity effects) would be potentially converted to non-forested systems as a result of high severity fire, while other acres of non-ponderosa pine would be increasingly encroached upon by pine, including aspen, grasslands, and oak. Aspen stands would continue to decline, and some stands would be likely to disappear. In the short term, there would be no impacts on air quality from prescribed fire. If the current average annual acres burned by wildfire remained the same, it is likely that the entire treatment area would burn with wildfire by 2050, along with the associated air quality impacts.

Table 30. Modeled fire type in 2020 under Alternative A by Restoration Unit

	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	No Fire	Surface Fire	Passive Crown Fire	Active Crown Fire	No Fire
		Acres by RU				% of RU			
Alt A 2020	RU 1	85,639	16,450	51,355	939	55%	11%	33%	1%
	RU 3	90,371	12,941	45,500	903	60%	9%	30%	1%
	RU 4	111,515	10,968	42,643	519	67%	7%	26%	0%
	RU 5	51,458	6,447	9,558	5,740	70%	9%	13%	8%
	RU 6	37,120	2,768	3,596	45	85%	6%	8%	<1%
	Total	**376,102**	**49,575**	**152,652**	**8,147**	**64%**	**8%**	**26%**	**<2%**

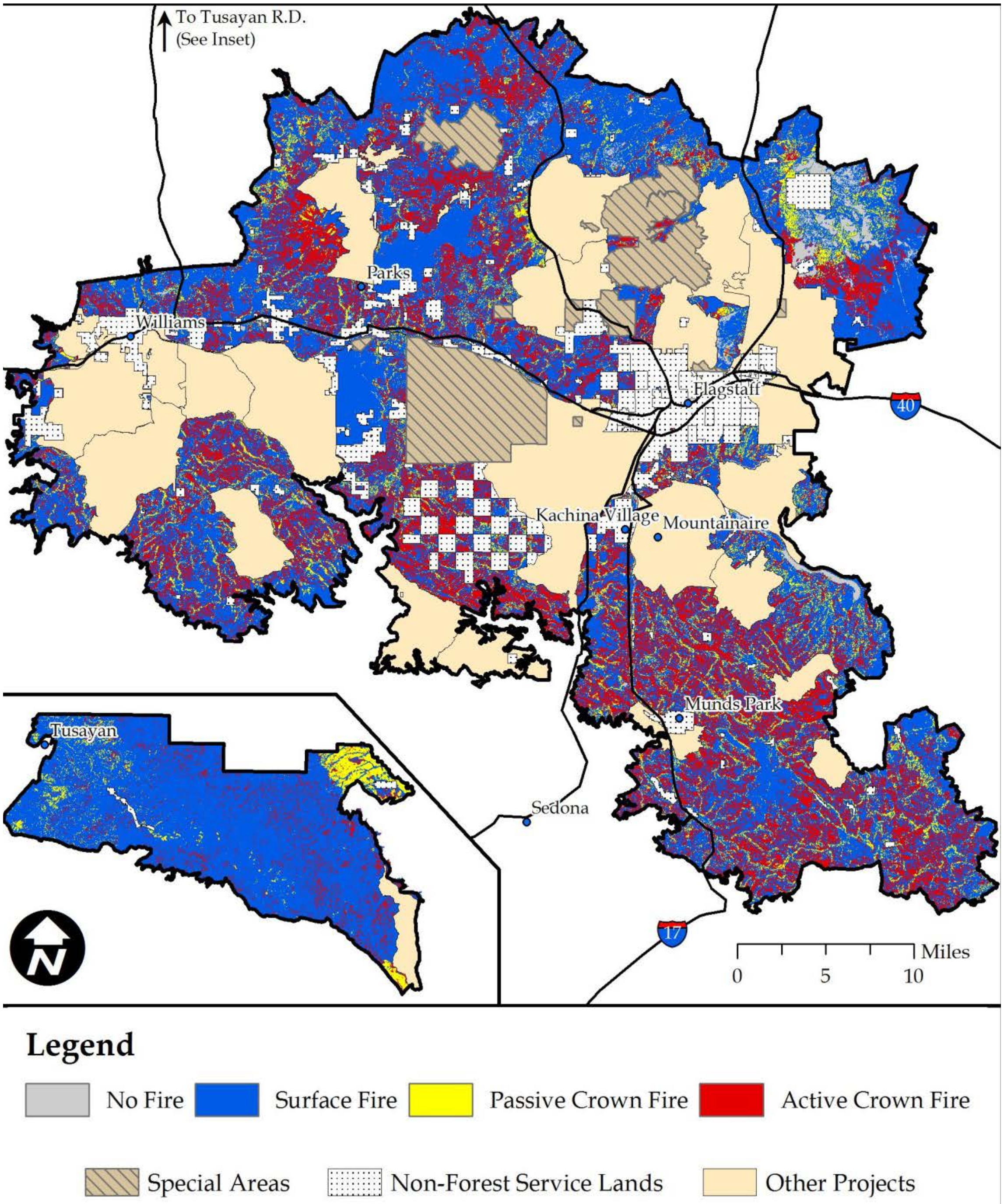


Figure 41. Modeled fire type for Alternative A, 2020

Data from the COF and KNF indicates that, without additional fires (prescribed or wildfire), the average fire return interval across the treatment area would increase to 80 years by 2020, and 160 by 2050. In addition to allowing surface fuels to buildup, this would allow ladder fuels to grow up in areas on the edges of denser forested areas, and woody species continue to encroach into grasslands and aspen.

Any fire that does occur in the treatment area would be wildfire, which can be beneficial or detrimental, depending on environmental conditions at the time of the fire, and the condition of the forests in which they burn. Figure 41 shows modeled fire type for 2020 if no treatments were implemented with 34% of the treatment area having potential for crown fire, 26% of which would be active crown fire.

Ponderosa pine

Fire is a keystone process for all ponderosa pine in the 4FRI area. Eliminating it as a restoration tool would not meet the purpose and need of 4FRI. Over time, indirect effects include a shift in species composition towards more species that are less fire tolerant (Fulé and Laughlin 2007, Laughlin et al. 2011). When wildfires did occur, about a third of the acres burned would have undesirable effects such as severely burned soil, erosion, flooding, debris flows, vulnerability to invasive weeds, decreased soil productivity affecting species composition and vegetative patterns (Moir 1988, Laughlin et al. 2011, Abella et al. 2007).

Under current management, 507,839 acres of ponderosa pine forests in the treatment area would continue to grow denser, surface fuel loads would continue to build up and canopies would continue to close up. The only acres on which fire would reduce the potential for undesirable fire effects and behavior would be those parts of wildfires which burn at a low severity. Annual wildfire acreage increased from 2001 – 2010, and wildfires burned an average of ~18,000/year in the project area. Of these acres, about 2/3 (10,000 acres) could produce desirable fire effects (RAVG data). Even if all 18,000 annual acres wildfire are counted as low severity, this alternative would lead to exceptionally dense stands over most of the project area (Covington et al. 2001). It is unlikely that the resultant dense stands would be sustainable over time, and large areas would be expected to burn with high severity fire, or killed by beetles and pathogens (McCusker et al. 2014). Even without pathogens, the potential is for over 200,000 acres of crown fire (34% of the area proposed for treatment under the action alternatives) under conditions similar to those under which the Schultz Fire burned in 2010. Those modeled conditions were not extraordinary, and more extreme conditions occur every year. High severity fires in ponderosa pine may cause changes to vegetative type/species composition that are likely to persist for decades or longer (Savage and Mast 2005).

None of the ponderosa pine habitat types listed below would meet desired conditions for fire type (Table 31). Under this alternative, there would be potential for crown fire in 38% of the ponderosa pine (192,919 acres), of which 29% (147,588 acres) would be active crown fire. LOPFAs would not meet desired conditions for fire type in ponderosa pine, with 35% of it (127,566 acres) having potential for crown fire, 26% of which would be active crown fire. There would be a risk of undesirable fire behavior and effects in the other pine habitats, with almost half of protected and target/threshold at risk of crown fire.

It is unlikely that many dense stands of ponderosa pine could be sustained for long, so the true “no-action” alternative is extensive mortality through fire or pathogens. Post-mortality biomass may be a different type of ecosystem, such as a persistent shrub type, grass-dominated system, or unnaturally dense ponderosa pine (Savage and Mast 2005).

Pine/Sage

With no treatment, the ~16,000 acres of potential pine/sage community in RU6 would continue to decline. Currently, sage dominates in some areas, and completely absent in others where prescribed fire was implemented with the objective of eliminating the sage. As ponderosa continues to increase in density, there would be increasing risk of sage being shaded out, as well as increasing risk to pine, sage, and other vegetative components of this vegetative community from high severity fires which could eliminate sage and other shrubs locally, in addition to changing the site potential because of high severity effects to the soil (chemical and physical changes resulting from the heat of the fires). Where there is an existing mosaic of sage and other shrubs, sage would continue to dominate some areas, except as affected by wildfires or when it becomes shaded out by pine.

Table 31. Modeled fire type by habitat and vegetation type under Alternative A.

Vegetation Type		Fire Type	Existing Conditions		Alt. A 2020	
			Acres	%	Acres	%
Ponderosa Pine*	**All Pine**	Surface	311,313	61%	309,651	61%
		Passive crown	48,023	9%	45,331	9%
		Active crown	143,186	28%	147,588	29%
	Protected	Surface	17,954	51%	16,963	48%
		Passive crown	3,034	9%	2,522	7%
		Active crown	14,106	40%	15,611	44%
	Target/ Threshold	Surface	4,275	49%	4,327	50%
		Passive crown	922	11%	1,142	13%
		Active crown	3,482	40%	3,209	37%
	Restricted	Surface	35,019	53%	35,188	64%
		Passive crown	6,540	10%	6,767	9%
		Active crown	24,756	37%	24,379	26%
	PFA/ dPFA	Surface	18,400	61%	18,141	60%
		Passive crown	2,903	10%	2,661	9%
		Active crown	8,560	29%	9,060	30%
	LOPFA	Surface	235,666	64%	235,031	64%
		Passive crown	34,624	9%	32,238	9%
		Active crown	92,282	25%	95,328	26%

* Nonburnable substrate constitutes <1% of ponderosa pine in the treatment area

Large/old trees

Under this alternative, about 194,804 acres meeting old growth conditions (see Silviculture Report for attributes required for old growth), and scattered large and old trees across the treatment area would be increasingly threatened by the increasing size and severity of wildfires (Swetnam 1990, Covington and Moore 1994, Swetnam and Betancourt 1998, Westerling et al. 2006). Old ponderosa pines are often more susceptible to mortality after fire (even low intensity fires) than younger mature trees (Kolb et al. 2007). The increasing size and severity of wildfires and the ensuing death of large/old ponderosa pines has been linked to fuel accumulation resulting from a century of fire exclusion (Covington et al. 2001, Hood 2010, Kolb et al. 2007). In this alternative, fires that do burn would be likely to occur during hotter, drier times of year when potential fire behavior and effects are more extreme. Generally, old or large trees cannot be prepped prior to burning when a wildfire is being managed primarily for suppression. There are usually opportunities to prep large or old trees in the path of a wildfire being managed primarily for resource benefit. In areas where wildfire would be a first entry burn, there would be a much greater potential for high severity fire than where there had been thinning and/or a low severity fire before a wildfire occurred. In this alternative, many old trees are killed or damaged by wildfire. Effects would include trees that are killed or severely damaged in a fire, and those trees that die or decline slowly as a result of fire effects that add to other stressors (Minard 2002).

Aspen

There are 1,516 acres of aspen within the treatment area. With no treatments or disturbance, it would be expected that the aspen would continue to decline. If wildfire burns though aspen, the larger clones (>300 stems/acre) could likely respond with prolific sprouting, and topkilling of some of the larger stems. Recent trends, however, show that browsing pressure would probably prevent the sprouts from reaching maturity so, without some sort of protection or change to ungulate browsing, clones would be weakened as the roots use up carbohydrates trying to keep suckering. Smaller clones that are already declining may be killed, or pushed closer to dying from ungulate browsing, particularly when combined with uncharacteristic fire effects at the wrong time of year, such as a hot fire in the spring. If they did respond by sprouting (likely), browsing of those sprouts would further weaken the stands, and some could disappear (DeLuca 2008, Amacher et al. 2001, Fairweather et al. 2007).

Gambel oak

Mature Gambel oak would increasingly be shaded out by the increase in ponderosa pine density. Up to a third of the area burned by wildfires that occur is likely to be high severity, which would decrease densities of larger oak. Copious sprouting would be the most like effect, further increasing the density of sprouts and small stems which are already over-represented on the landscape (Abella 2008a, Fulé et al. 1997a). Larger oaks would be topkilled by crown fire or high severity surface fire. The short term effects of a wildfire burning though Gambel oak would be a shift from few larger stems, to multiple smaller stems, which are already over represented on the landscape (Abella 2008a, Fulé et al. Where high severity fire occurs in pine/oak, the result in some areas may be persistent oak brush fields where oak and other shrubs are likely to sprout (Ffolliott and Gottfried 1991, Savage and Mast 2005).

Table 32 shows an insignificant change in crown fire potential over time for oak woodland. Where oak is dominant, this could be where oak stems are maturing and there is less ladder fuel available in the oak, or they would be shaded out by maturing pine in the vicinity. Regardless of the cause, active crown fire remains at unnaturally high levels and, when combined with passive crown fire, these oak woodlands are at risk from unnaturally high severity fire (Abella 2008a, Fulé et al. 1997a). Since small diameter oak is already over-represented on the landscape, this would move these acres away from the desired condition.

Table 32. Fire type modeled for existing conditions and Alternative A in 2020.

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
				Acres	%
Oak Woodland	No fire	25	<1	20	<1
	Surface	2,504	77%	2,553	78
	Passive crown	266	8%	225	7
	Active crown	466	14%	464	14

Grasslands

There are about 48,196 acres of grasslands within the treatment area that would continue to shrink as woody encroachment continued at increasing rates. Tree seedlings would continue to become established, leading to more acres of grassland being replaced by young forests. In encroached areas, crown fire potential would increase (Table 33). The increase in active crown fire from existing condition (2010) to 2020 indicates greater continuity in the acres of encroachment. For the most part, surface fire and passive crown fire would decrease woody encroachment, playing the ecological roles of fire in grasslands. Additionally, active crown fire can result in undesirable fire effects, such as high burn severity (detrimental soil effects), including killing the existing seed bank, damaging existing surface vegetation (other than encroaching woody species), and potentially giving invasive plant species a foothold. Under Alternative A, grasslands would not meet desired conditions for fire type. No action would result in continued encroachment of woody species and increasing cover of species not adapted to fire.

Table 33. Modeled fire type for grasslands under Alternative A.

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
		Acres	%	Acres	%
Grassland	No fire	2,493	5	2,496	5
	Surface	41,454	86%	41,454	86%
	Passive crown	3,059	6%	2,359	5%
	Active crown	1,153	2%	1,887	4%

Piñon/Juniper (PJ)

The 535 acres of PJ east of the town of Tusayan that were slated for a fuels treatment would continue to pose an increasing threat to the town of Tusayan based on potential fire behavior. Across the treatment area, there is an increase of in acres of modeled crown fire by 2020 (Table 34). PJ grows slowly, but the trajectory would continue until there was treatment of some kind, or wildfire. This may not be out of the natural fire regime for much of the PJ, but it is adjacent to ponderosa pine and could serve as ladder fuel if pushed into the pine by wind or terrain.

Table 34. Fire type modeled for Alternative A and 10 years post-treatment

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
		Acres	%	Acres	%
Pinyon/Juniper	No fire	367	<2%	348	<2%
	Surface	19,379	83%	19,436	83%
	Passive crown	1,523	7%	1,454	6%
	Active crown	2,047	9%	2,078	9%

Restoration Units

Under Alternative A (Table 30), none of the Restoration Units would meet desired conditions for less than 10 percent crown fire. Modeled fire type for the RUs ranges from 14% (RU6) to 44% (RU1). ”No fire” includes water, rock, roads, cinders, areas of sparse vegetation, and other acres on which there were insufficient fuels to carry fire under the conditions modeled. These acres range from 44 acres (>1%) in RU6 to 3,746 acres (6%) in RU5.

Restoration Unit 1

Restoration Unit 1 is currently of the most at risk of all the RUs in regards to fire type and current condition. It is of particular concern because the Lake Mary watershed is a source for the city of Flagstaff. The Lake Mary watershed would continue to be at a high risk of undesirable fire effects as the likelihood of high severity fire increased, with 44% of it being crown fire (Table 30).

Table 35. Fire type by vegetation and habitat types for Restoration Unit 1, Alternative A

	RU 1 acres =	154,383	Veg type acres	2010		Alt. A 2020	
	Vegetation Type	Type		Acres	%VT	Acres	%VT
Ponderosa Pine*	**All Pine**	Surface	144,113	80,257	56%	78,063	54%
		Passive		15,784	11%	15,187	11%
		Active		47,553	33%	50,391	35%
	Protected	Surface	29,052	15,020	52%	14,113	49%
		Passive		2,246	8%	1,874	6%
		Active		11,728	40%	13,005	45%
	Target/ Threshold	Surface	4,793	2,236	47%	2,258	47%
		Passive		504	11%	682	14%
		Active		2,042	43%	1,842	38%
	Restricted	Surface	25,710	12,731	50%	12,809	50%
		Passive		2,601	10%	2,859	11%
		Active		10,348	40%	10,019	39%
	PFA/ dPFA	Surface	4,670	2,594	56%	2,419	52%
		Passive		518	11%	484	10%
		Active		1,558	33%	1,766	38%
	LOPFA	Surface	79,889	47,676	60%	46,463	58%
		Passive		9,915	12%	9,288	12%
		Active		21,877	27%	23,759	30%
Other Vegetation*	Aspen	Surface	420	241	57%	212	50%
		Passive		40	9%	38	9%
		Active		140	33%	170	41%
	Grassland	Surface	8,135	6,131	75%	6,032	74%
		Passive		1,340	16%	1,046	13%
		Active		236	3%	625	8%
	Juniper Woodland	Surface	286	236	83%	241	84%
		Passive		12	4%	11	4%
		Active		38	13%	34	12%
	Oak Woodland	Surface	287	195	68%	204	71%
		Passive		62	21%	63	22%
		Active		30	11%	20	7%
	Pinyon/ Juniper	Surface	1,141	897	79%	888	78%
		Passive		115	10%	105	9%
		Active		95	8%	114	10%

* Nonburnable substrate constitutes <1% of ponderosa pine and about 1% of the treatment area in RU1

Ponderosa Pine comprises 144,113 acres of RU 1, more than the other Restoration Units. There is potential for over 67,805 acres of crown fire (46% of the pine), with 35% active crown fire. There are adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer upslope from the 4FRI treatment area, and the potential for flooding and debris flows downslope (Table 35).

Should a fire ignite on a slope below the mixed conifer, it would quickly move upslope and would be difficult to control, as well as burning at high severity for much of its extent. Additionally, portions of the city of Flagstaff occupy the northwestern corner of this RU, and the community of Elk Park is at risk.

When fire behavior is considered by vegetation and habitat type (Table 35), ponderosa pine would not meet desired conditions for fire type. Landscapes outside of PFAs (LOPFAs) would also not meet desired conditions, with 42% having potential for crown fire, 30% of it active crown fire. Over half of the acres of Target/Threshold habitat would be at risk of crown fire, along with 48% of the PFA/dPFA habitat. While these areas do not all have desired conditions relating to fire behavior, there is good potential for about 65,000 acres (46% of the ponderosa pine) of high severity fire, a subset of which would convert to a non-forested vegetation type.

Aspen occupies about 420 acres in Restoration Unit 1, 43% would have potential for crown fire. Effects would be as described on page 115.

Grasslands occupy a little over 8,000 acres of RU1, and 21% of it has potential for crown fire. Desired conditions for grasslands would not be met under this alternative for RU1, although the 13% of crown fire that is passive crown fire could be beneficial, decreasing encroachment. The 8% that is active crown fire could create some areas of undesirable fire effects on 625 acres (details on page 115.)

Oak/woodlands occupy about 287 acres scattered throughout RU1. About 29% of the oak woodlands would be likely to burn with a crown fire (other effects are as described on page 115).

Pinyon/Juniper woodlands have potential for ~264 acres of crown fire, the majority of which would be active crown fire. Most of the PJ is in Subunit 1-1 and/or on the easternmost area of RU1

Subunits

Subunit 1-3 includes the Lake Mary basin, a source watershed for the town of Flagstaff. Current conditions show 43% of it to have potential for crown fire, 31% of which is active crown fire. Additionally, Upper and Lower Lake Mary are popular recreation sites. Should wildfire burn though this watershed, the second order fire effects could jeopardize the water supply (from the lakes) as well as, at least temporarily, require the closure of the recreation sites. Subunit 1-1 includes Walnut Canyon National Monument, and is adjacent to Flagstaff and the Pulliam Airport. Subunits 1-3, 1-4 and 1-5 contain over 130,000 acres of ponderosa pine, most of which is habitat for Mexican Spotted Owls and goshawks. With no treatment, if a wildfire burned though these subunits, there is potential for over 57,000 acres of ponderosa pine habitat to burn with high severity. Some of this area could be expected to be converted to a non-forested type, effectively removing most of its value to MSO and goshawks (Table 36).

Table 36. Modeled fire type in subunits of RU1 for Alternative A by vegetation type for 2020

Alternative A	Acres	Fire Type (acres) No Fire	Surface	Passive	Active	Fire Type (%) No Fire	Surface	Passive	Active
1-1	**10,170**	**165**	**6,329**	**1,606**	**2,070**	**2%**	**62%**	**16%**	**20%**
Ponderosa Pine	8,914	113	5,563	1,430	1,809	<2%	62%	16%	20%
Grassland	567	18	290	55	204	3%	51%	10%	36%
Oak Woodland	173	0	120	52	1	0%	70%	30%	<1%
Pinyon-Juniper	515	34	356	69	56	7%	69%	13%	11%
1-2	**8,054**	**70**	**5,807**	**827**	**1,351**	**1%**	**72%**	**10%**	**17%**
Ponderosa Pine	6,517	24	4,426	739	1,328	<1%	68%	11%	20%
Grassland	1,537	45	1,380	89	23	3%	90%	6%	1%
1-3	**39,791**	**414**	**22,281**	**4,828**	**12,269**	**1%**	**56%**	**12%**	**31%**
Ponderosa Pine	36,461	103	19,927	4,430	12,001	0%	55%	12%	33%
Aspen	88	0	44	13	31	0%	50%	15%	35%
Grassland	3,241	310	2,309	385	237	10%	71%	12%	7%
1-4	**18,250**	**17**	**10,481**	**1,853**	**5,900**	**<1%**	**57%**	**10%**	**32%**
Ponderosa Pine	17,285	7	9,683	1,737	5,859	0%	56%	10%	34%
Grassland	519	11	407	87	15	2%	78%	17%	3%
Oak Woodland	83	0	59	11	13	0%	72%	13%	15%
Pinyon-Juniper	363	0	331	18	14	0%	91%	5%	4%
1-5	**78,119**	**274**	**40,741**	**7,337**	**29,766**	**<1%**	**52%**	**9%**	**38%**
Ponderosa Pine	74,936	226	38,463	6,852	29,396	<1%	51%	9%	39%
Aspen	332	0	167	25	140	0%	50%	8%	42%
Grassland	2,270	48	1,645	431	146	<3%	72%	19%	6%
Juniper Woodland	286	0	241	11	34	0%	84%	4%	12%
Oak Woodland	32	0	25	1	6	0%	78%	2%	20%
Pinyon-Juniper	262	0	201	18	44	0%	76%	7%	17%

Restoration Unit 3

Restoration Unit 3 currently has the second greatest potential for undesirable fire effects and behavior. Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. The north and east borders are Interstates 10 and 17 respectively, so fires burning in RU3 could affect the Interstates and/or Highway 89, the main route between Flagstaff and Oak Creek Canyon/Sedona/Verde Valley. Multiple drainages in RU3 line up with the prevailing winds, and have the potential to draw fire towards communities, such as Pumphouse Wash (Kachina Village), and Munds Canyon (Munds Park). Adjacency concerns for fire behavior include a number of communities (Figure 6) as well as Oak Creek and Sycamore Canyons. Second order fire effects (such as flooding, debris flows, deposition, erosion, etc.) would have potential to impact Oak Creek and Sycamore Canyons, with the specific locations depending on the slope, proximity, and size of high severity fire. Overall, with no treatment, there is potential for over 58,000 acres of crown fire (39% of the RU), of which over 45,000 (30% of the RU) would be active crown fire.

Ponderosa pine in RU3 would not meet desired conditions for fire type, with 43% that would have crown fire potential, of which 34% would be active crown fire. MSO and Goshawk habitat are at risk as well, with over half of the PFA/dPFA habitat and 58% of protected habitat at risk of crown fire. In the long run, it could be assumed that a subset of the 74,463 of pine that would burn with high severity would be permanently converted to non-forested habitat (Table 37).

Table 37. Fire type by vegetation type and habitat for Restoration Unit 3, Alternative A

RU 3 acres =		149,715	Veg type acres	2010		Alt. A 2020	
Vegetation Type		Type		Acres	%VT	Acres	% Vet Type
Ponderosa Pine*	**All Pine**	**Surface**	**129,226**	**72,776**	**56%**	**72,411**	**56%**
		Passive		**12,594**	**10%**	**12,035**	**9%**
		Active		**43,256**	**33%**	**44,151**	**34%**
	Protected	Surface	4,793	2,020	42%	1,932	40%
		Passive		611	13%	499	10%
		Active		2,076	43%	2,280	48%
	Target/ Threshold	Surface	3,899	2,039	52%	2,070	53%
		Passive		481	11%	460	12%
		Active		1,440	37%	1,367	35%
	Restricted	Surface	38,527	21,085	55%	21,148	55%
		Passive		3,672	10%	3,658	9%
		Active		13,704	36%	13,667	35%
	PFA/ dPFA	Surface	5,582	2,948	53%	2,734	49%
		Passive		605	11%	546	10%
		Active		2,026	36%	2,301	41%
	LOPFA	Surface	76,424	44,683	58%	44,527	58%
		Passive		7,288	10%	6,873	9%
		Active		24,010	31%	24,537	32%

Vegetation Type		Type	Veg type acres	2010 Acres	2010 %VT	Alt. A 2020 Acres	Alt. A 2020 % Vet Type
Other Vegetation*	Aspen	Surface	201	144	72%	137	68%
		Passive		40	20%	44	22%
		Active		16	8%	20	10%
	Grassland	Surface	12,772	11,670	91%	11,622	91%
		Passive		706	6%	583	5%
		Active		167	1%	305	2%
	Juniper Woodland	Surface	1,851	1,559	84%	1,537	83%
		Passive		49	3%	59	3%
		Active		240	13%	254	14%
	Oak Woodland	Surface	1,633	1,282	79%	1,298	80%
		Passive		75	5%	63	4%
		Active		269	16%	267	16%
	Pinyon/ Juniper	Surface	4,033	3,351	83%	3,366	83%
		Passive		175	4%	157	4%
		Active		501	12%	503	12%

* Nonburnable substrate constitutes <1% in ponderosa pine and <1% of the treatment area in RU3

Aspen occupies 201 acres of aspen in RU3, and 32% of it (64 acres) has potential for crown fire, all of which are in the northeast area of RU3. Additional effects are as described under RU1on page 115).

Grasslands occupy 12,772 acres in RU3, most of which are in Garland Prairie. Under this alternative, ~ 888 acres (7%) of the grasslands in RU3 would support crown fire. About 305 of those acres would be active crown fire and have potential to produce undesirable fire effects. Additional effects are as described under RU1on pages 115 and 116.

Oak woodlands occupy 1,633 acres in RU3, more than any other RU. These acres are scattered throughout the RU from the southern-most part of the treatment area in Subunit 1-5 to the westernmost. In RU3, 20% of Gambel oak would have the potential to produce crown fire. Additional effects are as described under RU1on page 115).

Pinyon/Juniper Woodlands in RU3 occupy about 5,884 acres. Most are close to the rim, or in the west/southwest part of the RU, primarily in Subunit 3-1 (Table 38). The majority of the crown fire potential in the PJ in RU3 would be active crown fire which would pose a control issue, as well as having the potential to initiate crown fire in ponderosa pine if wind and terrain were to push it that way.

Subunits

Within RU3, ponderosa pine does not meet desired conditions in any of the subunits (Table 38).

Table 38. Modeled fire type in subunits of RU3 by vegetation type for 2020.

		Fire Type (acres)				Fire Type (%)			
Alternative A	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
3-1	**23,145**	**72**	**15,201**	**2,004**	**5,868**	**0%**	**66%**	**9%**	**25%**
Ponderosa Pine	18,805	35	11,529	1,776	5,465	<1%	61%	9%	29%
Aspen	91	0	58	29	4	<1%	63%	31%	5%
Grassland	590	31	489	54	15	5%	83%	9%	3%
Juniper Woodland	907	1	777	36	94	0%	86%	4%	10%
Oak Woodland	845	1	702	36	106	0%	83%	4%	13%
Pinyon-Juniper	1,908	4	1,645	74	184	0%	86%	4%	10%
3-2	**32,726**	**296**	**23,016**	**2,455**	**6,958**	**1%**	**70%**	**8%**	**21%**
Ponderosa Pine	22,885	137	13,684	2,269	6,795	<1%	60%	10%	30%
Aspen	59	0	40	6	13	0%	68%	10%	22%
Grassland	9,611	159	9,231	179	41	2%	96%	2%	0%
Oak Woodland	172	0	61	2	109	0%	36%	1%	64%
3-3	**48,434**	**63**	**28,654**	**4,298**	**15,419**	**0%**	**59%**	**9%**	**32%**
Ponderosa Pine	44,426	48	25,333	4,069	14,976	0%	57%	9%	34%
Aspen	50	0	39	9	2	0%	77%	18%	5%
Grassland	1,353	9	1,124	126	94	1%	83%	9%	7%
Juniper Woodland	873	1	693	23	156	0%	79%	3%	18%
Oak Woodland	232	3	213	10	6	1%	92%	4%	3%
Pinyon-Juniper	1,500	3	1,253	60	185	0%	84%	4%	12%
3-4	**9,019**	**215**	**5,115**	**812**	**2,877**	**2%**	**57%**	**9%**	**32%**
Ponderosa Pine	8,920	201	5,075	804	2,840	2%	57%	9%	32%
Grassland	99	15	40	7	37	15%	40%	7%	38%
Oak Woodland	0	0	0	0	0	0%	100%	0%	0%
3-5	**36,392**	**257**	**18,384**	**3,373**	**14,378**	**1%**	**51%**	**9%**	**40%**
Ponderosa Pine	34,190	209	16,789	3,117	14,075	1%	49%	9%	41%
Aspen	2	0	1	0	1	0%	37%	25%	38%

Grassland	1,120	48	738	217	118	4%	66%	19%	11%
Juniper Woodland	70	0	67	0	4	0%	95%	0%	5%
Oak Woodland	384	0	322	16	46	0%	84%	4%	12%
Pinyon-Juniper	626	0	469	23	135	0%	75%	4%	21%

Subunit 3-2 includes an area along Interstate 40 from the outskirts of Flagstaff to Williams, and would have the potential for over 9,000 acres of crown fire. Subunit 3-3 encompasses Sycamore Canyon, and has the potential for almost 20,000 acre of high severity fire from crown fire. There would be potential for second order effects to the Sycamore Canyon Wilderness area from flooding and/or debris flows following high severity fire which could compromise the functioning of the water resources and adjacent riparian areas. Subunit 3-4 has potential for over 3,000 acres of high severity effects from crown fire, and is strategically important for the communities of Flagstaff, Kachina Village, and Munds Park, as well as Interstate 17. Ignitions starting in or near Pumphouse Wash and the canyon southwest of Munds Park would be likely to funnel Kachina Village and Munds Park. Additionally, water resources and riparian areas in these areas would be compromised by flooding and/or debris flows. Winds are generally out of the southwest, so fires starting in this RU would be pushed toward these communities and Interstate 17.

Restoration Unit 4

RU4 is located west and north of Flagstaff, and north of Williams and Interstate 10, and has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, RU4 has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. Areas of potential active crown fire would be adjacent to heavy fuel loading in mixed conifer on Kendrick and Sitgreaves mountains, and the San Francisco Peaks. With no treatment, there is potential for over 53,000 acres of crown fire (33% of the RU), of which over 42,000 acres (26% of the RU) would be active crown fire.

<u>Ponderosa pine</u> comprises 134,278 acres within RU4 and would not meet desired conditions, with 37% (>50,000 acres) having potential for crown fire (Table 39). Within the ponderosa pine, MSO and Goshawk habitat are at risk of high severity fire effects from crown fire.

The areas of the most contiguous crown fire in RU4 are downslope from mixed conifer on Kendrick, Sitgreaves, and the San Francisco Peaks. In these areas, crown fire could move upslope with at a rapid rate of spread, producing large areas of high severity fire on steep slopes. In these areas, second order fire effects could be extreme, such as occurred on the east side of the Peaks following the Schultz Fire, with sediment laden flood waters scouring out channels, and debris flows damming culverts and washing out and/or blocking roads.

<u>Aspen</u> occupies ~500 acres within RU4 which are widely scattered. As with the other RUs, the effects of a wildfire would be both beneficial and detrimental, depending on the initial condition of the stand. Additional effects are as described under RU1on page 115.

<u>Grassland</u> acres total over 22,000 acres in RU4, including Government Prairie. There would be potential for 1,412 acres of crown fire, with ~801 acres of active crown fire. These 801 acres have the potential for undesirable fire effects, while fire effects on the rest of the grassland area could reduce woody encroachment, moving 21,868 acres of grasslands towards the desired condition. With no proposed treatments, this would only occur if a wildfire burned across the entire area. Additional effects are as described under RU1on page 116.

Oak woodlands comprise 926 acres of RU4 and would support over 200 acres of crown fire. In RU4, these acres are widely scattered, and mostly in mostly stands <100 acres. Additional effects are as described under RU1on page 115.

Table 39. Modeled fire type by vegetation and habitat type for Restoration Unit 4

RU 4 acres =		165,645	Veg type acres	2010		Alt. A 2020	
Vegetation Type		Type		Acres	%VT	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**134,278**	**83,499**	**62%**	**83,359**	**62%**
		Passive		**10,590**	**8%**	**9,844**	**7%**
		Active		**39,763**	**30%**	**40,697**	**30%**
	Protected	Surface	558	379	68%	376	67%
		Passive		45	8%	38	7%
		Active		134	24%	145	26%
	Restricted	Surface	1,576	751	48%	770	49%
		Passive		196	12%	193	12%
		Active		621	39%	606	38%
	PFA/ dPFA	Surface	13,484	8,008	59%	7,989	59%
		Passive		1,250	9%	1,175	9%
		Active		4,221	31%	4,314	32%
	LOPFA	Surface	118,659	74,361	63%	74,224	63%
		Passive		9,100	8%	8,438	7%
		Active		34,786	29%	35,632	30%
Other Vegetation*	Aspen	Surface	497	403	81%	405	82%
		Passive		31	6%	26	5%
		Active		59	12%	62	12%
	Grassland	Surface	22,661	21,080	93%	21,137	93%
		Passive		788	3%	611	3%
		Active		645	3%	801	4%
	Juniper Woodland	Surface	118	69	59%	63	53%
		Passive		4	3%	3	2%
		Active		43	36%	50	42%
	Oak Woodland	Surface	926	669	72%	687	74%
		Passive		90	10%	61	7%
		Active		165	18%	176	19%
	Pinyon/ Juniper	Surface	7,165	5,855	82%	5,864	82%
		Passive		453	6%	423	6%
		Active		829	12%	857	12%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area in RU4

Pinyon/Juniper woodlands in RU4 are mostly on the west, northwest, and northern portions, occurring in stands, or groups of stands ranging from less than 10 acres to over 700. RU4 has more pinyon/juniper woodland than any other RU. With no treatment, wildfire occurring under modeled conditions would be expected to burn over 1,300 acres with high severity effects by 2020, over 900 of which would be active crown fire. Additional effects are as described under RU1on page 116.

Subunits

At the subunit level (Table 40) SU 4-5, the smallest SU in the project (6,943 acres), is adjacent to northwest Flagstaff, and has steep topography, so that the second order fire effects of any high severity fires have good potential to impact neighborhoods and schools. Currently, 35% of SU 4-5 has potential for crown fire, with 31% being active crown fire. Most of Government Prairie is in Subunit 4-4 and, with no treatment, wildfire could produce undesirable effects on 333 acres, with effects on the rest (~14,500 acres) moving those acres towards desired conditions.

Table 40. Modeled fire type in subunits of RU4 by vegetation type for 2020.

		Fire Type (acres)				Fire Type (%)			
Alternative A	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
4-2	**10,227**	**55**	**7,027**	**851**	**2,294**	**1%**	**69%**	**8%**	**22%**
Ponderosa Pine	7,381	15	4,748	719	1,900	0%	64%	10%	26%
Aspen	1	0	1	0	0	29%	71%	0%	0%
Grassland	328	19	300	8	1	6%	91%	3%	0%
Juniper Woodland	8	0	8	1	0	0%	92%	8%	0%
Oak Woodland	567	2	389	41	135	0%	69%	7%	24%
Pinyon-Juniper	1,941	19	1,581	82	259	1%	82%	4%	13%
4-3	**67,012**	**325**	**48,261**	**3,999**	**14,426**	**0%**	**72%**	**6%**	**22%**
Ponderosa Pine	55,312	308	38,065	3,506	13,433	1%	69%	6%	24%
Aspen	230	3	215	4	9	1%	93%	2%	4%
Grassland	6,951	11	6,345	156	439	<1%	91%	2%	6%
Juniper Woodland	31	0	30	0	1	0%	97%	0%	3%
Oak Woodland	325	0	279	18	28	0%	86%	5%	9%
Pinyon-Juniper	4,162	3	3,328	315	517	0%	80%	8%	12%
4-4	**81,487**	**137**	**51,714**	**5,831**	**23,804**	**<1%**	**63%**	**7%**	**29%**
Ponderosa Pine	65,003	54	36,313	5,357	23,280	0%	56%	8%	36%
Aspen	255	0	184	22	48	<1%	72%	8%	19%
Grassland	15,055	81	14,218	422	333	1%	94%	3%	2%
Juniper Woodland	78	2	25	2	49	3%	32%	<3%	63%
Oak Woodland	35	0	19	2	13	0%	55%	6%	39%
Pinyon-Juniper	1,062	0	955	26	81	0%	90%	2%	8%
4-5	**6,919**	**2**	**4,512**	**287**	**2,117**	**0%**	**65%**	**4%**	**31%**
Ponderosa Pine	6,581	1	4,233	262	2,085	0%	64%	4%	32%
Aspen	11	0	6	1	5	0%	52%	6%	42%
Grassland	327	2	273	24	28	<1%	84%	7%	9%

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 mostly on Mount Eldon, immediately upslope and adjacent to northern Flagstaff) (Table 41). Adjacency concerns include housing developments, including Doney Park, Timberline, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. The northeastern area of this RU has scattered cinder cones, and cinder areas which support only sparse vegetation. In these areas, active crown fire is less likely because of low continuity of both surface and canopy fuels. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity (see map, Appendix D). Overall, with no treatment, there is potential for over 16,000 acres of crown fire (22% of the RU), of which over 5,700 (13% of the RU) would be active crown fire.

Ponderosa pine in RU5 would not meet desired conditions (Table 41), with 25% of the area having potential for crown fire, of which 15% would be active crown fire. Some of the active crown fire in PACs on the northwest side of Mt. Eldon would occur on slopes greater than 30 to 40%. Protected habitat would have potential for 34% (299 acres) of crown fire, of which 167 acres would be active crown fire.

Table 41. Fire type by vegetation type and habitat for Restoration Unit 5

RU 5 acres =		73,203	Veg type acres	2010		Alt. A 2020	
Vegetation Type		Type		Acres	%VT	Acres	%VT
Ponderosa Pine*	**All Pine**	**Surface**	**59,034**	**41,109**	**70%**	**40,308**	**68%**
		Passive		**6,821**	**12%**	**6,026**	**10%**
		Active		**7,376**	**12%**	**8,953**	**15%**
	Protected	Surface	859	535	62%	541	63%
		Passive		132	15%	112	13%
		Active		167	19%	182	21%
	Restricted	Surface	606	451	74%	461	76%
		Passive		71	12%	58	10%
		Active		83	14%	87	14%
	PFA/ dPFA	Surface	2,227	1,343	60%	1,341	60%
		Passive		419	19%	346	16%
		Active		325	15%	400	18%
	LOPFA	Surface	55,341	38,780	70%	37,965	69%
		Passive		6,199	11%	5,510	10%
		Active		6,801	12%	8,285	15%
Other Vegetation*	Aspen	Surface	403	332	82%	336	83%
		Passive		24	6%	17	4%
		Active		43	11%	45	11%
	Grassland	Surface	4,536	2,521	56%	2,574	57%
		Passive		222	5%	116	3%
		Active		105	2%	156	3%
	Juniper Woodland	Surface	74	67	90%	67	90%
		Passive		7	9%	7	9%
		Active		0	1%	1	1%
	Oak Woodland	Surface	386	349	91%	355	92%
		Passive		20	5%	16	4%
		Active		1	0%	1	0%
	Pinyon/ Juniper	Surface	8,771	7,804	89%	7,818	89%
		Passive		277	3%	265	3%
		Active		393	4%	402	5%

* Nonburnable substrate constitutes <1% of ponderosa pine and about 8% of the entire treatment area in RU5

Aspen comprises 403 acres of RU4. Eight percent would have potential for crown fire, of which 11% (45 acres) would be active crown fire (Table 41). Additional effects are as described under RU1on page 115.

Grasslands in RU5 would have potential for crown fire on 272 acres (6%), of which 156 acres would be active crown fire. Additional effects are as described under RU1on page 116.

Oak woodlands comprise 523 acres of RU5. Under this alternative, by 2020, there would be potential for 31 acres of crown fire in oak woodlands. Additional effects are as described under RU1on page 115.

Pinyon/Juniper woodlands would have potential for 674 acres of crown fire, by 2020, an increase of ~100 acres. Additional effects are as described under RU1on page 116.

Subunits

Table 42 shows 67% surface fire in SU5-2, the area most severely affected by the Schultz Fire. Subunit 5-2 includes many acres of cinder cones that are too sparsely vegetated to carry fire, as well as areas that were affected by flooding and debris flows resulting from the Schultz Fire. Upslope from north flagstaff there would be potential for high severity fire effects on steep slopes (>30%) in RU 5-1. Effects would include flooding and debris flows potentially affecting residential areas resulting from high severity fire in these areas would be likely to affect those areas downslope, including infrastructure, with the effects depending on the location, severity, timing, and extent of the area burned with high severity effects.

Table 42. Modeled fire type for Restoration Unit 5 subunits by vegetation type

Alternative A	Acres	Fire Type (acres)				Fire Type (%)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
5-1	**21,341**	**792**	**16,647**	**1,280**	**2,621**	**4%**	**78%**	**6%**	**12%**
Ponderosa Pine	18,040	746	13,577	1,178	2,539	4%	75%	7%	14%
Aspen	392	5	328	15	44	1%	84%	4%	11%
Grassland	1,239	19	1,131	65	24	2%	91%	5%	2%
Oak Woodland	95	0	88	7	0	0%	92%	8%	0%
Pinyon-Juniper	1,574	23	1,523	15	14	1%	97%	1%	1%
5-2	**51,863**	**4,948**	**34,811**	**5,167**	**6,937**	**10%**	**67%**	**10%**	**13%**
Ponderosa Pine	40,994	3,001	26,732	4,848	6,414	7%	65%	12%	16%
Aspen	10	0	8	2	1	0%	74%	19%	7%
Grassland	3,297	1,670	1,443	51	132	51%	44%	2%	4%
Juniper Woodland	74	0	67	7	1	0%	90%	9%	1%
Oak Woodland	291	14	267	9	1	5%	92%	3%	0%
Pinyon-Juniper	7,196	263	6,295	250	388	4%	87%	3%	5%

Restoration Unit 6

Restoration Unit 6 (Table 43) is the smallest of the RUs, and lies immediately south of, and adjacent to Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area (Table 43). Active crown fire in RU6 would mostly be dispersed, with only a few areas of contiguous crown fire. Overall, with no treatment, there would be potential for over 6,000 acres of crown fire (14% of the RU), of which a little over 3,000 (8% of the RU) would be active crown fire.

Ponderosa pine would not meet desired conditions, because 13% of the ponderosa pine (5,633 acres) would have potential for crown fire. When ponderosa pine is considered by habitat type, there would be 10% of the PFA/dPFA habitat that would have potential for crown fire.

Grasslands occupy just 93 acres of grassland in RU6. The 2 acres of crown fire (passive) modeled would be beneficial, decreasing woody encroachment, reinvigorating shrubs and moving these acres towards the desired condition.

Oak woodlands comprise just 30 acres, and would support mostly passive crown fire (20 acres). As with the other RUs, crown fire in the oak would be likely to kill larger stems, and produce multiple smaller stems. Additional effects are as described under RU1on page 115.

Table 43. Fire type by vegetation type and habitat for Restoration Unit 6

RU 6 acres =		1	Veg type acres	2010		Alt. A 2020	
Vegetation Type		Type		Acres	%VT	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**41,189**	**33,673**	**82%**	**35,511**	**86%**
		Passive		**2,233**	**5%**	**2,239**	**5%**
		Active		**5,238**	**13%**	**3,394**	**8%**
	PFA/ dPFA	Surface	4,050	3,506	87%	3,658	90%
		Passive		111	3%	110	3%
		Active		430	11%	278	7%
	LOPFA	Surface	37,139	30,167	81%	31,853	86%
		Passive		2,123	6%	2,129	6%
		Active		4,808	13%	3,116	8%
Other Vegetation*	Grassland	Surface	93	89	96%	90	97%
		Passive		2	2%	2	2%
		Active		1	1%	0	0%
	Juniper Woodland	Surface	13	10	79%	10	79%
		Passive		3	21%	3	21%
		Active		0	0%	0	0%
	Oak Woodland	Surface	30	9	30%	9	31%
		Passive		20	68%	20	68%
		Active		1	2%	0	1%
	Pinyon/ Juniper	Surface	2,206	1,472	67%	1,500	68%
		Passive		504	23%	504	23%
		Active		229	10%	201	9%

* Nonburnable substrate constitutes <1% of ponderosa pine, and <1% of the entire treatment area within RU6

Pinyon/Juniper woodland occupies 2,219 acres of RU6, and would support ~608 acres of crown fire. The only 'fuel' treatment in the 4FRI is largely in the Pinyon/Juniper in RU6, adjacent to the airport and the town of Tusayan. The desired condition for those acres is no crown fire so, under Alternative A, the Pinyon/Juniper would not meet desired conditions.

Subunits

The majority of the treatment area in RU6 is in Subunit 6-3 (Table 44) which, along with SU6-4, is adjacent to Grand Canyon National Park. Just east of the town of Tusayan are 535 acres for which potential fire behavior would be a growing concern. In Subunit 6-3, 12% of the Pinyon/Juniper has potential for crown fire, 146 acres of which would be active crown fire. Although the severity of the potential fire behavior and effects in this area may be within the historic fire regime, fire exclusion of the patchy, mixed severity fires that were probably typical of the fire regime in RU6 have homogenized the PJ somewhat, so there could be the possibility of fires occurring that would be of larger extent than historic records indicate were typical (Huffman et al. 2006).

Table 44. Modeled fire type in subunits of RU6 by vegetation type for 2020.

Alternative A	Acres	Fire Type (acres)				Fire Type (%)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
6-2	**5,551**	**7**	**4,833**	**411**	**299**	**<1%**	**87%**	**7%**	**5%**
Ponderosa Pine	5,069	7	4,472	298	292	0%	88%	6%	6%
Pinyon-Juniper	483	0	361	114	7	<1%	75%	24%	<2%
6-3	**34,109**	**33**	**30,275**	**893**	**2,908**	**<1%**	**89%**	**3%**	**8%**
Ponderosa Pine	32,635	33	29,111	730	2,761	<1%	89%	2%	8%
Grassland	85	0	83	2	0	0%	97%	3%	0%
Juniper Woodland	13	0	10	3	0	0%	79%	21%	0%
Pinyon-Juniper	1,375	0	1,071	158	146	0%	78%	11%	11%
6-4	**3,870**	**4**	**2,012**	**1,464**	**390**	**0%**	**52%**	**38%**	**10%**
Ponderosa Pine	3,484	4	1,928	1,212	341	0%	55%	35%	10%
Grassland	7	0	7	0	0	0%	100%	0%	0%
Oak Woodland	30	0	9	20	0	0%	31%	68%	1%
Pinyon-Juniper	348	0	68	232	48	0%	19%	67%	14%

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness desired openness. As described on page 15, the desired openness is an indication of the relative desired post-treatment interspace/tree group condition. Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 168. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 86 for more details).

Canopy characteristics

As described in the Methodology section on page 29, canopy characteristics are used in modeling potential fire behavior and can be used to show trends that affect fire behavior and effects for conditions not modeled. For example, increasing horizontal continuity in canopy fuels indicates increasing likelihood of active crown fire and the associated effects, and areas of contiguous passive crown fire are likely to become active crown fire with increased wind. Modeled changes to canopy base height (CBH) and canopy bulk density (CBD) are shown in Table 45 and display changes and effects that may not be apparent in fire behavior data. Desired conditions are for CBH to be 18 feet or higher and for CBD to be 0.05 kg/m^3 or lower. This alternative would not meet desired conditions for CBH by 2020 for CBH or CBD. Table 45 displays modeled changes in canopy characteristics from 2010 through 2050 with no mechanical treatments or fire (wildfire or prescribed fire) after 2020. Shaded cells indicate a condition that does not meet desired conditions. Note: desired conditions for CBH and CBD do not apply to PACs or Core Areas.

Table 45. Canopy characteristics under Alternative A 2020 and Existing Condition

Alt A	CBH (feet)			CBD (kg/m3)			CC (%)			% of pond pine
Desired Openness	**2010**	**2020**	**2050**	**2010**	**2020**	**2050**	**2010**	**2020**	**2050**	
High	15.4	17.1	22.5	0.061	0.062	0.060	41	43	47	41%
Moderate	14.7	16.5	22.2	0.061	0.061	0.060	43	45	50	24%
Low (Mechanical)	16.4	18.5	24.8	0.063	0.063	0.058	42	45	48	6%
Low (Burn Only)	14.0	15.7	20.9	0.046	0.047	0.049	33	36	42	18%
Very Low (Burn Only)	14.5	16.6	22.0	0.063	0.062	0.060	41	43	46	2%
Very Low (Mechanical)	15.5	17.3	23.8	0.062	0.061	0.061	48	50	54	4%
Very Low (PAC Burn Only)	14.4	16.1	21.8	0.067	0.067	0.067	49	51	54	4%
Very Low/ No Proposed Treatments (Core Areas)	14.2	15.8	22.1	0.070	0.071	0.069	51	52	55	1%
No Proposed Treatments	16.5	18.1	23.6	0.049	0.050	0.051	39	41	46	0.4%
Weighted Average[2]	15.00	16.7	22.3	0.059	0.059	0.058	41	43	47	

Figure 42 shows the canopy cover increasing, while canopy base height increases and canopy bulk density decreases. These three trends together indicate an unhealthy forest, as canopy cover increases, shading out lower branches, while increasing the potential for conditional (active) crown fire.

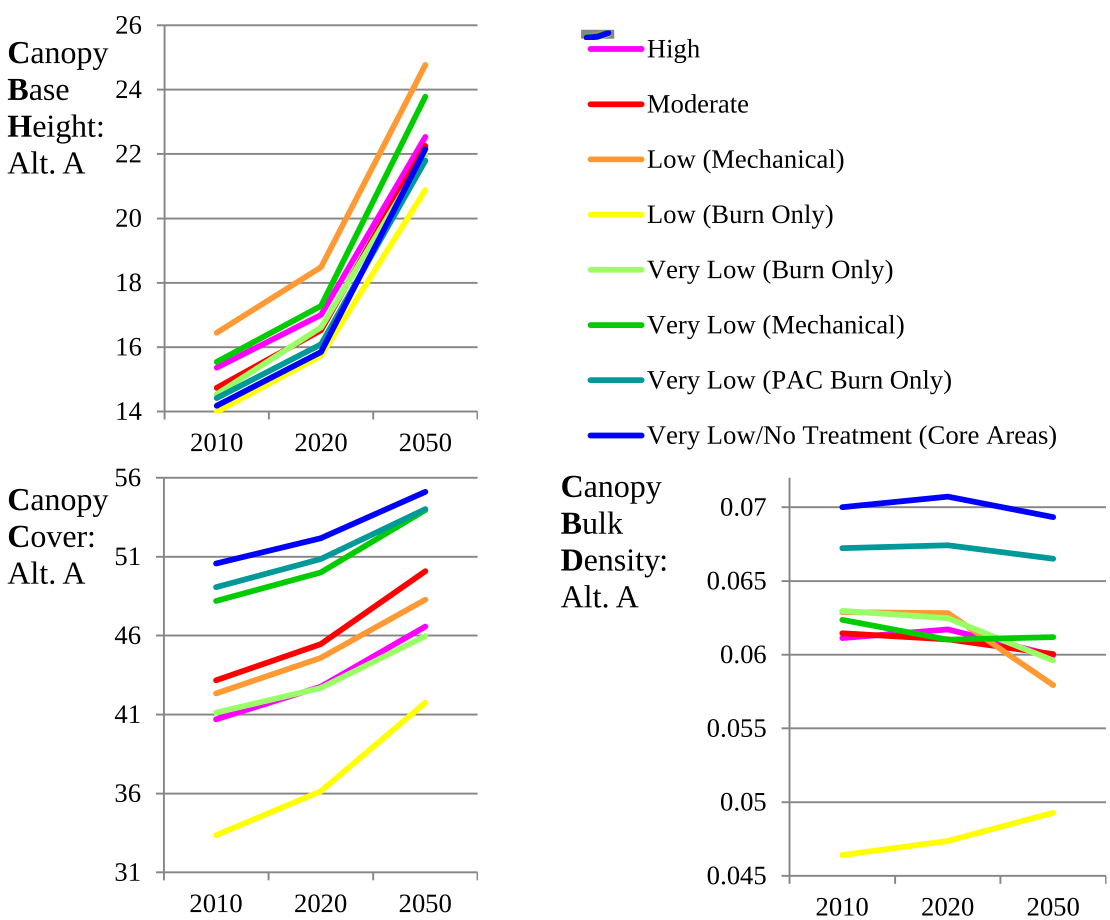


Figure 42 shows modeled trends in canopy characteristics under Alternative A.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Litter, duff, and Coarse Woody Debris greater than 3" diameter (CWD>3") contributing to flammability, surface fire intensity, surface fire effects, soil effects, and emissions. Duff and CWD contribute to emissions more than other fuels because they can and do smolder for long periods of time at temperatures that don't always allow for complete combustion. Surface litter is one of the primary methods of spread, so it is included in the emissions discussions. The initial flame front in a crown fire consumes large amounts of fuel in a relatively short time. Litter, duff, and CWD can smolder for hours, days, or longer. Mechanical thinning alone can decrease the potential for crown fire by breaking up vertical and horizontal canopy fuel continuity, but initially may increase surface fuel loadings until activity fuels are removed or burned. Initial thinning impacts may create temporary fire 'breaks' where there are skid trails, or other surface disturbance have moved surface fuels around, but surface fuels are generally not removed from a treatment area, and remain a potential source of heat and emissions. Surface fuels may be patchier following thinning but, are still available fuels.

Surface fuel loading by treatment ability to maintain desired openness

Twenty tons per acre was used as the upper end for recommended surface fuel loading. Historical values were around 5 tons/acre on the high end for CWD, and less than 2.5 tons/acre for duff (Brown et al. 2003). Assuming ~2.5 tons/acre of litter, under Alternative A, by 2020 none of the area would be within the historical range of surface fuel loading, and would exceed it by 2050 (Table 46).

Table 46. Modeled changes in tons/acre of litter, duff, and CWD>3", Alternative A. Shaded cells do not meet desired or recommended conditions.

Alt A	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			% pond. pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.7	4.4	7.1	3.1	3.8	4.3	3.1	3.3	3.9	9.9	11.5	15.2	41
Moderate	3.7	4.6	7.4	3.9	4.6	5.2	3.1	3.3	4.1	10.7	12.5	16.7	24
Low (Mechanical)	3.8	4.7	7.7	3.2	3.9	4.4	3.3	3.5	4.1	10.3	12.1	16.3	6
Low (Burn Only)	3.2	3.8	5.9	2.5	3.1	3.7	2.9	3.0	3.5	8.6	9.9	13.2	18
Very Low (Burn Only)	3.8	4.6	7.8	3.2	3.8	4.3	3.2	3.4	4.0	10.2	11.8	16.0	2
Very Low (Mechanical)	5.0	6.5	10.7	5.0	5.6	6.1	3.9	4.2	5.1	13.9	16.3	21.9	4
Very Low (PAC Burn Only)	6.0	7.8	12.5	4.8	5.5	6.1	5.1	5.4	6.2	15.9	18.6	24.8	4
Very Low/ No Proposed Treatments (Core Areas)	5.8	7.6	12.4	5.1	5.8	6.3	4.7	5.0	5.9	15.6	18.4	24.6	1
No Proposed Treatments	3.0	3.9	6.7	3.8	4.4	5.0	2.4	2.6	3.4	9.3	10.9	15.0	<1
Weighted Average[2]	3.73	4.60	7.37	3.34	4.02	4.56	3.22	3.40	4.05	10.30	12.02	15.98	

Table 46 shows changes in litter, duff, and CWD>3" as modeled over 40 years with no treatment of any kind or wildfire. The modeling shows a steady increase of litter, duff, and CWD>3". Under this alternative, duff loads continue to increase, with a maximum of over 6 tons/acre. When this is combined with litter and CWD>3", total surface fuel loading of these three components ranges from ~9 to ~19 tons/acre by 2020, and 15 to 25 tons/acre by 2050. These types of fuel loadings could produce undesirable fire effects, including large quantities of emissions.

Figure **43** shows modeled changes in surface fuel loading of the combined tons/acre for duff, litter, and CWD over 40 years, assuming no treatment and no disturbances of any kind, including fire. The trends for all levels of treatment intensity would result in increasing amounts of nutrients locked up in dead biomass, and increasingly suppressing surface vegetation, and increasing the potential for precipitation to be intercepted by litter and duff before it can reach the ground.

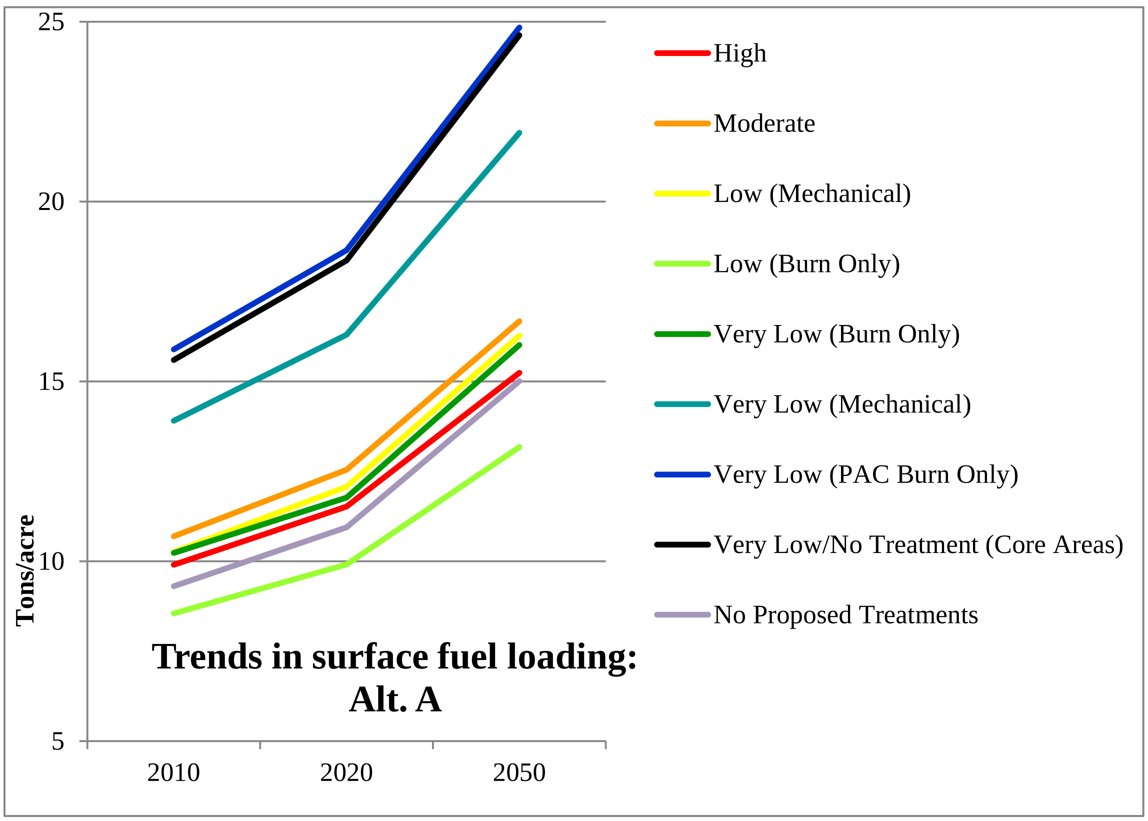


Figure 43. Trends in surface fuel loading under Alternative A.

Surface fuel loading by stand

When broken out by the stand level, areas that would have the highest surface fuel loading are shown in Figure 44, and are most often associated with PACs and Core Areas. RUs 1 and 3 would have the highest surface fuel loading. Under Alternative A, there would be over 17,000 acres with surface fuel loading greater than 20 tons/acre, and over 144,000 acres with fuel loading between 15 and 20 tons/acre. By 2040, almost 20 percent of the treatment area would have fuel loads exceeding 20 tons/acre, and an additional 18% would be in the 15 – 20 tons/acre range. In Figure 44, tan areas indicate areas excluded from potential treatment because of special designation, (Wilderness, etc.), implementation of other projects, or other NEPA planning.

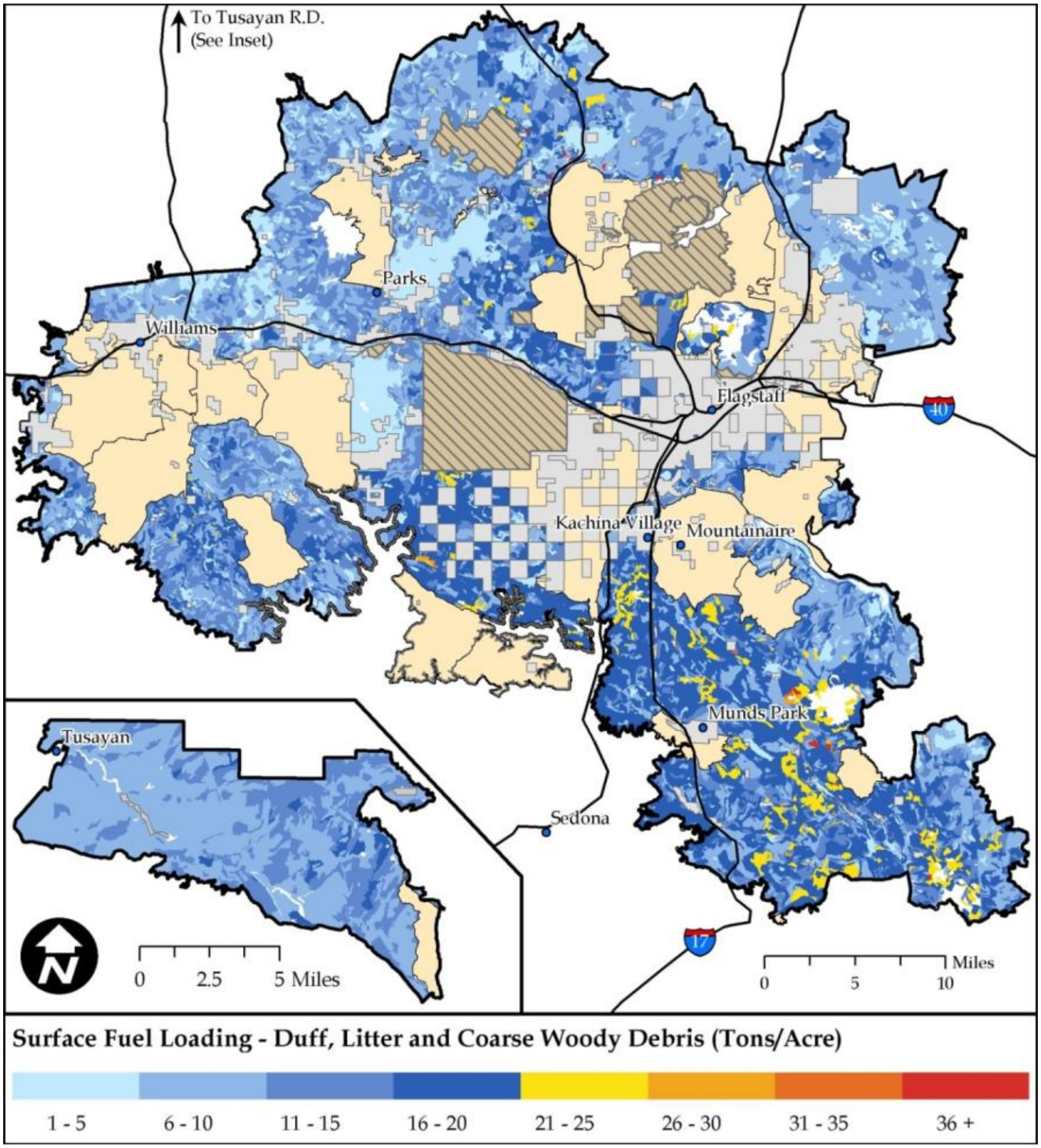


Figure 44. Modeled surface fuel loading for Alternative A, 2020

Fire Regime/Condition Class

Under Alternative A, ponderosa pine ecosystems would increasingly become departed from desired conditions, increasing the risk to key ecosystem components. Table 47 shows VCC as modeled for 40 years of ponderosa pine. In Alternative A, ponderosa pine starts in, and stays in an FRCC3, as VCC, fire frequency, and fire severity become increasingly departed from the reference condition.

Acres of grasslands in VCC1 would decrease in the absence of any type of treatment, as woody species continued to encroach and species composition shifted in favor of less fire adapted species. Acres of ponderosa pine in VCC 2 and 3 would continue to increase, leaving just 2% in VCC 1. Ponderosa pine in the project area would be at a high risk of losing key ecosystem components, should there be a disturbance event, such as fire or extended drought.

Table 47. Modeled changes to Fire Regime/Condition Class under Alternative A.

VCC – Alt. A	2010		2020		2050	
	Acres	%	Acres	%	Acres	%
1	71,097	14%	55,862	11%	10,157	2%
2	126,960	25%	116,803	23%	147,273	29%
3	309,782	61%	335,174	66%	350,409	69%
Vegetation departure =	66%		69 %		84 %	
Fire Severity Departure =	74%		78 %		83 %	
Fire Return Interval Departure =	80%		90 %		95 %	
FRCC of treatment area =	**3**		**3**		**3**	

Fire Return Interval

Fire return intervals (FRI), (page 37), are a characteristic of a fire regime, and a coarse measure of the health of a system. The fire return interval from 2001 through 2010 was calculated to be 43 years for the 1.4 million acres of ponderosa pine and grassland areas on the forests area. The estimated fire return interval for the treatment area is currently about 40 years. This is double the desired maximum average for ponderosa pine on the Mogollon Rim. From 2001 to 2013, the average number of acres that burned within the treatment area was around 15,000 (dividing the acreage burned by the total number of acres, so 590,000/15,000 = ~40). With no additional fire the average annual acreage burned decreases, increasing the average FRI (Table 48) so by 2050, the average FRI for the treatment area would be 160 years.

Table 48. Average fire return intervals for Alternative A

	# of years averaged (years)	Average annual acres burned	Fire Return Interval
Existing conditions	10 (2001 -2010)	15,000 (2001 -2010)	40
Alt. A 2020	20 (2001- 2020)	7,500 (2001- 2020)	80
Alt A 2050	40 (2001- 2050)	3,750 (2001- 2050)	160

Emissions: Air Quality and Ecological Effects

The timing and type of smoke effects would change little initially but, as the likelihood of large fires would increase along with, the potential for air quality levels that exceed National Ambient Air Quality Standards (NAAQS), and nuisance smoke. Restoration Units 1 and 3 have the greatest potential to produce emissions outside of those produced by the flaming front of a crown fire because of surface fuel loading. This alternative would not increase potential smoke impacts during certain times of the year when smoke impacts are largely from prescribed fire (pile burning, broadcast burns, and jackpot burning), generally, mid/late fall, winter, and early spring. The likelihood and degree of potential impacts from wildfire smoke would continue to increase as fuel loading increased. Wildfire smoke is less predictable, less frequent, and more concentrated than emissions from prescribed fires.

Emissions from surface fuels burning in a wildfire in stands that have been thinned, but not burned are not statistically different than those from stands in their existing condition (Figure **45**). Figure 46 displays emissions from surface fuels burning in wildfires after various treatments including: Left: no treatment; second from left, after two prescribed fires; third from the left, after only mechanical treatment and furthest right, after mechanical treatment and two prescribed fires. Wildfire would be the only source of emissions from the treatment area under this alternative. Figure 46 shows differences in emissions from surface fuels under different treatment scenarios and identical fire conditions. This does not show the effects of the canopy fuels which, in the initial flame front, are a significant producer of emissions from fuels that do not burn in prescribed fires either because they have been removed from the forest, or because prescribed fires in ponderosa pine and the associated vegetation types (aspen, grasslands, oak) rarely consume much of the canopy fuel load. Emissions from canopy fuels in a crown fire are generally of shorter duration since they are produced as the flaming front passes by. Much of the lingering smoke comes from duff, CWD, litter, stumps, and other fuels that can smolder.

In this alternative, smoke impacts generated from the proposed treatment area would only come from wildfires. The impacts would be infrequent (a few times a year); more severe when they occur; and the duration, location, and extent of area/s affected would be largely unpredictable.

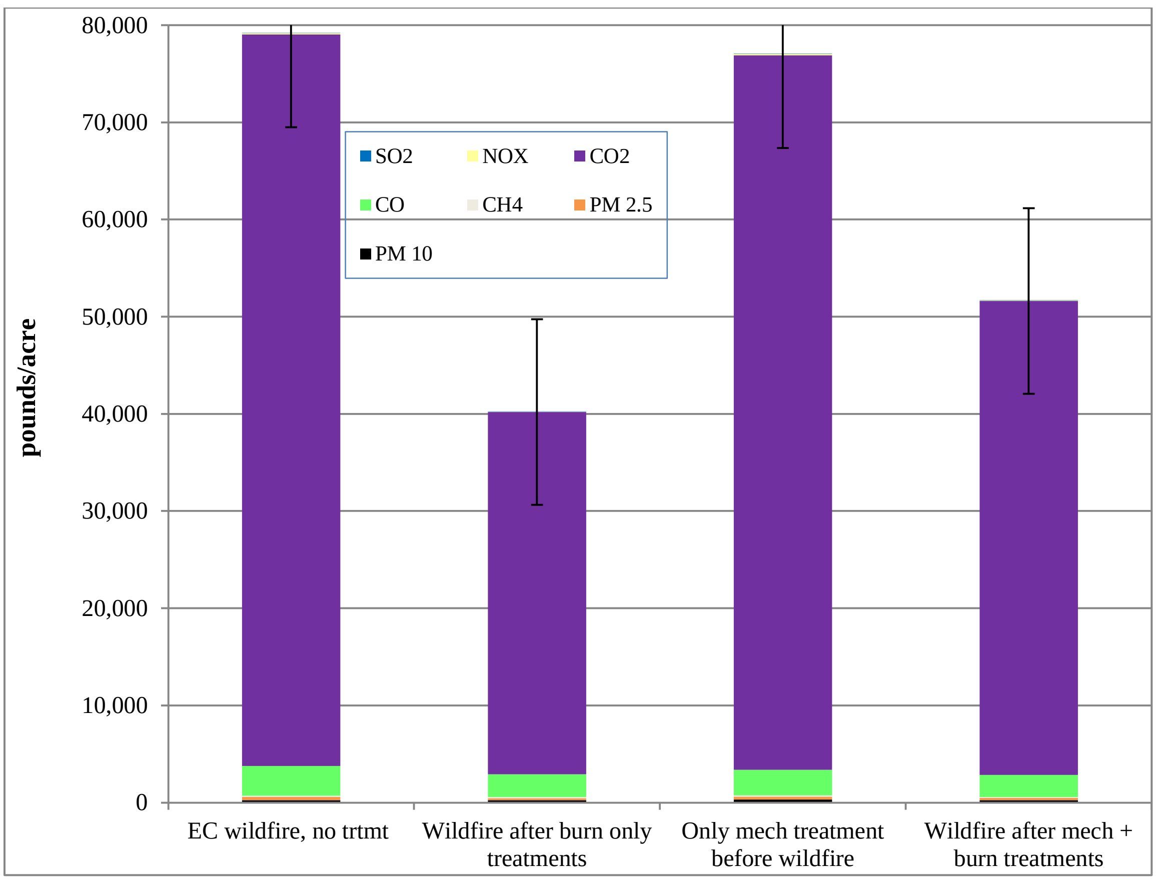


Figure 45. Emissions from surface fuels burning in wildfires after various treatments

Ecological effects of Smoke

Smoke has been shown to be a factor in the germination of many native plants (Abella et al., 2007, Abella 2009), and may be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1975, Zimmerman et al.1987). With no prescribed fire, the only smoke would come from wildfires. Population dynamics for species that depend on smoke for germination would depend on the chance of a wildfire burning though the area at a beneficial severity. The effects of smoke on tree health are less certain, but there would be no mitigating effects to mistletoe and other tree diseases.

Roads

There would be no change to the existing road condition under this Alternative Except for natural changes that occur to roads that were closed under the 2012 Travel Management Rule.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

As described above, with no treatment, there would be more and larger fires of higher severity than occurred historically, or than are sustainable on the landscape. In recent years, fires on the Mogollon Rim that have taken human lives, destroyed homes/property/infrastructure, and produced high severity effects across large areas not adapted to high severity fire including Rodeo/Chediski 2002 (469,000 acres), Wallow 2011 (538,000 acres), and Whitewater 2012 (~297,000 acres). Such fires permanently change tens of thousands of acres of forests when they burn with high severity in areas which are not adapted to high severity fire. There is broad consensus that such fires will continue to burn in this area if no action taken, though the specific extent and location of the negative effects could not be known until an incident occurs. First order effects would include (but are not limited to): chemical and physical changes to soil, high levels of mortality across ~30% or more of the burned area (assuming ~30% high severity), consumption and/or killing of the seed bank, consumption of organic material in soil, including flora and fauna, conversion of forested habitat to non-forested habitat. Second order fire effects would include (but are not limited to) erosion, flooding, debris flows, destroyed infrastructure, changes in visitation to the forest and the economies of local businesses that depend on visitors and degradation of water resources for wildlife and humans. Some of these effects would last just a few days or weeks (infrastructure would be rebuilt), some would take years to recover, some changes would be permanent. For example, topsoil is critical to healthy surface vegetation and would take centuries to recover though, with climate change, it is unknown exactly what the ecological trajectory would be. The loss of old growth and old trees would require decades to centuries to recover.

Effects common to all proposed prescribed fire treatments in all Action Alternatives

Fire is a natural process with which the ponderosa pine and associated ecosystems within the 4FRI project evolved. It will occur eventually as high or low severity fire, depending on the condition of the forest, and the environmental conditions at the time of the fire. Over 85% of the area burned in wildfires managed for suppression may be low-severity, producing multiple benefits to the ecosystem, producing less smoke than high severity fire in forested ecosystems (RAVG database accessed July 15, 2012). With fires managed for resource objectives, it can be 100% of the area. Prescribed fire can be used as a proxy for such fires, providing more control over where and when they occur. Most of the effects of the natural role of fire could not be effectively replicated means other than fire. These effects include nutrient recycling; seed scarification (by both heat and smoke); promotion of a mosaic of seedlings, shrubs, forbs, and grasses; regulating surface fuel loads, changes in soil moisture, changes to albedo, etc.. Within prescribed fire units, fire would contain the dominance of some species, while enhancing that of others (Pyke et al. 2010, Laughlin and Fulé 2008, Laughlin and Fulé 2011), such as *Ceanothus fendelerii*, *Robinia neomexicana*, legumes, aspen, *Penstemon* spp., C3/C4 grass distribution, and the mosaic of ponderosa pine. Benefits from prescribed fire are numerous and include a controlled reduction in both surface and canopy fuels which is needed across the treatment area. Over time, prudent use of prescribed burning, particularly when combined with mechanical thinning, would reduce the potential for damage from wildfires, as well as the costs associated with fire suppression (Jaworski 2014). Fire increases structural heterogeneity and diversity, creating mosaics within stands and over larger areas. Burning promotes natural regeneration of ponderosa pine, providing favorable seedbeds and enhancing the growing environment for survival (Harrington and Sackett 1992).

The effectiveness of using prescribed fire as a tool, alone or combined with mechanical means to restore ponderosa pine to a healthier, more sustainable and resilient conditions is well documented (Fulé et al. 2001b, Roccaforte et al. 2008, Strom and Fulé 2007, Fulé et al. 2012). In a systematic review of 54 studies with quantitative data, Fulé et al. (2012) found that:

- Canopy fuels and both fine and coarse surface fuels were significantly reduced relative to controls in burn-only treatments, though the conditions under which a burn is conducted affect the efficiency of a prescribed burn.
- Fine and coarse surface fuels significantly increased in thin-only treatments
- Surface fuels changed little in thin + burn treatments, but had a greater effect than either thinning alone or burning alone on reducing tree density, basal area, and canopy cover.

The proposed treatments would create a mosaic of interspaces and groups (of ponderosa pine) of various sizes that would be maintained with fire. This mosaic is also a mosaic of crown fire potential, with some groups having potential for crown fire under some circumstances, with the surrounding interspaces causing crown fire to transition back to surface fire.

Post-treatment conditions for the action alternatives would include openings that would be managed to promote regeneration. Prescribed fire would be an important tool for creating receptive seedbeds for successful regeneration by consuming surface fuels, creating bare, mineral soil, allowing seeds better contact with soil. As seedlings and small saplings mature, fire and competition would thin trees, maintaining the desired trajectory for a fire-adapted landscape, so that an appropriate number of seedlings survive to maintain healthy forest conditions.

The longevity of the effects of a prescribed fire depends on the specific effect being evaluated; the condition of the burned area before a burn; the conditions under which it burned, and post-treatment conditions (such as precipitation). For example, a denser forest will accumulate litter faster than a more open forest; soil conditions and moisture affect the rate of decay; the germination and survival of seedlings depends on cone production and environmental conditions for the first 2-3 years. Maintenance Return Intervals were described on page 37.

On the south rim of the Grand Canyon (adjacent to Restoration Unit 6), fire has been observed to burn with low severity, thinning regeneration and keeping the system open with significantly more than 20 years between fires where forest conditions are close to historic conditions (Fulé and Laughlin 2007).

In the long term, fire would help maintain a shifting, sustainable, resilient mosaic of groups, interspaces, and openings. Without regeneration openings, even with fire, the space occupied by incoming regeneration would begin to fill in the interspaces and, in the long run, as the seedlings mature, it would increase horizontal and vertical canopy continuity so that, if crown fire did initiate, there would be potential for larger areas of high severity effects.

First entry burns are those burns which are the first time fire occurs in an area that has missed several fire cycles (for the project area, this would be 10 – 20 years). In ponderosa pine and other Fire Regime 1 ecosystems, first entry burns:

- Consume or lethally scorch needles/scales/leaves on the lower branches of trees and shrubs, effectively raising the Canopy Base Height, decreasing Canopy Bulk Density, and decreasing the likelihood of crown fire initiation (direct effects) (Keyes and O’Hara 2002). May include burning activity fuels resulting from thinning.

- Consume/reduce a large portion of surface fuels, with the amount of dead/down woody fuels less than 3 inches in diameter consumed depending primarily on fuel moisture and environmental conditions at the time of the burn) (direct effects).

- Are likely to decrease rotten coarse woody debris and increase sound coarse woody debris in the short term (2-4 years) as some shrubs, branches, or small trees are killed (Waltz et al. 2003) (direct and indirect effects).

- Thin out some small trees, particularly seedlings, maintaining a mosaic of groups and interspaces (Figure 9, Figure 46) (direct effects). Those that survive are healthier because of reduced competition for resources, a flush of post-burn nutrients and, their lower branches/fuels are removed, making them more resistant to future fires.

Objectives in a first entry burn are usually related to consumption of accumulated surface fuels, raising canopy base height, decreasing canopy bulk density, and some group or single tree torching to reduce canopy closure (direct effects). When these are the primary objectives, the ideal timing for the burn may be different than the timing of prescribed fires intended as maintenance burns. In areas where fire has been excluded for many decades, a single prescribed fire is inadequate to reduce fuels (Lynch et al. 2000).

Second entry burns are those burns which occur within a few years of a first entry burn. For second entry burns, fuel loads would be significantly lower than in first entry burns, producing much less smoke and with lower potential for high severity fire. A second entry burn should occur after surface fuels have recovered sufficiently to produce fire behavior sufficient to meet burn objectives.

Figure 46. Seedlings and saplings that will become part of the fuel load for the next fire following this first entry burn in the project area.

Objectives of second entry burns are likely to relate to reducing the fuel loading as it has been augmented by the effects of the first entry burn. If a branch is alive following a burn, it will drop the scorched needles sooner; if the branch itself has been killed, the needles tend to be retained until removed by weathering (Ryan 1982). Scorched and blackened needles usually drop from the crown within one year of the fire. For a second entry burn, dead wood from seedlings and shrubs top-killed in the first entry burn are part of the fuel load (Figure 46). Dead needles from the lower branches have fallen to the ground and are now part of the surface fuel load (Figure 47).

Figure 47. Needle-fall from a first entry burn becomes fuel loading for a second entry

Maintenance burns in ponderosa pine generally begin with the 2nd or 3rd 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 10 – 15 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, etc. 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.

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). Figure 48 displays the number of fires by the month for which they were reported for those ranger districts on the Coconino and Kaibab National Forests which are included in the treatment area for 4FRI. Note: this shows the number of wildfires, not the acres burned. The number of fires is not analogous to the number of acres burned. Conditions from March through early July are often dry, hot and windy, so fires that escape initial attack are likely to burn more acres than fires that start during the monsoon season when rain is likely to extinguish or slow fires that are started.

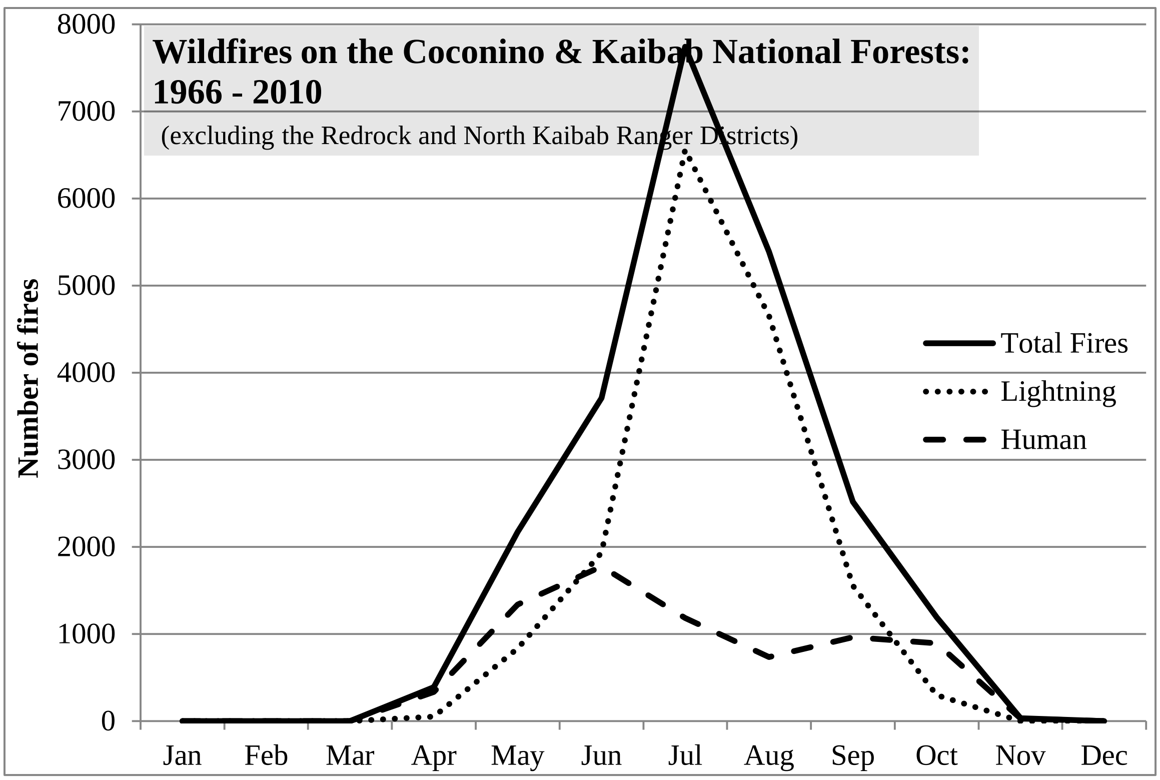


Figure 48. Number of fires within the treatment area

Large/old trees

Where site specific mitigation is needed to limit damage or mortality to large or old trees, it is best accomplished by reducing accumulations of fuels within the dripline and in the immediate vicinity of the trees. These fuels may include litter, duff, accumulations of woody fuels, ladder fuels, or any fuel that could produce sufficient heat to lethally damage a tree. This can be accomplished manually, mechanically, or though fire treatments. Potential measures include implementing prescription parameters, ignition techniques, raking, wetting, leafblowing, thinning, or otherwise mitigating fire impacts to the degree necessary to meet burn objectives. Throughout the life of this project, it is likely that some large and/or old trees would be damaged or killed by prescribed fire. It would not be possible to mitigate every large and/or old tree over 30,000 to

40,000 acres of prescribed fire units each year.

Crowning and Torching Indices

In response to public comments on the proposed action, an analysis was added to compare changes in crowning and torching indices for ponderosa forests where future management would include prescribed fire, and forests for which there are no treatments or fires beyond what is in the proposed actions.

Crowning and Torching indices are measures of how strong the wind must blow for crownfire to occur and are one indicator of the vulnerability of a forest to the high severity effects that result from crown fire (Fulé et al., 2012). The Torching Index (TI) indicates the wind speed at which crown fire could initiate. The Crowning Index (CI) indicates the wind speed at which a crown fire that has initiated could be sustained as an active crown fire. In a healthy ponderosa pine forest, both indices would be high, meaning that the forest can withstand high wind speeds without the occurrence of crown fire. Historically, frequent fires maintained that condition by regulating surface fuel loading (limiting fireline intensity/flame length), maintaining a mosaic of seedlings/saplings/shrubs (reducing ladder fuels and breaking up horizontal and vertical fuel structure), and maintaining canopy base heights that would make it unusual for crown fire to initiate, and very unusual for active crown fire to be sustained.

This analysis compares the modeled response of one of the most common stand conditions across the ponderosa pine in the project area following one thinning and two prescribed fires.

The modeling was done with the Forest Vegetation Simulator – Fire/Fuels Extension (FVS and FFE). In 2010, the stand show indices that would be expected from a stand that could support conditional crown fire (described on page 28) because the stand has a high canopy bulk density (0.11 kg/m3), high canopy closure (51%) and a low canopy base height (13). The surface would be shaded and/or has sufficient surface litter to suppress surface vegetation – including ladder fuels. In its 2010 condition, the stand can support crown fire if it moves into the stand as crown fire at a wind speed of 26 mph (Figure 50). It can support torching (torching is the same as passive crown fire) at a wind speed of 43 mph – the speed at which surface fire would burn with an intensity sufficient to produce flame lengths of at least 6.5 feet (1/2 the height of the canopy base height) (Figure 49). Following thinning in 2012, the crowning index jumps, because thinning breaks up the horizontal and vertical continuity of the canopy fuels. Conversely, the torching index decreases further, because the additional surface fuels resulting from thinning alone have increased the potential surface fire intensity. Prescribed fires in 2015 and 2019 increase both indice, raising canopy base height, decreasing surface fuels, and decreasing canopy bulk density. The largest increase is in the torching index which goes from 30, following thinning, to 83 following the second prescribed fire as canopy base height increases.

Following prescribed fire modeled in 2019, the indices remain statistically identical until the prescribed fire in 2029. At that point, both indices increase in the stand that had the prescribed fire, and both decrease in the stand without fire. For the next two burn cycles (2039 and 2049), the trend is for both indices to increase in the stand that is being ‘treated’ with prescribed fire, and decreases in the stand with no treatments. Regeneration is modeled to initiate following the prescribed fires in 2015 and 2019, but plays little role in these indices until it matures to a point that it plays a role as a ladder fuel, and the program adjusts canopy base height to show the effect. This regeneration ‘pulse’ is most obvious in 2040 where the TI drops precipitously to 15. The CI continues a slow, steady decrease as canopy fuels become more contiguous. Following the prescribed fire in 2019, the indices remain statistically identical until the prescribed burn in 2029.

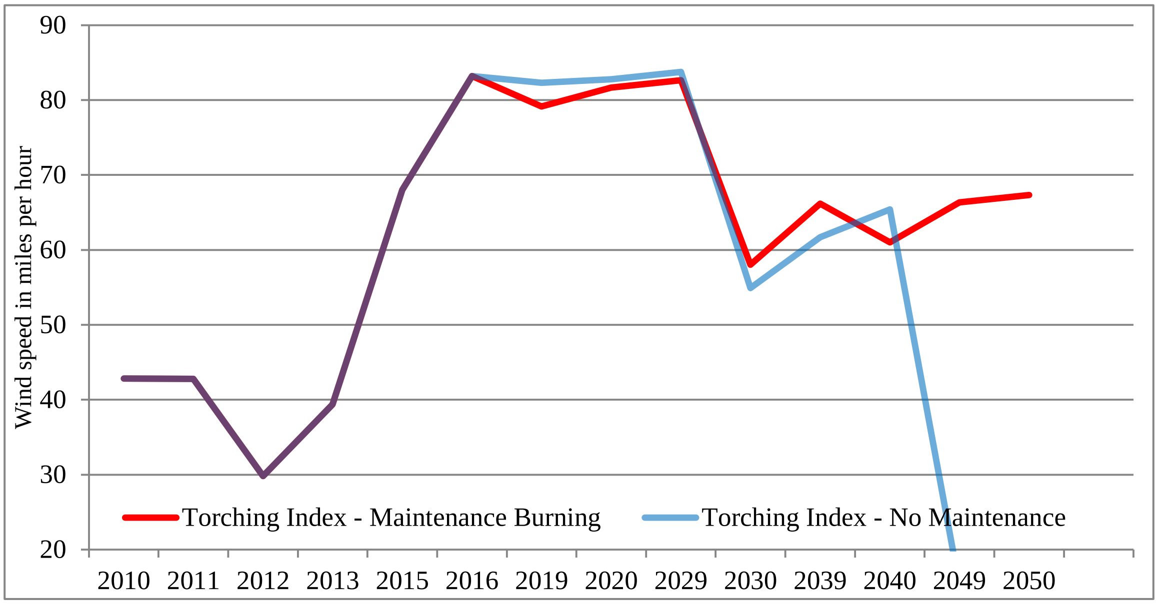


Figure 49. Torching indices comparing maintenance burning and no maintenance burns.

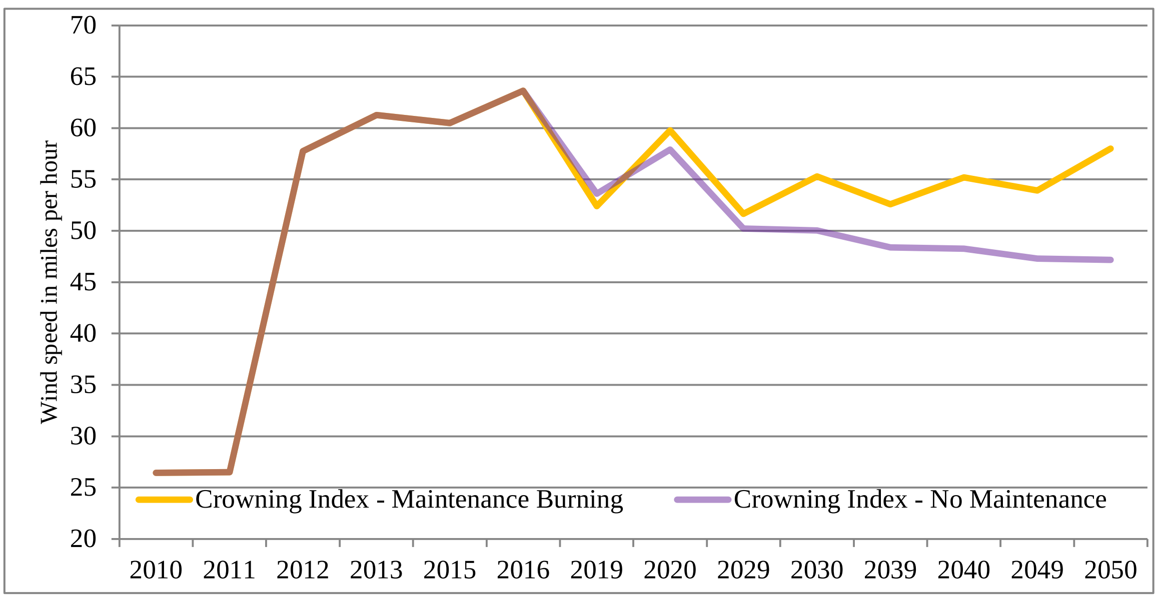


Figure 50 Crowning indices comparing maintenance burning and no maintenance burns.

Figure **50** and Figure 49 show the changes in TI and CI in a stand that was thinned in 2012, and had prescribed fires implemented in 2015 and 2019. Following 2019 the stand was modeled for; 1) no treatments of any kind and; 2) prescribed fires implemented every 10 years (2029, 2039, 2049). The effects of maintenance burning are clear to see in graphs for both indices, as well as the effects of no treatments.

Alternative B

From a fire ecology perspective, direct and indirect effects of Alternative B relate primarily to treatments that include mechanical thinning, prescribed fire, or both to meet the purpose and need of the 4FRI. This alternative proposes to conduct about 583,330 acres of restoration activities over about 10 years or until objectives are met. On average, 45,000 acres of vegetation would be mechanically treated annually. On average, 40 - 60,000 acres of prescribed fire would be implemented annually across the Forests (within the treatment area). Up to two prescribed fires[2][3] would be conducted on all acres proposed for burning over the 10-year period. Restoration activities would:

- Mechanically thin about 384,966 acres, including to 16-inch dbh within 18 MSO PACs.
- Implement prescribed fire on about 384,966 acres, including low-severity prescribed fire within 70 MSO PACs (excluding core areas).
- Utilize prescribed fire only (no mechanical treatments) on about 198,364 acres.
- Construct about 520 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed).
- Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no new permanent roads would be constructed). Of these miles, about 30 miles would be improved to allow for haul (primarily widening corners to improve turn radii) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.
- Decommission 726 miles of existing system and unauthorized roads on the Coconino NF.
- Decommission 134 miles of unauthorized roads on the Kaibab NF.
- Restore 74 springs and construct up to 4 miles of protective fencing.
- Restore 39 miles of ephemeral channels.
- Construct up to 82 miles of protective (aspen) fencing.
- Allocate/manage as old growth 40% of ponderosa pine and 77% of pinyon-juniper woodland on the Coconino NF and manage 35% of ponderosa pine and 58% of pinyon-juniper on the Kaibab NF.

Thinning, whether or not slash was removed from the site, would give managers more control of the amount and timing of emissions. As thinning and first-entry burns were completed, burn windows would expand for larger areas so more burning could occur when ventilation was good. Fewer and healthier trees, as a result of thinning and would be more fire resistant, and understory and surface vegetation would become established. With lower surface fuel loading, and canopy fuels adapted to fire, burn windows would be broader than for initial entry burns. Decision space

[3] A single prescribed fire may include burning piles and a follow-up broadcast burn. Prescribed fire would be implemented as indicated by monitoring data to augment wildfire acres, with the expectation that desired conditions would require a fire return interval of about 10 years.

for managing unplanned ignitions would expand as 4FRI (and other projects) are implemented. Up to two prescribed fires would be implemented, which may include pile burning months in advance of broadcast burns. Ideally, prescribed fires would occur on an average of every 10 years, depending on yearly fluctuations in climate/weather at different locations within the treatment area. Some areas will have had prescribed fire or wildfire within the last 10 – 15 years, so prescribed fires that are implemented would be maintenance burns. Limitations (wildlife concerns, smoke, funding, resource availability, etc.) may make it difficult to attain an average of a 10 year fire return interval across the proposed treatment area. Burning some areas on a slightly longer return interval may be acceptable (drier areas such as Tusayan) and/or may specifically be target to reduce smoke in sensitive receptors as mitigation for prescribed fires.

This alternative would meet direction in the Forest Service Manual 5100 (page 9) which includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. Objectives of fire management on lands managed by the USFS include:

1. Forest Service fire management activities shall always put human life as the single, overriding priority. The proposed actions of the 4FRI fully support incorporation of the highest standards for firefighter and public safety and are expected to improve and enhance the safety of the public as it relates to wildland fire.

2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement. 4FRI proposes to achieve restoration by restoring ecosystems within the treated area to a condition so that fire, when it occurs, would be beneficial to the ecosystems in which it burns without threatening lives, property, or resources. This would be achieved by fully integrating local industry, mechanical and fire prescriptive treatments, and providing for sustainable supplies of goods, services, and social values though implementation of appropriate fire management activities.

Forest Plan Amendments

Three non-significant forest plan amendments would be required on the Coconino NF to implement the proposed action:

- **Amendment 1** would add language to allow mechanical treatments up to 16-inch dbh to improve habitat structure (nesting and roosting habitat) in 18 MSO PACs. The amendment would remove language that limits PAC treatments in the recovery unit to 10% increments and language that requires the selection of an equal number of untreated PACs as controls. The amendment would remove language referencing monitoring (pre and post treatment, population, and habitat monitoring). Replacement language would defer final project design and monitoring to the FWS biological opinion specific to MSO for the project.

  The amendment, which is specific to restricted habitat in pine-oak, would allow for designating less than 10% of restricted habitat on the Coconino NF as target or threshold (i.e., future nesting and roosting habitat) based on the quality of the habitat. Definitions of target and threshold habitat would be added.

- **Amendment 2** would add the desired percentage of interspace within uneven-aged stands to facilitate restoration in goshawk habitat (excluding nest areas), add the interspace distance between tree groups, add language clarifying where canopy cover is and is not measured, allow 28,952 acres to be managed for an open reference condition, and add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.

- **Amendment 3** would remove the cultural resource standard that requires achieving a "no effect" determination and would add the words "or no adverse effect" to the remaining standard. In effect, management would strive to achieve a "no effect" or "no adverse effect" determination.

Effects of implementing plan amendments

Amendment 1 (Coconino NF): If amendment 1 is implemented, the resulting decreases in CBH, CBD, and CC would have the indirect effect of slightly decreasing crown fire potential for 18 MSO PACs that would receive mechanical treatments. An additional indirect effect would be to increase the ability of fire managers to implement prescribed fire within PACs because of decreased potential fire behavior. If amendment 1 is not implemented on the Coconino NF, 18 PACs (~10,000 acres) would retain the current forest structure placing them at high risk of high severity fire. Potential fire behavior would make it difficult to implement prescribed fire because of narrow burn windows (weather and fuel conditions that produce the desired fire effects and behavior). If prescribed fires were implemented adjacent to PACs, it is more likely that firelines (ground disturbance) would need to be created to avoid burning PACs. There would be little effect on emissions, except for slight decreases in emissions in the event of wildfire following mechanical treatments within the PACs, or increases in the event of wildfires in the PACs.

Amendment 2 (Coconino NF): If amendment 2 is implemented, it would allow 28,952 acres to be managed for an open reference condition. An indirect effect of managing for open conditions would be to have little potential for active crown fire, moving these acres towards the desired conditions. Open conditions would, in the long run, produce fewer emissions because of less litter and debris from trees, and greater herbaceous component to surface fuels, which is a flashier fuel, burning faster and more cleanly quickly than woody fuels. If amendment 2 is not implemented on the Coconino NF, some treatments could be implemented, but would not move these acres as far towards desired conditions as they would be under the amendment.

Amendment 3 (Coconino NF): If amendment 3 is implemented, it would allow fire to be used to meet objectives if it was determined to be the best tool. Additionally, it would allow all significant, or potentially significant inventoried sites that are not considered 'fire sensitive' to be included in burn units. If amendment 3 is not implemented, all significant, or potentially significant inventoried sites within burn units, regardless of if they are considered 'fire sensitive' or not, would be managed for 'no effect'.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative B are discussed in the following order:

1. Fire behavior is discussed at the treatment area scale
2. Potential fire type is discussed by vegetation type
3. Within Restoration Units and Subunits, fire type is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced by breaking up the vertical and horizontal continuity of canopy fuels, decreasing excessive surface fuel loads of litter and duff (all direct effects), and replacing them with the light, flashy fuels that would be stimulated by post-treatment conditions (second order effects). Wildfire behavior would benefit the ecosystems in which it burned, and would not threaten lives, resources, or infrastructure, except where they are near or downslope from wildlife habitat that could not be treated as intensively as the rest of the treatment area at this time. Air quality impacts (indirect effects) could increase some as prescribed fires are implemented.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to surface and canopy fuels, would remain lower than existing condition for about 37% of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by changes to canopy and surface fuels, would remain lower than existing condition for about 31% of the ponderosa pine in the treatment area. Air quality impacts could decrease some as the majority of the treatment area would be in maintenance burn mode, producing fewer emissions per acre. However, since there would be more acres burned, the number of days of air quality impacts could increase.

When analyzed at the scale of the treatment area, Alternative B would meet the purpose and need by moving the project area towards the desired condition of having potential for less than 10% crown fire as modeled under the conditions that produced the Schultz Fire (Table 49) crown fire. Table 49 displays modeled fire type for Alternative B across the entire treatment area. Non-burnable substrates constitute ~1% of the treatment area and were not included in the acres shown fire potential fire type.

Table 49. Modeled fire type for Alternative B and Existing Condition.

Modeled Fire type (% area)	Existing Condition	Alternative B
Surface fire	61	94
Passive crown fire	9	3
Active crown fire	28	2

A direct effect of implementing Alternative B, would be changes to the horizontal and vertical continuity of canopy fuels. As that continuity is broken up, an indirect effect would be decreased potential for crown fire from 37% of the treatment area to 5% of the treatment area, with potential for active crown fire decreasing from 28% to 2% (indirect effect). The amount of potential crown fire remaining after proposed treatments would be well within the historic ranges of ponderosa pine in this area. As illustrated by Figure 51, much of the remaining potential for active crown fire would be in Restoration Units 1 and 3. In most cases, it would occur in MSO and goshawk habitat (Table 50).

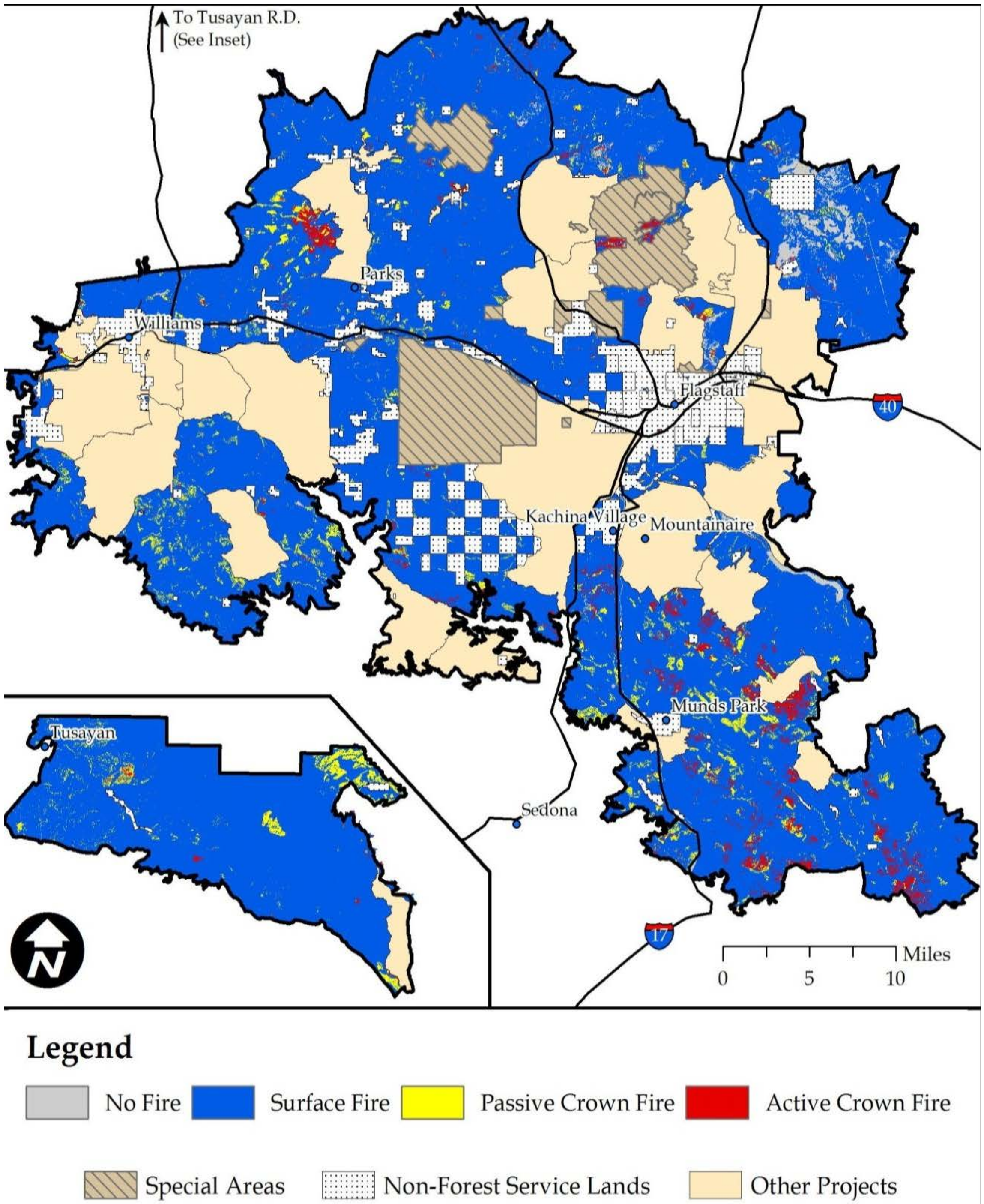


Figure 51. Modeled fire type for Alternative B, 2020

Ponderosa Pine

At the project area scale, ponderosa pine would meet desired conditions under Alternative B (<10% crown fire). When ponderosa pine is broken down by habitat type across the whole treatment area, at least 26% (9,298 acres) of protected habitat would have potential for crown fire (Table 50), and 8,483 acres of restricted habitat would have potential for passive crown fire.

Table 50. Modeled fire type by habitat/vegetation type for 2020, Alternative B.

Vegetation Type		Fire Type	Existing Conditions		Alt. B 2020	
			Acres	%	Acres	%
Ponderosa Pine*	**All Pine**	**Surface**	**311,313**	**61%**	**476,400**	**94%**
		Passive crown	**48,023**	**9%**	**17,303**	**3%**
		Active crown	**143,186**	**28%**	**8,846**	**2%**
	Protected	Surface	17,954	51%	25,803	73%
		Passive crown	3,034	9%	2,195	6%
		Active crown	14,106	40%	7,103	20%
	Target/ Threshold	Surface	4,275	49%	8,299	95%
		Passive crown	922	11%	44	1%
		Active crown	3,482	40%	143	4%
	Restricted	Surface	35,019	53%	57,785	87%
		Passive crown	6,540	10%	8,483	13%
		Active crown	24,756	37%	58	0%
	PFA/ dPFA	Surface	18,400	61%	27,521	92%
		Passive crown	2,903	10%	1,934	6%
		Active crown	8,560	29%	402	1%
	LOPFA	Surface	235,666	64%	356,993	97%
		Passive crown	34,624	9%	4,648	1%
		Active crown	92,282	25%	950	0%
Other Vegetation*	Aspen	Surface	1,120	74%	1,192	78%
		Passive crown	135	9%	248	16%
		Active crown	258	17%	73	5%
	Grassland	Surface	41,491	86%	41,577	86%
		Passive crown	3,059	6%	2,954	6%
		Active crown	1,153	2%	1,110	2%
	Juniper Woodland	Surface	1,941	83%	2,335	100%
		Passive crown	74	3%	2	0%
		Active crown	320	14%	0	0%
	Oak Woodland	Surface	2,504	77%	3,231	99%
		Passive crown	266	8%	1	0%
		Active crown	466	14%	6	0%
	Pinyon/Juniper	Surface	19,379	83%	22,571	97%
		Passive crown	1,523	7%	346	1%
		Active crown	2,047	9%	45	0%

* Nonburnable substrate constitutes <1% of all ponderosa pine and about 1% of the entire treatment area

Restricted habitat generally includes Gambel oak, which is likely what would provide the ladder fuels for passive crown fire. Decreasing the horizontal and vertical continuity of canopy fuels is a direct effect of the proposed treatments that would allow sunlight to reach the surface, increasing surface temperatures, and decreasing dead fuel moisture content at the surface. This, combined with increased surface winds with fewer trees blocking the wind, could increase surface fire intensity, flame length, and rate of spread even if surface fuels were the same before and after thinning (Omi and Martinson 2004, Scott 2003). Therefore, canopy fuel treatments reduce the potential for crown fire (indirect effect) at the expense of slightly increased surface fire behavior (fireline intensity, flame length, and rate of spread). However, critical levels of fire behavior (limits of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires, as all crown fires are uncontrollable. Although surface intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally more controllable (Scott 2003). After the first prescribed fire, surface fuels would be lower so, even with the changes described above, the potential fire behavior and effects would be improved following the treatments under Alternative B.

Pine/Sage

A direct effect of thinning the pine on 5,261 of the 16,064 acres with potential for pine/sage would be decreased shading of the surface vegetation, including sage. Other direct effects of prescribed fire in ponderosa pine include, thinning of seedlings and some saplings, and consumption of surface fuels. Indirect effects of prescribed fire would be the maintenance of a mosaic of sage, other shrubs, and herbaceous vegetation at the surface by consuming decadent woody shrub debris, nutrient recycling, and providing the mineral soil seedbed preferred for sage regeneration by seed. Some shrubs would sprout in the years following a fire, further maintaining a multi-aged stands of shrubs, and a shifting mosaic of shrubs and herbaceous vegetation.

Large/old trees

Mechanical treatments and prescribed fire would be implemented to help sustain large/old trees across the landscape, and make them more resistant and resilient to natural disturbances such as fire. Throughout the life of this project, it is likely that some large and/or old trees may be damaged or killed by prescribed fire, by direct and/or indirect effects, despite mitigation measures. However, under this alternative thinning and prescribed fire would decrease potential fire effects in the vicinity of most old and/or large trees, decreasing the likelihood of lethal damage in the event of a wildfire. Under Alternative B, the potential for fire-related mortality of large and/or old trees would be reduced across the landscape. Ignition techniques or other mitigations would be employed to minimize residence time in duff adjacent to old trees whenever possible. Under this alternative, low severity fire would be used in the vicinity of old trees and, to the degree it is practicable, ladder fuels and excessive surface fuel buildups adjacent to old trees would be removed before burning. Scorch is one of the primary factors in large and old tree mortality (Jerman et al. 2004), and is influenced by the vertical arrangement of fuels. Prescribed fire and mechanical treatments in the vicinity of old and/or large trees would decrease fuel loading in the immediate vicinity of these trees, decreasing the potential for crown scorch.

Mitigation measures (page 227) are unpredictable, and site specific (Kolb et al. 2007, Hood 2007), and some can have negative effects of their own. Raking, for example, can remove fine, live roots in the surface organic layers, which may compound the effects of additional shallow roots being damaged by fire, though it is unlikely to actually kill the tree. Low intensity fire that causes little crown scorch can stimulate resin production in old trees that may attract bark beetles, increasing tree mortality. Mitigation measures implemented a year or more before a burn, such as thinning or raking, may improve the health of the tree, improving its response to fire.

Aspen

Fire and mechanical thinning are proposed for 1,227 acres of aspen under Alternative B. The most common effect of fire on aspen is to sucker as an indirect response to fire, regardless of the fire type. A direct effect of implementing Alternative B would be decreased fuel loading in decadent aspen stands, where some aspen stands had over 40 tons/acre of CWD. An indirect effect of Alternative B is the reduction of active crown fire potential to 5%, while increasing passive crown fire to 16% and an increase to 78% surface fire. Many stands in the project area are stressed, but are still likely to respond to a low severity fire by suckering, though the timing of a fire would be important, with fall fires likely to be more beneficial. Where encroaching conifers are cut out of aspen and prescribed fires are implemented, the expected result would be a decrease in decadent, unhealthy stems and an increase in suckering. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, allowing some sprouting and the survival of some large stems. Decadent stems would either be partially consumed or topkilled by fire. The death of mature aspen stems, by fire (direct effect) would not in itself cause for alarm because of the natural ability of aspen roots to readily regenerate after death of the overstory trees, though there would likely be a shift in the ratio of large stems to suckers. The decreased albedo of the soil surface (indirect effect), decreased shad, and the flush of nutrients would contribute the suckering for the first growing season, allowing the new sprouts to grow tall fast enough to compete with herbaceous vegetation, most of which would also be rejuvenated.

The suckers would be at risk of browsing from ungulates which would be attracted by the new growth so fencing or other deterrents would be implemented where possible to minimize access by ungulates. Under Alternative B, up to 82 miles of fencing or other deterrent would be implemented to protect aspen from browsing ungulates. If jackstrawing was employed, it would increase the resistance to control of fires burning in jackstrawed areas, and could limit access to fires in the vicinity. If prescribed fire was implemented in a stand where jackstrawing has been completed, objectives for the stand and the burn would have to be carefully assessed to determine what fire behavior is appropriate and safe for meeting both control and resource objectives. Surface fire effects, should the jackstrawing burn under conditions that allow fire to consume most of it at once (wildfire), would be high or very high severity to vegetation and soil in the immediate vicinity.

Fire is a valuable tool that would be used to help regenerate aspen clones, and would be particularly effective when combined with mechanical treatment where the degree of conifer encroachment is too high to be managed with fire alone (Strand 2009, Jones and DeByle 1985). Although pure aspen stands usually do not burn well, those with enough fuel to carry a fire would be expected to respond well to treatments (Shepperd 1986).

Gambel Oak

Within the project area, fire is a keystone process with which the habitat for the northern goshawk and Mexican spotted owl evolved. Fire, along with bunch grass competition, helps keep pine from out-competing Gambel oak (Abella 2008, Reynolds et al. 1992), an important forage plant for many wildlife species. Fire is a recommended management tool for improving goshawk habitat, and fire suppression is credited with degrading goshawk habitat by changing forest structure and composition (Reynolds et al. 1992).

Fire of any kind is unlikely to eliminate Gambel oak from a site. High severity wildfires that remove competing vegetation often facilitate development of oak brushfields on sites formerly dominated by ponderosa pine (Abella and Fulé 2008), but low severity surface fire is likely to benefit Gambel oak.

The thinning of ponderosa pine stems in areas dominated by Gambel oak, combined with decreased canopy fuels from prescribed burning (decreased CBD and CC) would decrease shading from ponderosa pine (direct effect) which has been, in part, responsible for the decline of larger diameter oak (>6"dbh). It is likely that there would be some mortality in large diameter oak from prescribed fire (direct effects), particularly in first entry burns in areas where fire has been removed from the system for 20 years or more but, in general, prescribed fires would be low severity and, to the degree it is practical, mitigations would be implemented to minimize negative impacts to larger diameter oak (see design features, page 369).

Direct effects would include some small and medium diameter oak being topkilled by fire, but few oak stems greater than 6 inches would be expected to be topkilled by prescribed fire (Abella, 2008b). The immediate result would be a decrease in small diameter oak (less than 2"), but oak sprout following low severity burns so, after 2-4 years, the result would be an increase in small diameter oak stems from prolific sprouting (Harrington 1985). Burning oak with a return interval of less than 10 years on most sites, with summer burns when possible, would move oak towards presettlement conditions (Fulé et al. 1997a, Fulé et al. 2005), with more larger diameter oak, and fewer small diameter. The overall effect of Alternative B on Gambel oak would be a shift in the ratio of small to large diameter oak as very few large ones are killed, but small ones increase. In the long term, the decreased risk of high intensity and/or high severity fire would benefit Gambel oak by decreasing the potential for fire to topkill large stems.

Overall, the effects to Gambel oak under Alternative B would be beneficial and, at the scale of the treatment area, would shift the potential for crown fire in the oak woodlands from 22% (732 acres), of which 14% (466 acres) is active crown fire, to 7% (7 acres), of which 6 acres would be active crown fire. Oak is a component of restricted habitat within the ponderosa pine type.

Grasslands

Alternative B proposes to implement prescribed fire on 48,423 acres of grassland vegetation. However, it is Operational Burn only, so these acres would only be burned if/as needed to facilitate burning in pine and aspen. If all the Operational Burns analyzed were implemented, prescribed fires would benefit the grasslands by decreasing woody encroachment, and decreasing the potential for crown fire by a little over 100 acres (Table 50).

On those acres with potential for active crown fire (1,110 acres), there could be undesirable fire behavior and effects, such as high burn severity (detrimental soil effects), including killing the existing seed bank, consuming organic soil matter, and potentially giving invasive plant species a foothold.

Ponderosa pine encroachment into grassland areas has been in progress for so long that on at least 3,346 acres, trees are too large for fire to be an effective thinning tool. While the first fire or two may kill some trees and reduce the potential for crown fire, they also significantly increase the resistance of the trees from future fires by consuming or killing fine fuels (needles) on the lower branches so heat from subsequent fires does no additional damage. That would render the trees effectively fireproof. Mechanically cutting larger trees would allow fire to remove the smaller ones, in addition to resuming other natural roles of fire in grasslands (recycling nutrients, killing some pathogens, scarifying seeds, etc.). Grasslands would benefit from wildfire or prescribed fire because, where fuels are herbaceous, even under extreme conditions, fire would be beneficial to the system.

Restoration Unit 4 has almost twice the acres of grasslands than the other RUs, which includes Government Prairie (Table 51). Passive crownfire in all RUs is likely to be beneficial, while active crown fire is likely to produce some undesired effects. Under Alternative B, grasslands would not meet desired conditions for fire type in any of the grasslands.

Fire effects in grasslands would include:

- Killing woody encroachment, particularly ponderosa pine (direct effect)
- Rejuvenating ‘wolfy’ grasses and decadent shrubs (indirect effect)
- Scarifying seeds with smoke and/or heat (direct effect – the germination of these seeds would be an indirect effect)
- Recycling nutrients (indirect)

Table 51. Modeled fire type in grasslands by Restoration Unit for Alternative B

RU	Fire Type	Grassland acres*	Existing		Alt. B 2020	
			Acres	%	Acres	%
RU1	Surface	8,135	6,131	75%	6,168	76%
	Passive crown		1,340	16%	1,305	16%
	Active crown		236	3%	233	3%
RU3	Surface	12,772	11,670	91%	11,710	92%
	Passive crown		706	6%	678	5%
	Active crown		167	1%	170	1%
RU4	Surface	22,661	21,080	93%	21,089	93%
	Passive crown		788	3%	749	3%
	Active crown		645	3%	601	3%
RU5	Surface	4,536	2,521	56%	2,521	56%
	Passive crown		222	5%	219	5%
	Active crown		105	2%	105	2%
RU6	Surface	93	89	96%	89	96%
	Passive crown		2	2%	3	3%
	Active crown		1	1%	1	1%

*Nonburnable substrate constitutes about 5% of grassland areas within the treatment area in Alternative B

Pinyon/Juniper Woodland (PJ)

Pinyon/Juniper (PJ) is not a candidate for restoration under the 4FRI. There are 535 acres that are being mechanically treated in RU6 with a fuels reduction objective, and 25,117 acres that are being included under ‘Operational Burn’, with the objective of facilitating prescribed fire in ponderosa pine or grasslands as needed. The objective if they are burned would be to use a fire that would produce low severity effects sufficient to provide a ‘black-line’ for the associated Restoration Unit. An occasional tree may torch, that is the nature of PJ, but it would be isolated and it would be the exception. As modeled, potential fire crown fire in all PJ would be decreased (Table 52) by 15%. Potential crown fire in the area of RU6 being treated with fuels reduction objectives would reduce crown fire by 2%, virtually eliminating it (Table 53).

In the ~25,000 acres of PJ that could have operational burning only, direct effects would be expected to be minimal, with maximum fire behavior being scattered torching on less than 400 acres out of ~25,000. Huffman et al. (2009) found that prescribed fire in Pinyon/Juniper, when implemented by hand crews, produced few significant reductions in hazardous fuel loads. Fuel reduction by fire alone would require more extreme weather conditions and fire behavior than are normally used for prescribed fire because the natural fire regime of much of the PJ in the project area is for small, high severity fires. Broadening the range of acceptable weather and fire behavior increases the risk of fire escape. A burn-only approach is likely to be unsuitable for pinyon/juniper projects in the wildland–urban interface which is where the units of PJ fuels reduction in the treatment area are located.

Table 52. Modeled fire type in all Pinyon/Juniper under Alternative B.

	Fire Type	Existing Condition %/Acres	Alt. B 2020 %/Acres
Pinyon/ Juniper	No fire	348/1.5	354/1.5
	Surface fire	83/19,379	97/22,571
	Passive crown fire	7/1,523	1/346
	Active crown fire	9/2,047	0/45

Table 53. Modeled fire type in the Pinyon Juniper in Restoration Unit 6

	Fire Type	Existing Condition %/Acres	Alt. B 2020 %/Acres
Pinyon/Juniper	No fire	0/<.1	0/<0.1
	Surface fire	67/1,472	85/1,877
	Passive crown fire	23/504	15/329
	Active crown fire	10/229	0/0

Restoration Units

At the scale of the Restoration Unit, Alternative B would meet desired conditions for fire type. Post-treatment potential for crown fire ranges from 2% in RU5 to 8% in RU1 (Table 54). ”No fire” includes water, rock, roads, cinders, areas of sparse vegetation, and other acres on which there were insufficient fuels to carry fire under the conditions modeled. These acres range from 44 acres (0.11%) in RU6 to 5,736 acres (7.84%) in RU5.

Table 54. Modeled fire type for Alternative B by Restoration Unit.

		Fire Acres			Fire %		
	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	Surface Fire	Passive Crown Fire	Active Crown Fire
Alt. B (2020)	RU 1	140,266	6,650	6,550	91%	4%	4%
	RU 3	139,502	7,551	1,767	93%	5%	1%
	RU 4	160,272	3,688	1,041	97%	2%	1%
	RU 5	65,806	1,048	613	90%	1%	1%
	RU 6	41,460	1,919	106	95%	4%	0%
	Total	**547,306**	**20,855**	**10,079**	**93%**	**4%**	**2%**

Restoration Unit 1

Restoration Unit 1 is of particular concern because the Lake Mary watershed is a source of water for the city of Flagstaff, as well as being a popular recreation site. There is also an observatory just north of Lower Lake Mary, and Walnut Canyon National Monument is adjacent to the treatment area. There would be adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer adjacent to the treatment area. However, potential fire behavior adjacent to these areas would be reduced from existing conditions. Under Alternative B, potential fire behavior would decrease, reducing the chance of fire spreading into the mixed conifer upslope and adjacent to the treatment area on Mormon Mountain. It would also decrease the risk of fire to the city of Flagstaff to the northwest. Under Alternative B, RU1 would meet desired conditions for fire behavior except for grasslands (Table 55).

Table 55. Modeled fire type by vegetation and habitat for Restoration Unit 1.

RU 1 acres =		154,383	Veg type acres	2010		Alt. B 2020	
Vegetation Type		Type		Acres	%VT	Acres	%VT
Ponderosa Pine*	**All Pine**	**Surface**	**144,113**	**80,257**	**56%**	**132,184**	**92%**
		Passive		**15,784**	**11%**	**5,260**	**4%**
		Active		**47,553**	**33%**	**6,214**	**4%**
	Protected	Surface	29,052	15,020	52%	21,146	73%
		Passive		2,246	8%	1,929	7%
		Active		11,728	40%	5,919	20%
	Target/ Threshold	Surface	4,793	2,236	47%	4,559	95%
		Passive		504	11%	16	0%
		Active		2,042	43%	206	4%
	Restricted	Surface	25,710	12,731	50%	22,533	88%
		Passive		2,601	10%	3,146	12%
		Active		10,348	40%	6	0%
	PFA/ dPFA	Surface	4,670	2,594	56%	4,595	98%
		Passive		518	11%	61	1%
		Active		1,558	33%	13	0%
	LOPFA	Surface	79,889	47,676	60%	79,350	99%
		Passive		9,915	12%	108	0%
		Active		21,877	27%	71	0%
Other Vegetation*	Aspen	Surface	420	241	57%	272	65%
		Passive		40	9%	76	18%
		Active		140	33%	72	17%
	Grassland	Surface	8,135	6,131	75%	6,168	76%
		Passive		1,340	16%	1,305	16%
		Active		236	3%	233	3%
	Juniper Woodland	Surface	286	236	83%	286	100%
		Passive		12	4%	0	0%
		Active		38	13%	0	0%
	Oak Woodland	Surface	287	195	68%	280	98%
		Passive		62	21%	1	0%
		Active		30	11%	6	2%
	Pinyon/ Juniper	Surface	1,141	897	79%	1,076	94%
		Passive		115	10%	7	1%
		Active		95	8%	25	2%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment unit within RU1

Ponderosa pine occupies 144,113 acres of RU1, more than the other Restoration Units. Modeled post-treatment conditions indicate that 8% (11,474 acres) of the pine would have potential for crown fire, with 4% (6,214 acres) of it being active crown fire (Table 55).

Overall, the ponderosa pine vegetation type in RU1 would meet desired conditions for fire behavior. However, post-treatment conditions for protected habitat show 27% (7,848 acres) would have potential for crown fire, 20% (5,711 acres) of which would be active crown fire. Restoration Unit 1 has the most PACs of any RU, including all, or parts of 35 PACs. Over 54% of all crown fire in ponderosa pine is in MSO or goshawk habitat (not counting Landscapes outside of PFAs). About 46% of the active crown fire in the ponderosa pine in RU1 would be in protected or restricted habitat.

Aspen occupy 420 acres in RU1, of which 72 acres (17%) would have potential for crown fire under modeled conditions. Alternative B proposes one burn in aspen stands by 2020. This would be low to moderate severity fire, benefiting the aspen by consuming accumulations of litter, some CWD, and killing conifer seedlings/saplings encroaching into the stands. Additional effects expected are described on page 148.

Grasslands would have potential for crown fire on 1,154 acres (14%) of grassland in RU1. Fire would decrease woody encroachment (Table **56**). In the 233 acres (3%) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects. Treatments proposed in Alternative B would move the grasslands towards desired conditions, modeled post-treatment fire type. Additional effects expected are described on page150.

Oak woodlands occupy 287 acres of RU1. Potential for crown fire in oak woodlands under Alternative B would decrease to 2%, with 2% (7 acres) being active crown fire. In the short run it would increase sprouting and small-diameter stems. Additional effects are described on page 149.

Pinyon/Juniper woodlands occupy 1,427 acres in RU1. Crown fire potential in Pinyon/Juniper woodland would decrease by 226 acres. Pinyon/Juniper in RU1 is Operational Burning, but the effects of these burns would be beneficial. Additional effects are described on page 151.

Subunits

Subunit 1-1 includes Walnut Canyon, is adjacent to Flagstaff and the Pulliam Airport, and is the closest subunit in RU1 to the city of Flagstaff. Following treatments, there is potential for 3% (308 acres) of crown fire, though most of it is passive crown fire (Table **56**).

Table 56. Modeled fire type for the Subunits in RU1 under Alternative B.

		Fire Type (acres)				Fire Type (%)			
Alternative B	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
1-1	**10,170**	**158**	**9,676**	**289**	**47**	**2%**	**95%**	**3%**	**0%**
Ponderosa Pine	8,914	111	8,709	92	2	1%	98%	1%	0%
Grassland	567	13	315	194	45	2%	56%	34%	8%
Oak Woodland	173	0	173	0	0	0%	100%	0%	0%
Pinyon-Juniper	515	33	479	3	0	6%	93%	1%	0%
1-2	**8,054**	**61**	**7,741**	**232**	**20**	**1%**	**96%**	**3%**	**0%**
Ponderosa Pine	6,517	24	6,353	140	0	<1%	97%	2%	0%
Grassland	1,537	37	1,388	92	20	2%	90%	6%	<2%
1-3	**39,791**	**425**	**36,189**	**1,533**	**1,643**	**1%**	**91%**	**4%**	**4%**
Ponderosa Pine	36,461	103	33,821	1,020	1,517	0%	93%	3%	4%

Aspen	88	0	33	16	39	0%	37%	18%	45%
Grassland	3,241	322	2,336	498	87	10%	72%	15%	3%
1-4	**18,250**	**16**	**17,467**	**197**	**571**	**0%**	**96%**	**1%**	**3%**
Ponderosa Pine	17,285	6	16,631	103	546	0%	96%	1%	3%
Grassland	519	10	409	92	9	2%	79%	18%	<2%
Oak Woodland	83	0	75	1	6	0%	91%	2%	7%
Pinyon-Juniper	363	0	351	2	11	0%	97%	0%	3%
1-5	**78,119**	**258**	**69,193**	**4,398**	**4,269**	**0%**	**89%**	**6%**	**5%**
Ponderosa Pine	74,936	211	66,671	3,905	4,149	0%	89%	5%	6%
Aspen	332	0	239	61	33	0%	72%	18%	10%
Grassland	2,270	47	1,720	430	73	2%	76%	19%	3%
Juniper Woodland	286	0	286	0	0	0%	100%	0%	0%
Oak Woodland	32	0	32	0	0	0%	100%	0%	0%
Pinyon-Juniper	262	0	246	3	14	0%	94%	1%	5%

Active crown fire would only account for 45 acres, and would be scattered. Subunit 1-3 includes the Lake Mary basin, a source watershed for the town of Flagstaff. Under Alternative B, 8% of it would have potential for crown fire, 4% of which would be active crown fire. The majority of the active crown fire in Subunit 1-3 is on the south and west sides of the Subunit, furthest away from the lakes in PACs. The potential for crown fire is decreased in Subunits 1-4 to 4% and 1-5 to 11%. Almost all of the active crown fire is in PACs, with passive crown fire scattered throughout the units. Alternative B would meet desired behavior for all Subunits in RU1.

Under Alternative B, grasslands would meet desired conditions in Subunits 1-2, 1-3, 1-4, and 1-5. They would not meet desired conditions in SU1-1, with potential for 42% of the grasslands having potential for crownfire, 8% of which (194 acres) would be active crown fire. The passive crown fire would be beneficial for the grasslands, but decreasing encroaching trees.

Restoration Unit 3

Winds on the Mogollon Rim, particularly during the fire season, are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. To the north and east, Interstates 40 and 17 are adjacent to RU3, so that smoke from wildfires would have potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, and Williams. Other adjacency concerns for fire behavior include Flagstaff at the top right of the RU, Kachina Village, and Oak Creek and Sycamore Canyons. Under Alternative B, the potential for undesirable fire behavior and effects in Restoration Unit 3 would be reduced sufficiently to meet desired conditions (<10% potential for crown fire). Crown fire potential is reduced to 6% of the treatment area (9,318 acres) with 1% being active crown fire (1,767 acres). There would still be potential for active crown fire in PACs in Kelly Canyon and Pumphouse Wash, including potential for some active and passive crown fire on slopes greater than 30 and 40 percent. Passive crown fire is scattered across the RU.

Ponderosa pine occupies 129,226 acres in RU3. Following proposed treatments, 6% (8,362 acres) would have potential for crown fire, and 1% (1,586 acres) would be active crown fire. MSO protected habitat would account for 1,066 acres of the active crown fire, about 68% of the crown fire in ponderosa pine in RU3 (Table 57).

Aspen occupies 201 acres of RU1. Seventy-six acres (38%) would have potential for crown fire, all of which would be passive crown fire. Effects would be as described on page 148.

Grasslands would have potential for crown fire on 848 acres (6%) of grassland in RU3, the fire would decrease woody encroachment. In the 170 acres (0%) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects. Treatments proposed in Alternative B would move the grasslands towards desired conditions in RU3. Additional expected effects would be as described on page 150.

Table 57. Modeled fire type by vegetation and habitat for Restoration Unit 3.

RU 3 acres =		149,715		2010		Alt. B 2020	
Vegetation Type (VT)		Type	VT acres	Acres	%VT	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	Surface	129,226	72,776	56%	120,198	93%
		Passive		12,594	10%	6,779	5%
		Active		43,256	33%	1,583	1%
	Protected	Surface	4,793	2,020	42%	3,399	71%
		Passive		611	13%	249	5%
		Active		2,076	43%	1,066	22%
	Target/ Threshold	Surface	3,899	3,899	2,039	52%	96%
		Passive		2,039	481	11%	1%
		Active		418	1,440	37%	3%
	Restricted	Surface	38,527	21,085	55%	33,268	86%
		Passive		3,672	10%	5,144	13%
		Active		13,704	36%	52	0%
	PFA/ dPFA	Surface	5,582	2,948	53%	4,951	89%
		Passive		605	11%	507	9%
		Active		2,026	36%	123	2%
	LOPFA	Surface	76,424	44,683	58%	74,840	98%
		Passive		7,288	10%	851	1%
		Active		24,010	31%	215	0%
Other Vegetation*	Aspen	Surface	201	144	72%	125	62%
		Passive		40	20%	76	38%
		Active		16	8%	0	0%
	Grassland	Surface	12,772	11,670	91%	11,710	92%
		Passive		706	6%	678	5%
		Active		167	1%	170	1%
	Juniper Woodland	Surface	1,851	1,559	84%	1,848	100%
		Passive		49	3%	0	0%
		Active		240	13%	0	0%
	Oak Woodland	Surface	1,633	1,282	79%	1,626	100%
		Passive		75	5%	0	0%
		Active		269	16%	0	0%
	Pinyon/ Juniper	Surface	4,033	3,351	83%	3,994	99%
		Passive		175	4%	18	0%
		Active		501	12%	15	0%

* Nonburnable substrate constitutes <1% in ponderosa pine, and <1% for the entire treatment area within RU3

Oak woodlands occupy 1,633 acres of RU3. There would be no potential for crown fire in oak woodlands under Alternative B under conditions modeled. Additional expected effects are as described on page 149.

Pinyon/juniper woodlands occupy 4,033 acres in RU3. Crown fire potential in Pinyon/Juniper woodland would decrease to 33 acres (down from 676 acres in the existing condition). Pinyon/Juniper in RU3 is all Operational Burning, but would benefit from the prescribed fires that would be implemented. Additional expected effects would be as described on page 151.

Subunits

Crown fire potential in all subunits in RU3 (Table 58) would meet desired conditions for fire type, ranging from 4% in SU 3-2 (1,150 acres) to 8% in SUs 3-4 (712 acres) and 9% in 3-5 (3,222 acres).

Table 58. Modeled fire type in RU3 subunits, Alternative B. Shaded cells would not meet desired conditions.

Alternative B	Acres	Fire Type (acres)				Fire Type (%)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
3-1	**23,145**	**58**	**21,591**	**1,438**	**57**	**<1%**	**93%**	**6%**	**0%**
Ponderosa Pine	18,805	39	17,373	1,345	48	<1%	92%	7%	0%
Aspen	91	0	51	40	0	0%	56%	44%	0%
Grassland	590	14	513	54	10	2%	87%	9%	2%
Juniper Woodland	907	1	907	0	0	0%	100%	0%	0%
Oak Woodland	845	1	844	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,908	4	1,904	0	0	0%	100%	0%	0%
3-2	**32,726**	**276**	**31,301**	**971**	**179**	**<1%**	**96%**	**3%**	**1%**
Ponderosa Pine	22,885	133	21,858	770	125	<1%	96%	3%	1%
Aspen	59	0	37	22	0	0%	62%	38%	0%
Grassland	9,611	143	9,235	179	54	1%	96%	2%	1%
Oak Woodland	172	0	172	0	0	0%	100%	0%	0%
3-3	**48,434**	**75**	**45,620**	**2,353**	**385**	**0%**	**94%**	**5%**	**1%**
Ponderosa Pine	44,426	59	41,841	2,187	341	0%	94%	5%	1%
Aspen	50	0	36	14	0	0%	71%	29%	0%
Grassland	1,353	6	1,149	152	45	<1%	85%	11%	3%
Juniper Woodland	873	2	871	0	0	0%	100%	0%	0%
Oak Woodland	232	5	226	0	0	2%	98%	0%	0%
Pinyon-Juniper	1,500	3	1,497	0	0	0%	100%	0%	0%
3-4	**9,019**	**230**	**8,077**	**297**	**415**	**<3%**	**90%**	**3%**	**5%**
Ponderosa Pine	8,920	216	8,030	268	406	2%	90%	3%	5%
Grassland	99	13	47	29	10	14%	44%	29%	10%
Oak Woodland	0	0	0	0	0	0%	100%	0%	0%
3-5	**36,392**	**257**	**32,912**	**2,492**	**730**	**1%**	**90%**	**7%**	**2%**
Ponderosa Pine	34,190	219	31,097	2,210	664	1%	91%	6%	2%
Aspen	2	0	2	0	0	0%	100%	0%	0%
Grassland	1,120	38	766	265	51	3%	68%	24%	5%
Juniper Woodland	70	0	70	0	0	0%	100%	0%	0%
Oak Woodland	384	0	384	0	0	0%	100%	0%	0%
Pinyon-Juniper	626	0	593	18	15	0%	95%	3%	2%

Subunit 3-4 includes that part of Flagstaff south of I-40 and west of I-17, including Kachina Village. There are PACs in the southern part of Subunit 3-4 that would have potential for both passive and active crown fire, some of it on slopes steeper than 30 or 40 percent). PACs in Subunits 3-4 and 3-5 also have most of the active crown fire potential within each Subunit. Grasslands would not meet desired conditions in Subunits 3-1, 3-3, 3-4, and 3-5, with crown fire potential as high as 39% in SU3-4.

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 10, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. Under Alternative B, RU4 would have the potential for 4,739 acres of crown fire (3%) of which 1,041 acres (1%) would be active crown fire (Table 59). Most of the crown fire in RU4 would be in scattered patches, with few areas of contiguous active crown fire greater than about 15 acres, mostly in areas classified as grasslands or other non-pine vegetation. There would be larger contiguous acreages of passive crown fire in PFAs and areas of lower intensity treatments, and some burn only treatments.

Table 59. Modeled fire type by vegetation type and habitat for RU4, Alternative B

RU 4 acres =		165,645	Veg type acres	2010		Alt. B 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**134,278**	**83,499**	**62%**	**130,544**	**97%**
		Passive		**10,590**	**8%**	**2,903**	**2%**
		Active		**39,763**	**30%**	**440**	**0%**
	Protected	Surface	558	379	68%	503	90%
		Passive		45	8%	16	3%
		Active		134	24%	39	7%
	Restricted	Surface	1,576	751	48%	1,378	87%
		Passive		196	12%	192	12%
		Active		621	39%	0	0%
	PFA/ dPFA	Surface	13,484	8,008	59%	12,261	91%
		Passive		1,250	9%	1,072	8%
		Active		4,221	31%	146	1%
	LOPFA	Surface	118,659	74,361	63%	116,403	98%
		Passive		9,100	8%	1,622	1%
		Active		34,786	29%	253	0%
Other Vegetation*	Aspen	Surface	497	403	81%	458	92%
		Passive		31	6%	35	7%
		Active		59	12%	0	0%
	Grassland	Surface	22,661	21,080	93%	21,089	93%
		Passive		788	3%	749	3%
		Active		645	3%	601	3%
	Juniper	Surface	118	69	59%	116	99%

	Woodland	Passive		4	3%	0	0%
		Active		43	36%	0	0%
	Oak Woodland	Surface	926	669	72%	924	100%
		Passive		90	10%	0	0%
		Active		165	18%	0	0%
	Pinyon/ Juniper	Surface	7,165	5,855	82%	7,140	100%
		Passive		453	6%	0	0%
		Active		829	12%	0	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of all treatment area within RU4

Ponderosa Pine in RU4 would have less than 1% (440 acres) with potential for active crown fire, and 2% (2,903 acres) with potential for passive crown fire.

Aspen occupy 497 acres in RU4. Potential for crown fire in aspen would be reduced to 7% (35 acres), none of which would be active crown fire. Additional expected effects would be as described on page 148.

Grasslands occupy 22,661 acres in Restoration Unit 4, including Government Prairie, a grassland area of ~20,000 acres, along with other scattered grassland areas. These grassland areas would be included as Operational Burn. Potential crown fire would be 6% (1,350 acres) across all the grasslands in RU4 following prescribed fires. Although the effects of wildfires that would occur subsequent to treatments would move grasslands towards desired conditions, modeled post-treatment fire type does not meet desired conditions for RU1.

Oak Woodlands would have no potential for crown fire under the conditions modeled, down 255 acres from the existing condition. Additional effects expected would be as described on page 149.

Pinyon/Juniper woodlands would also have no potential for crown fire under conditions modeled. As with grasslands, these areas would be Operational Burn and, post-treatment, would include 7,234 acres of surface fire. Additional effects expected would be as described on page 151.

Subunits

Subunit 4-5, though the smallest SU in the project at 6,919 acres, is adjacent to the city of Flagstaff, and has steep topography, so that the second order fire effects of high severity fires have good potential to impact neighborhoods and schools. Under Alternative B, all Subunits in RU4 would meet desired conditions for fire type overall, and in ponderosa pine. Grasslands in SU4-3, 4-4, and 4-5 would not meet desired conditions for fire type. Subunit 4-5 would have potential for only 99 acres of crown fire, of which 53 acres would be active crown fire (Table 60). None of the contiguous crown fire in Subunit 4-5 should be more than ½ acre. The majority of crown fire in RU4 is in Subunit 4-3, on the northwest and north side of the peaks, and west of Sitgreaves.

Table 60. Fire type in subunits of RU4 by major vegetation type as modeled for 2020.

		Fire Type (acres)				Fire Type (%)			
Alternative B	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
4-2	**10,227**	**74**	**9,902**	**219**	**32**	**1%**	**97%**	**2%**	**0%**

Ponderosa Pine	7,381	21	7,119	211	31	<1%	96%	3%	0%
Aspen	1	0	1	0	0	40%	60%	0%	0%
Grassland	328	29	289	8	2	9%	88%	2%	<1%
Juniper Woodland	8	0	8	0	0	0%	100%	0%	0%
Oak Woodland	567	2	565	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,941	22	1,919	0	0	1%	99%	0%	0%
4-3	**67,012**	**325**	**64,508**	**1,643**	**537**	**<1%**	**96%**	**2%**	**1%**
Ponderosa Pine	55,312	306	53,351	1,404	251	1%	96%	3%	0%
Aspen	230	3	224	3	0	1%	98%	1%	0%
Grassland	6,951	12	6,417	236	286	<1%	92%	3%	4%
Juniper Woodland	31	0	31	0	0	0%	100%	0%	0%
Oak Woodland	325	0	325	0	0	0%	100%	0%	0%
Pinyon-Juniper	4,162	3	4,159	0	0	0%	100%	0%	0%
4-4	**81,487**	**242**	**79,045**	**1,780**	**420**	**0%**	**97%**	**2%**	**1%**
Ponderosa Pine	65,003	63	63,546	1,278	116	0%	98%	2%	0%
Aspen	255	0	224	31	0	0%	88%	12%	0%
Grassland	15,055	178	14,102	471	303	1%	94%	3%	2%
Juniper Woodland	78	2	76	0	0	2%	98%	0%	0%
Oak Woodland	35	0	35	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,062	0	1,062	0	0	0%	100%	0%	0%
4-5	**6,919**	**3**	**6,818**	**46**	**53**	**0%**	**99%**	**1%**	**1%**
Ponderosa Pine	6,581	1	6,528	10	42	0%	99%	0%	1%
Aspen	11	0	9	2	0	0%	82%	18%	0%
Grassland	327	2	281	33	11	1%	86%	10%	3%

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 acres). Adjacency concerns include housing developments, including Doney Park, Timberline, and the city of Flagstaff, which would be downslope from many wildfires occurring in this RU. Under Alternative B, 2% (1,661 acres) of RU5 would have potential for crown fire, of which 1% (613 acres) would be active crown fire. There are many areas, some larger than 500 acres, in the north and eastern areas of this RU that are cinder substrate, and have no potential for fire. These areas consist of cinder cones, and cinder soils which generally support sparse vegetation. In these areas, active crown fire is less likely because of decreased potential for high intensity surface fire. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

Ponderosa pine in RU5 meets desired conditions (Table 61), with 2% of the area having potential for crown fire, 1% of which would be active crown fire. Some of the active crown fire in PACs on the northwest side of Mt. Eldon would occur on slopes greater than 30%. Protected habitat would retain potential for 9% crown fire (78 acres), all of which would be active crown fire.

Aspen occupies 403 acres within RU5. Potential for crown fire in aspen would be reduced to 15% (61 acres), all of which would be passive crown fire. Additional expected effects would be as described on page 148.

Grasslands in RU5 would have potential for crown fire on 7% (342 acres) of the 4,536 acres of grasslands in RU5. Fire would decrease woody encroachment (direct effect), though there would be potential for active crown fire on 2% (105 acres) of the grasslands in RU5. Although the effects of wildfires that would occur subsequent to treatments proposed in Alternative B would further move the grasslands towards desired conditions, modeled post-treatment fire type does not meet desired conditions for RU5. Additional effects would be as described on page 150.

Oak woodlands, under Alternative B, would have decreased potential for crown fire, down to 0% (<1 acre). This would meet desired conditions of <10% crown fire in Gambel oak woodlands. Additional effects would be as described on page 149.

Pinyon/Juniper crown fire potential would decrease to 16 acres (down from 266 in the existing condition). PJ in RU1 is all Operational Burning, but would benefit from the prescribed fires that would be implemented. Additional effects would be as described on page 151.

Table 61. Fire type by vegetation type and habitat for Restoration Unit 5

RU 5 acres =		73,203	Veg type acres	2010		Alt. B 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**59,034**	**41,109**	**70%**	**54,029**	**92%**
		Passive		**6,821**	**12%**	**766**	**1%**
		Active		**7,376**	**12%**	**504**	**1%**
	Protected	Surface	859	535	62%	755	88%
		Passive		132	15%	1	0%
		Active		167	19%	78	9%
	Restricted	Surface	606	451	74%	606	100%
		Passive		71	12%	0	0%
		Active		83	14%	0	0%
	PFA/ dPFA	Surface	2,227	1,343	60%	1,943	87%
		Passive		419	19%	115	5%
		Active		325	15%	22	1%
	LOPFA	Surface	55,341	38,780	70%	50,725	92%
		Passive		6,199	11%	650	1%
		Active		6,801	12%	403	1%
Other Vegetation*	Aspen	Surface	403	332	82%	337	84%
		Passive		24	6%	61	15%
		Active		43	11%	0	0%
	Grassland	Surface	4,536	2,521	56%	2,521	56%
		Passive		222	5%	219	5%
		Active		105	2%	105	2%
	Juniper Woodland	Surface	74	67	90%	74	100%
		Passive		7	9%	0	0%
		Active		0	1%	0	0%
	Oak Woodland	Surface	386	349	91%	371	96%
		Passive		20	5%	0	0%

		Active		1	0%	0	0%
	Pinyon/ Juniper	Surface	8,771	7,804	89%	8,474	97%
		Passive		277	3%	2	0%
		Active		393	4%	5	0%

* Nonburnable substrate constitutes about 6% of ponderosa pine and about 8% of the entire treatment area within RU5

Subunits

Subunit 5-1 has potential for a few areas of contiguous active crown fire, roughly 70 acres are within ½ mile of, and uphill from the Schultz Pass Road, some of which is on slopes greater than 30%. Other patches are close to 30 acres, on the northwest side of the Peaks. Subunit 5-2 includes much of the youngest, most sparsely vegetated cinder cones, as well as areas that were affected by the second order fire effects resulting from the Schultz Fire. Table 62 shows that, under Alternative B, at the subunit scale, both subunits would meet desired conditions at the subunit scale, and in ponderosa pine. Neither subunit would meet desired conditions for fire type in grasslands.

Table 62. Modeled fire type in subunits of Restoration Unit 5 by vegetation type for 2020.

		Fire Type (acres)				Fire Type (%)			
Alternative B	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
5-1	**21,341**	**795**	**19,622**	**498**	**425**	**4%**	**92%**	**2%**	**2%**
Ponderosa Pine	18,040	747	16,531	355	406	4%	92%	2%	2%
Aspen	392	5	327	61	0	1%	82%	15%	0%
Grassland	1,239	19	1,119	82	19	<2%	90%	7%	<2%
Oak Woodland	95	0	95	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,574	24	1,550	0	0	1%	98%	0%	<1%
5-2	**51,863**	**4,940**	**46,184**	**550**	**189**	**10%**	**89%**	**1%**	**0%**
Ponderosa Pine	40,994	2,988	37,498	411	98	7%	91%	1%	<1%
Aspen	10	0	10	0	0	0%	100%	0%	0%
Grassland	3,297	1,672	1,402	137	86	51%	43%	4%	<3%
Juniper Woodland	74	0	74	0	0	0%	100%	0%	0%
Oak Woodland	291	15	276	0	0	5%	95%	0%	0%
Pinyon-Juniper	7,196	266	6,924	2	4	4%	96%	0%	0%

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of and adjacent to Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area. Modeled post-treatment conditions indicate potential for less than 1% (106 acres) of active crown fire, all of which would be in four areas, the largest of which is of less than 30 acres (Table 63). There would be potential for 4% of RU6 (1,919 acres) to support passive crown fire, which would be widely dispersed, with concentrations in areas with components of juniper and oak, particularly on the northeastern and southeastern corners. Alternative B would meet desired conditions in RU6 at the Restoration Unit scale.

Ponderosa pine in RU6, along with all the associated habitat types, would meet desired conditions for <10% crown fire. When considered by vegetation/habitat type, all types would have potential for less than 10% crown fire, with 92% (98 acres) of the active crown fire in ponderosa pine occurring in PFA/DPFA habitat.

Grasslands occupy 93 acres in RU6, of which 4 acres would have potential for crown fire. These 93 acres would be burned as Operational Burn, with no restoration objectives for prescribed fire. However, with potential for only 1 acre of undesirable effects from fire behavior, they would benefit from whatever fire occurred. Alternative B would meet the intent of desired conditions for grasslands in RU6, coming within an acre of the desired condition for fire type. Additional effects are described on page 150.

Oak woodlands (30 acres) would be Operational Burn, with less than an acre having potential for crown fire. For more details of expected effects, refer to page 151.

Table 63. Modeled fire type by vegetation and habitat for Restoration Unit 6

RU 6 acres =		43,530	Veg type acres	2010		Alt. B 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**41,189**	**33,673**	**82%**	**39,444**	**96%**
		Passive		**2,233**	**5%**	**1,595**	**4%**
		Active		**5,238**	**13%**	**106**	**0%**
	PFA/ dPFA	Surface	4,050	3,506	87%	3,770	93%
		Passive		111	3%	179	4%
		Active		430	11%	98	2%
	LOPFA	Surface	37,139	30,167	81%	35,674	96%
		Passive		2,123	6%	1,416	4%
		Active		4,808	13%	8	0%
Other Vegetation*	Grassland	Surface	93	89	96%	89	96%
		Passive		2	2%	3	3%
		Active		1	1%	1	1%
	Juniper Woodland	Surface	13	10	79%	11	83%
		Passive		3	21%	2	17%
		Active		0	0%	0	0%
	Oak Woodland	Surface	30	9	30%	30	100%
		Passive		20	68%	0	0%
		Active		1	2%	0	0%
	Pinyon/ Juniper	Surface	2,206	1,472	67%	1,886	86%
		Passive		504	23%	320	14%
		Active		229	10%	0	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU6

Pinyon/Juniper woodland in RU6 has fuel reduction objectives. Under Alternative B (Table 64), There would be potential for 427 acres of passive crown fire, and no active crown fire. Most of the Pinyon/Juniper in RU6 would be Operational Burn. There are 535 acres for which the objective is fuels reduction. Under Alternative B, there would be potential for just 2 acres of crown fire in PJ in those acres. For more details of expected effects, refer to page 151.

Table 64. Modeled fire type in Pinyon/Juniper with and without fuels objectives in RU6.

Vegetation Type	Fire Type	Alternative B 2020 (all PJ)		Alternative B 2020 (PJ with fuels objective)	
		%	Acres	%	Acres
Pinyon/ Juniper	No fire	0	0	0	0
	Surface	98	22,516	100	533
	Passive crown	2	384	0	2
	Active crown	0	43	0	0

Subunits

As indicated in Table 65, Subunits 6-2 and 6-3 would meet desired conditions for fire type under Alternative B, with 1% or less of each vegetation type in each subunit having potential for active crown fire. In Subunit 6-4, there is diverse vegetation in most of the stands showing potential for passive crown fire, including juniper and Gambel oak. Figure 28 shows the structure of the area, with multiple ladder fuels, but open areas between clumps of vegetation, with ponderosa pine as the dominant species.

Table 65. Modeled fire type in subunits of Restoration Unit 6 by vegetation type for 2020.

		Fire Type (acres)				Fire Type (%)			
Alternative B	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
6-2	**5,551**	**7**	**5,377**	**167**	**0**	**0%**	**97%**	**3%**	**0%**
Ponderosa Pine	5,069	7	4,896	166	0	0%	97%	3%	0%
Pinyon-Juniper	483	0	481	1	0	0%	100%	0%	0%
6-3	**34,109**	**33**	**33,104**	**867**	**105**	**<1%**	**97%**	**3%**	**0%**
Ponderosa Pine	32,635	33	31,746	752	104	<1%	97%	2%	0%
Grassland	85	0	82	3	1	0%	96%	3%	1%
Juniper Woodland	13	0	11	2	0	0%	83%	17%	0%
Pinyon-Juniper	1,375	0	1,266	109	0	0%	92%	8%	0%
6-4	**3,870**	**4**	**2,979**	**886**	**1**	**0%**	**77%**	**23%**	**0%**
Ponderosa Pine	3,484	4	2,803	677	1	<1%	80%	19%	0%
Grassland	7	0	7	0	0	0%	100%	0%	0%
Oak Woodland	30	0	30	0	0	0%	100%	0%	0%
Pinyon-Juniper	348	0	139	209	0	0%	40%	60%	0%

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 15, desired openness is an indication of the relative desired post treatment interspace/tree group condition.

In relation to fire behavior, canopy characteristics primarily affect the potential for crown fire which produces undesirable fire effects and is extremely difficult to control. In regards to fire effects, canopy characteristics relate to crown fire, which is lethal because ponderosa pine does not sprout. In regards to fire behavior, surface fuel loading from litter, duff, and CWD can smolder for long periods of time, making it difficult to detect across a very recently burned landscape. 'Mop up', following a fire, is almost always in these fuel types. "Mop up" refers to carefully surveying a burned area on foot to ensure there are no remaining embers or 'smokes'. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 86 for more details).

Canopy characteristics affecting fire behavior

Changes to Canopy Cover (CC), Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are direct effects, though they are not always apparent in the fire behavior data (indirect effects). Post-treatment canopy characteristics (2020), under Alternative B would support fire behavior that would meet desired conditions for fire behavior (Table 63). Desired conditions for CBH are 18 feet or higher; desired conditions for canopy bulk density (CBD) are 0.05 kg/m3 or less. Table 66 displays modeled changes in canopy characteristics from 2010 through 2050 with no mechanical treatments or fire (wildfire or prescribed fire) after 2020. Shaded cells indicate a condition that does not meet desired conditions for ponderosa pine. Note: desired conditions for CBH and CBD do not apply to PACs or Core Areas.

Table 66. Modeled changes in canopy characteristics for Alternative B.

Alt B	CBH (feet)			CBD (kg/m3)			CC (%)			% of pond pine
Desired Openness	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	15	28	29	0.061	0.025	0.031	41	21	29	42
Moderate	15	25	26	0.061	0.030	0.040	43	26	36	24
Low (Mechanical)	16	26	28	0.060	0.036	0.042	41	29	37	5
Low (Burn Only)	14	20	25	0.046	0.036	0.037	33	27	32	18
Very Low (Burn Only)	15	21	26	0.063	0.048	0.049	41	35	39	2
Very Low (Mechanical)	16	24	30	0.062	0.050	0.051	48	44	51	4
Very Low (PAC Burn Only)	14	17	23	0.067	0.065	0.064	49	49	53	4
Very Low/No Proposed Treatments (Core Areas)	14	16	22	0.070	0.071	0.069	51	52	55	1
No Proposed Treatments	16	18	23	0.069	0.069	0.063	43	45	47	<1
Weighted Average[4]	15	25	27	0.059	0.032	0.037	41	26	34	

Table 66 shows modeled changes from existing condition (2010 data) through post-treatment (2020) and 20 years post-treatment (2050). Those areas receiving the lowest intensity treatment would remain in a condition that would be likely to support crown fire. The rest of the treatments show improved conditions that would remain within desired conditions though 2050. Canopy Bulk Density decreases from 2010 to 2020, showing clearly the results of treatments, except in

Core Areas which are not treated under this Alternative. By 2050, CBD would be increasing, as trees mature and canopies grew. Higher CBDs increase the probability of crown fire initiation and propagation through the canopy as active crown fire. From 2010 to 2020, proposed treatments would increase canopy base height to at least 18 feet for 95% of the ponderosa pine.

Figure **52** shows the trends for CBH, CBD, and canopy cover (CC). Modeling assumed all treatments were completed in 2019, and from 2020 through 2050 there were no additional treatments (mechanical or fire), or disturbances of any kind (wildfire, insects/disease, blowdown, etc.). With the exception of the lowest intensity treatments, the trends indicated from 2010 to 2020 would be expected to increase surface fire and decrease crown fire.

Trends from 2020 to 2050 show increasing potential for conditional crown fire. The increased canopy cover and increased CBH would trend towards conditions that would allow crown fire to carry though the canopies of trees, though it would need to initiate in an adjacent stand or area because CBH would be too high.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of proposed treatments that have indirect effects on fire behavior and effects. Litter, duff, and Coarse Woody Debris greater than 3" diameter (CWD>3") contribute to multiple characteristics of a fire regime, including, but not limited to: flammability, surface fire intensity, scorch height, flame length, and surface fire effects.

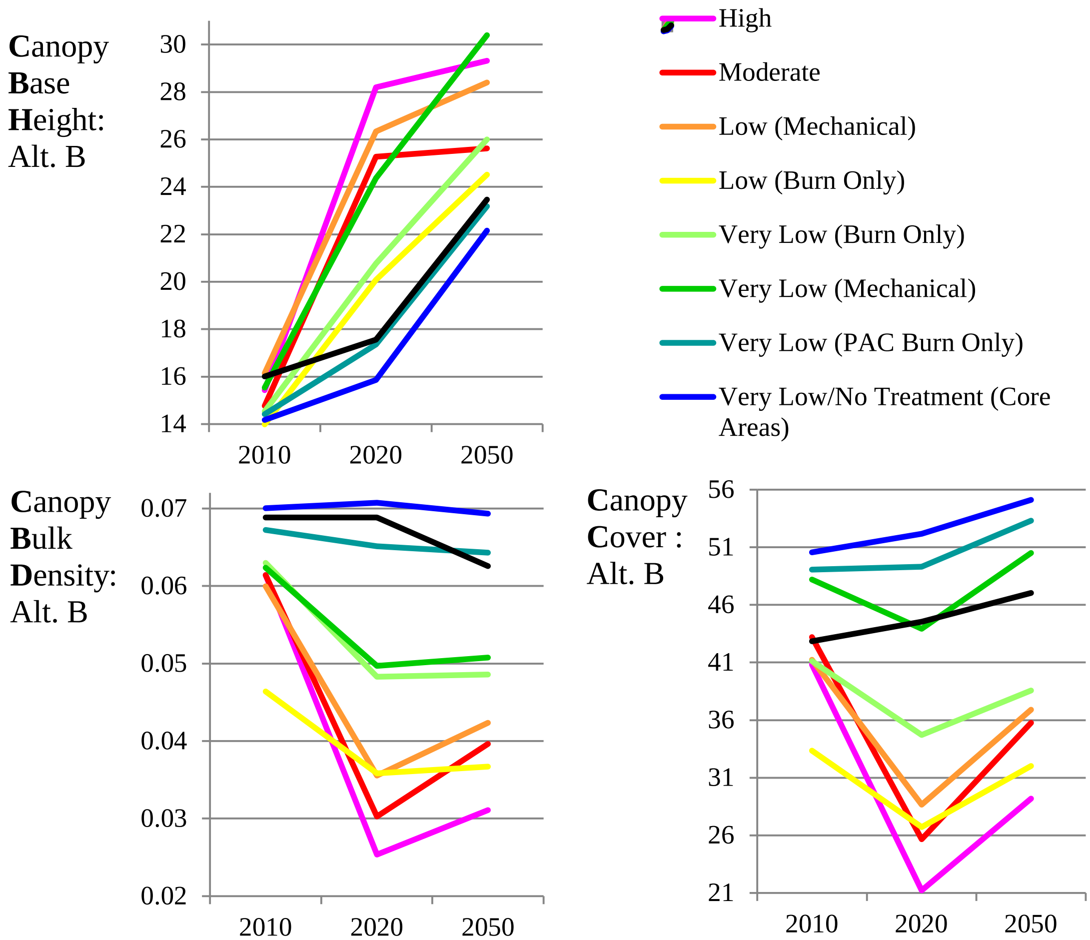


Figure 52. Modeled trends in canopy fuels under Alternative B.

They contribute more than other fuels to emissions. High surface fuel loading can cause high severity effects, both direct and indirect, to soils, and surface biota (such as roots, seeds, forbs, and other species adapted to low severity fire) (Lata 2006, Neary et al. 2005, Valette et al. 1994), as well as producing air quality impacts. Mechanical thinning alone can contribute significantly to decreasing the potential for crown fire by breaking up vertical and horizontal canopy fuel continuity, but does not decrease surface fuel loading (Fulé et al. 2012). Initial thinning impacts may include temporary fire 'breaks' where there are skid trails, or other surface disturbance, but surface fuels are generally not removed from the treatment area, and remain a potential source of heat and emissions. Surface effects may be spottier following thinning because residual fuels often include jackpots or small piles. Where fuels have been pushed into piles or furrows, by design or happenstance, they may smolder for a long time.

As with fire behavior and canopy characteristics, a direct effect on fuel loading in regards to fire effects and emissions would be an improvement for all levels of desired openness except the lowest two (Figure 53). There are no specific desired conditions for litter or duff, but they are an important component of the effects of the proposed treatments. Forest plan direction for CWD would be met for all but Very Low (PAC Burn Only) in 2020.

A direct effect of prescribed fires would be the consumption of some CWD and, although more is often produced as an indirect effect of the burn (Waltz et al. 2003, Haase and Sackett 2008, Roccaforte et al. 2012), it may be of a different stage of decay that does not fill the same ecological niche. Surface fuel loading can be managed with fire and felling techniques to increase or decrease woody debris in different size classes. A direct effect of Alternative B could be that some areas would be deficit in CWD for a few years following treatment but, given the trend shown, it would only be a few years before it met desired conditions again and, with maintenance burning, it should be possible to maintain desired levels.

Surface fuel loading by treatment ability to maintain desired openness

Historical values were around 5 tons per acre on the high end for CWD and less than 2.5 tons/acre for duff (Brown et al, 2003) so, assuming ~2.5 for litter, all of the areas except the lowest two would be within the historical range of surface fuel loading in 2020, and would exceed it by 2050.

Figure 53 shows changes in surface fuel loading for 2010, 2020, and 2050 by desired openness. The areas with lower desired openness are primarily those associated with MSO habitat, have the highest fuel loading in all modeled years, as well as the lowest canopy base heights (CBH), the higher canopy bulk density (CBD), and the highest canopy cover (CC). Alternative B project-level changes in surface fuel loading (litter, duff, and CWD>3") are a result of the ability of different treatment types to attain a mosaic of interspaces and tree groups.

The decreased litter, duff, and canopy fuels indicated in the last section would allow more precipitation to reach the surface, because there would be fewer canopy fuels to intercept it. Increased light to the surface would stimulate an increase in surface vegetation, providing light, flashy fuels that would produce low intensity/ low severity surface fires in the future, the behavior and effects of which ponderosa pine and its associated species are well adapted to.

Out of these three categories of surface fuels, CWD is the one that increases the fastest by tons/acre, and is easily managed with fire and felling techniques to increase or decrease woody debris in different size classes should adjustments need to be made to ensure forest plan guidelines for CWD are met (Table 67). Table 67 shows modeled changes in litter, duff, and CWD>3" for Alternative B over 40 years (2010, 2020, 2050). Assumptions are that treatments mechanical treatment and two prescribed burns occur between 2012 and 2019 and from 2020 to

2050, there are no additional treatments of any kind. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD.

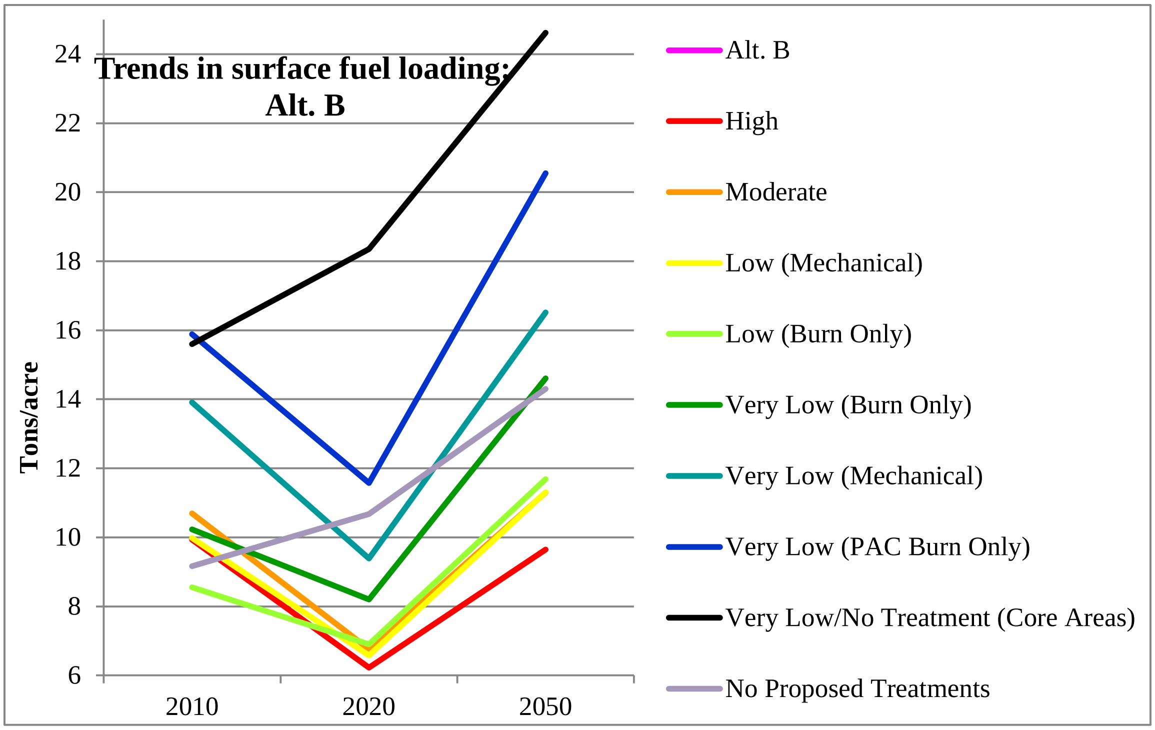


Figure 53. Modeled trends of surface fuel loading for Alternative B.

As indicated in Table 67, the average total fuel loading by treatment openness under Alternative B decreases from over 10 tons per acre in before treatment, to a 7 tons/acre following treatments. By 2050, total fuel loading surpass pre-treatment levels. The areas with the lowest desired openness (None (Core Areas)) begins at 15.6 tons/acre, increasing to 18.41 tons per acre following treatments in 2020. By 2050, total fuel loading in the lowest treatment is at almost 25 tons/acre, exceeding pre-treatment levels by 10 tons per acre. The biggest increases are in CWD>3".

Table 67. Modeled changes in surface fuel loading for Alternative B

Desired openness	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			% pond pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.7	2.8	4.7	3.1	1.3	2.5	3.2	2.2	2.5	9.9	6.2	9.6	42%
Moderate	3.6	2.8	5.3	3.9	1.8	3.4	3.1	2.2	2.6	10.7	6.8	11.3	24%
Low (Mechanical)	3.6	2.6	5.5	3.2	1.7	3.2	3.2	2.2	2.6	10.0	6.6	11.3	5%
Low (Burn Only)	3.2	2.8	6.2	2.5	1.6	2.6	2.9	2.5	2.9	8.6	6.9	11.7	18%
Very Low (Burn Only)	3.8	3.2	7.8	3.2	2.0	3.4	3.2	3.0	3.4	10.2	8.2	14.6	2%
Very Low (Mechanical)	5.0	2.7	6.3	5.0	2.6	5.5	3.9	4.1	4.8	13.9	9.4	16.5	4%
Very Low (PAC Burn Only)	6.0	3.3	8.5	4.8	3.0	6.0	5.1	5.3	6.0	15.9	11.6	20.5	4%

No Proposed Treatments (Core Areas)	5.8	7.6	12.4	5.1	5.8	6.3	4.7	5.0	5.9	15.6	18.4	24.6	1%
No Proposed Treatments	3.3	4.0	6.7	2.9	3.5	3.8	3.0	3.2	3.8	9.2	10.7	14.3	<1%
Weighted avg[4]	3.7	2.8	5.5	3.3	1.6	3.0	3.2	2.5	2.9	10.3	7.0	11.4	

Surface fuel loading by stand

Figure 54 shows the distribution of surface fuel loading across the project area. Assumptions are that from 2012 to 2020, thinning and two prescribed burns were completed and after 2020, there was no mechanical treatment, prescribed fire, or wildfire. As described on page 86, there is no forest plan guidance on total surface fuel loading. However, the effects of surface fuel loading are potentially significant, because it has the potential to cause the death of large/old trees, destroy wildlife habitat, and cause irreversible high severity effects if it burns under the wrong conditions. Combining litter, duff, and CWD, it seems reasonable to assume that if these three total >20 tons/acre (discussion on page 30), the potential fire effects could include sufficient heat to increase tree mortality, consume organic matter in the top layers of soil, including living roots, seeds, mycorrhizae, or cause other undesirable fire effects, such as the impacts of emissions on humans and wildlife if those areas burn under conditions that are not optimum for smoke dispersal. While this does not represent a 'desired condition', it can inform a discussion on the potential fire direct and indirect fire effects from surface fuel loading. This does not specifically relate to wildlife requirements, but includes other fuel loading components and considerations.

Surface fuel loading was also analyzed at the stand level (Figure **54**). Under Alternative B, in 2020 there would be about 1,048 acres with surface fuel loading greater than 20 tons/acre, and 4,370 acres in the 15 – 20 tons/acre range. By 2040 there would be 5,572 acres with surface fuel loading exceeding 20 tons/acre, and 54,825 in the 15 – 20 tons/acre range. In Figure 54 it can be seen that, following treatment, surface fuels have been reduced to recommended levels over most of the treatment area. The exceptions (bottom right) are mostly in RU 1 in PACs, with some areas of exceedence north and northwest of San Francisco Peaks.

[4] Weighted averages for desired openness are based on the 507,839 acres acres of ponderosa pine proposed for treatment under each alterntive.

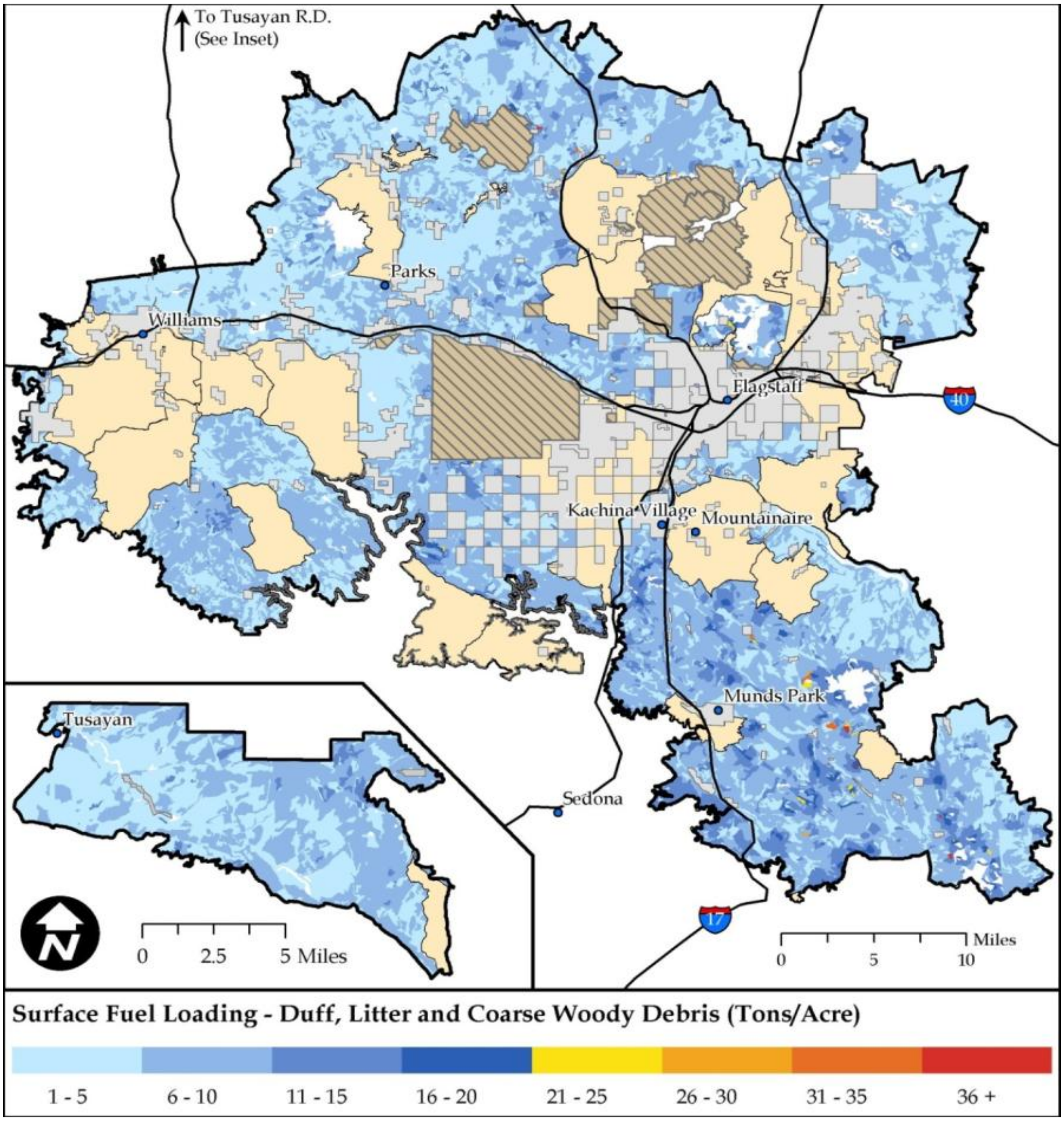


Figure 54. Modeled surface fuel loading for Alternative B.

Fire Regime/Condition Class

Under Alternative B, Fire Regime/Condition Class (FRCC) would move toward the desired condition. The desired condition is for there to be no acres in FRCC3. Alternative B moves the ponderosa pine from FRCC 3 to FRCC2 post-treatment, significantly lowering the risk to key ecosystem components. With no disturbance of any kind (mechanical or fire treatments, wildfire, insects, disease, etc.), the effects of the treatments proposed in Alternative B persist, maintaining an FRCC of 2 after 30 years. Acres of grasslands in FRCC1 would decrease in the absence of any type of treatment, as woody species continued to encroach and species composition shifted in favor of less fire adapted species. Although treatments in grasslands under Alternative B would only occur as Operational Burning, where it is implemented, prescribed fire would improve the stability of key ecosystem elements. Treatments proposed under Alternative B would shift over 223,000 acres of ponderosa pine from VCC3 to VCC2 (Table 68).

Table 68. Fire Regime/Condition Class as modeled for ponderosa pine, Alternative B

VCC – Alt. B	2010		2020		2050	
	Acres	%	Acres	%	Acres	%
1	71,097	14%	132,038	26%	76,176	15%
2	126,960	25%	350,409	69%	248,841	49%
3	309,782	61%	25,392	5%	182,822	36%
Vegetation departure =	66%		39%		70%	
Fire Severity Departure =	74%		40%		55%	
Fire Return Interval Departure =	80%		20%		60%	
FRCC of treatment area =	**3**		**2**		**2**	

Fire Return Interval

Fire return intervals, as described on page 37, are a characteristic of a fire regime, and a coarse measure of the health of a system. This analysis uses running averages of acres treated by planned and unplanned fire for each Alternative As a fixed number per year in order to make broad comparisons between alternatives. In reality, there are wide fluctuations in the number of acres treated each year which depend on weather, resource availability, public tolerance, funding, and logistics.

The estimated fire return interval for the proposed treatment area is currently about 40 years, double the desired maximum average for ponderosa pine on the Mogollon Rim. This should be interpreted with caution, however, because it is the long term cycle of fire return intervals that regulates a system. Two prescribed fires would set the treatment area on a trajectory towards a restored condition, but maintenance fires would continue to be needed to avoid the ecosystem slipping back to an unsustainable condition.

Table 69 shows the calculated fire return intervals from 2001 through 2010 based on an average of 15,000 acres burning annually. Averages begin in 2001 as an estimate for the 4FRI treatment area.

Table 69. Fire Return Intervals for Alternative B

	# of years averaged	Average annual acres burned	Fire Return Interval over years averaged
Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
Alt B 2020	20 (2001- 2020)	58,333 (2001- 2020)	10
Alt B 2050	40 (2001- 2050)	29,167 (2001- 2050)	21

When the acres proposed for annual burning under this Alternative are added, and the total is averaged over 20 years (2001 – 2020), the average fire return interval would be 10 years. Assuming there are no more fires of any kind between 2020 and 2050, average annual acres burned in 2020 is averaged over the 50 year period (2001 – 2050) as a 20 year fire return interval.

Under Alternative B, the fire return interval over the treatment area would return to the desired frequency, and move the fire regime back towards a sustainable, resilient condition. Those areas that are not proposed for burning under the FRI would not reach, or move towards a sustainable resilient fire regime.

Emissions: Air Quality and Ecological Effects

This alternative would meet the purpose and need, and desired conditions for Air Quality. During windows of opportunity, whenever fire weather and expected fire effects are favorable, fire managers on the Coconino and Kaibab National Forests strive to treat as many acres with wildland fire as possible every year, while remaining within legal, climatological, social, and logistical limits. This means that the only change that is likely to occur under this Alternative would be from the greater flexibility in blocking out burn units, because so much more area would have been treated and/or planned and analyzed for prescribed fire. There may also be room some potential for increased coordination of resources between forests in the area. Impacts on air quality are indirect effects of implementing prescribed fire. Although the impact of this is not quantifiable at this time, it would likely be an increase in annual acres burned with no increase in air quality impacts, because it could increase the number of acres that could be burned in a single burn period.

Potential air quality impacts during implementation of Alternative B, and the necessary maintenance burning after the initial implementation has been completed may be noticeable, although National Ambient Air Quality Standards would not be exceeded. Initial entry burns produce much more emissions per acre than subsequent burns (see discussion on page 37). However, even if the slash was removed from the forest and although the prescribed burning would be spread over many years, the area to be burned would increase significantly and periodic burning would be required across the treatment area to maintain a low fuel load and a healthy forest.

Under this alternative, prescribed fire would need to be implemented on up to 58,333 acres annually to produce an average fire return interval of 10 years across 583,330 acres proposed for prescribed fire. Implementing prescribed fire as proposed in Alternative B would result in lower emissions than if the area burned in a wildfire because there would be less biomass to burn.

Air quality provides an example of short- and long-term trade-offs in implementing restoration across large areas. There is a risk of short-term human health impacts from prescribed fire. The emissions from prescribed fires, as opposed to wildfires, can be managed by carefully distributing (prescribed) fire over time and space, as well as under appropriated weather conditions (Cohesive Strategy 2002, page 39). Under Alternative B, air quality impacts would be most likely to those portions of the Little Colorado River Airshed east and northeast of Flagstaff; the Colorado River Airshed north of Williams and including all of the treatment area in RU6; and the Verde River Airshed. There is a small chance that there could be some impact to the northern portions of the Lower Salt River Airshed.

The combination of prescribed fire and mechanical thinning is the most effective means of limiting emissions from wildland fires by reducing and breaking up fuel continuity. Mechanical treatments proposed by 4FRI would reduce fuels by combinations of cutting and burning. In some cases, thinning would be implemented prior to prescribed burning, allowing higher intensity fire to be used where appropriate, and effectively minimizing potential wildfire emissions by removing some canopy fuels. Thinning generally increases surface fuel loading somewhat because of slash and other debris that break or fall off trees as they are processed, even when the majority of the material is removed from site (Fulé et al. 2012). Disturbance of surface fuels may provide temporary fuel breaks by re-arranging surface fuels where there are skid trails, tire tracks, and other surface disturbances which break up surface fuel continuity while slightly increasing the amount. In other areas, prescribed fire may precede thinning. This may be appropriate if an area would not be thinned for several years in order to reduce flammability in the interim by beginning the process of reducing surface fuel loads, increasing canopy base height, and decreasing canopy bulk density. It may also occur if there is an opportunity to expand an adjacent burn unit to include part of the treatment area to increase efficiency. It may also facilitate timelier implementation of prescribed fires if there is no need to wait a year or two for the mechanical treatments to be completed. In some cases, it may be preferable to use fire as a thinning agent when the site is to steep or remote to access with mechanical methods.

During the day, when units are ignited, smoke would be expected to travel on prevailing winds, away from sensitive receptors, and dissipate. Most smoke would dissipate, but some may surface. Short-term nighttime nuisance smoke could settle down the drainages into the towns below, particularly during early morning hours. Nighttime smoke would be expected to reside in low areas down slope from the burn units, because night time winds are generally calm. Daytime smoke would be expected to dissipate mostly downwind from the burn unit. Burn plans written for implementation of the proposed prescribed fires would include modeling to determine the most appropriate conditions under which to burn in order to minimize smoke impacts.

The amount of smoke allowed by the DEQ would not increase, and any burning done in the proposed treatment areas would comply with the National Ambient Air Quality Standards (NAAQS). The number of days of smoke impacts, as well as nuisance smoke (emissions that comply with NAAQS but are considered by the public to be a nuisance) may increase under these alternatives, for the following reasons. Both the Coconino and Kaibab National Forests already burn on the high end of what would be their maximum acres and allowed emissions. Under Alternatives B, the number of acres available for prescribed fire would increase by 583,333 acres, which could average an additional 58,333 acres a year with prescribed fire and wildfire. This, in turn, would increase the flexibility for the forests in laying out burn units and managing prescribed fires. With potential for larger burn units, it would be possible to burn ‘hotter’, so that, although more acres may be burned at one time, the heat created by increased fire behavior is could provide more ‘lift’ for the smoke, increasing dispersal and minimizing smoke impacts.

In the long term, once an area has been burned once, there is less fuel and, thus, lower emission potential. The combination of lower fuel loads and larger burn units would allow more acres to be burned without exceeding NAAQS.

In the short term, as ‘1st entry’ burns are implemented, impacts would increase noticeably. Acres with high fuel loading would be burned, in a first step toward restoring the natural fire regime. In the long term, the same acres would produce less smoke, along with maintaining an ecosystem that is resilient to fire, and benefits from it.

In the short term, implementing acres of prescribed fire produces low severity effects that are beneficial for the landscape. In the long term, high severity fires are no longer possible on the majority of acres that are treated.

Air quality impacts can be predicted from prescribed fire, and the public notified of when and where to expect impacts in advance of a burn. Wildfires are less predictable and, though general patterns of smoke movement on the landscape are known, there is much less surety of where and when there would be impacts.

Figure 54 shows post-treatment surface fuel loading would decrease to post-treatment levels, decreasing the volume of potential emissions from wildfires and future prescribed fires. However, there is no change in CWD fuel loading for Very Low (PAC Burn Only) treatments (19,975 acres). In these areas, smoldering fuels would produce high levels of smoke, as well as a high likelihood of high severity fire effects.

Ecological effects of smoke

From an ecological perspective, the indirect effects of smoke are important to the germination of many native plants, and in some cases appears to be more important than heat (Abella 2006; Abella et al. 2007, Abella, 2009, Keeley and Fotheringham 2002, Schwilk and Zavala 2012), many of which occur in the treatment area, including *Nama dichotomum, Heliomersis longifolia, Penstemon spp., Artemisia ludoviciana, Erigeron speciosus, and Symphyotrichum falcatum.* *S*moke may also be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt, 1975; Zimmerman et al. 1987). This alternative would increase the area over which the ecological roles smoke could be maintained, and help to restore the health and natural diversity of surface vegetation.

Stream/spring restoration

Restoration of 39 miles of ephemeral streams, and 74 springs would occur inside of existing treatments, with post-treatment conditions meeting desired conditions, but would not be expected to have much effect on fire behavior or effects in the short run. In the long run, restored hydrology in these areas, particularly springs, may result in increased surface fuel loading near springs, allowing wildfire or prescribed fire to creep closer to the water source than is generally possible now. Forest plan direction allows prescribed fire for fuels management riparian areas.

Roads

Under this alternative, there would be 860 miles of roads decommissioned. From 2001 through 2010, over 30,555 acres of human ignited wildfires burned on Williams, Tusayan, Flagstaff, and Mogollon Rim Ranger Districts, 17% of all acres burned in wildfires. Many wildfires that are started by humans begin in proximity to roads so, under this Alternative, there could be fewer human-started wildfires. The more heavily used of these roads have functioned as fire breaks in the past. Once decommissioned, surface fuel loading would eventually grow back, allowing fire to burn across the area. During the implementation of the mechanical treatments, roads constructed or reconstructed for access (520 miles) would be available for access to burn units, and/or to be used as firelines for burns.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

There would be impacts to air quality, as an indirect effect associated with the implementation of the proposed prescribed fire treatments; however NAAQS would not be exceeded. Before any prescribed fires can be implemented, a prescribed burn plan must be written and signed by the authorizing line officer. For prescribed fire, burn plans include burn techniques, prescriptions, Emission Reduction Techniques, etc. That would be expected to maintain emissions levels at acceptable levels. Approval to burn on a given day must be approved by the Arizona Department of Environmental Quality, before a burn can be initiated. None of the proposed actions are expected to exceed NAAQs, though nuisance smoke may increase in duration to the degree that the public would tolerate it in those areas discussed the Emissions section of Alternative B in this report (page 172).

Alternative C

As with Alternative B, from a fire ecology perspective, the direct and indirect effects of Alternatives C relate to treatments that include mechanical thinning, prescribed fire, or both. The majority of these effects are identical to, or nearly identical to those described for Alternative B.

The Coconino and Kaibab National Forests would conduct restoration activities on approximately 586,110 acres over a period of 10 years or until objectives are met. On average, 45,000 acres of vegetation would be mechanically treated annually. On average, 40 – 60,000 acres of prescribed fire would be implemented annually across the Forests (within the treatment area). Up to two prescribed fires[4][5] would be conducted on all acres proposed for burning over the 10-year period. Restoration activities would:

- Mechanically thin trees on approximately 431,049 acres, including mechanically treating up to 18-inch dbh within 18 Mexican spotted owl protected activity centers.
- Prescribed fire would be implemented on approximately 586,110 acres, including low-severity prescribed fire within 70 Mexican spotted owl protected activity areas (including 54 core areas).
- Utilize prescribed fire only (no mechanical treatments) on approximately 155,061 acres.
- Construct approximately 520 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed).
- Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no new permanent roads would be constructed). Of these miles, approximately 30 miles would be improved to allow for haul (primarily widening corners to improve turn radii) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.
- Decommission 726 miles of existing system and unauthorized roads on the Coconino NF.
- Decommission 134 miles of unauthorized roads on the Kaibab NF.
- Restore 74 springs and construct up to 4 miles of protective fencing.
- Restore 39 miles of ephemeral channels.
- Construct up to 82 miles of protective (aspen) fencing.
- Construct up to 15 weirs and 20 weather stations (up to 3 total acres of disturbance) to support watershed research.
- Allocate/manage as old growth 40% of ponderosa pine and 77% of pinyon-juniper woodland on the Coconino NF and manage 35% of ponderosa pine and 58% of pinyon-juniper woodland on the Kaibab NF.

There would be a paired watershed research project implemented, involving six small watershed (smaller than 6th code).

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[5] A single prescribed fire may include burning piles and a follow-up broadcast burn. Prescribed fire would be implemented as indicated by monitoring data to augment wildfire acres, with the expectation that desired conditions would require a fire return interval of about 10 years.

Forest Plan Amendments

Three non-significant forest plan amendments would be required on the Coconino NF to implement Alternative C:

- **Amendment 1** would allow mechanical treatments up to 18-inch dbh to improve habitat structure (nesting and roosting habitat) in 18 MSO PACs. It would allow low-severity prescribed fire within 54 MSO PAC core areas. The amendment would remove language that limits PAC treatments in the recovery unit to 10% increments and language that requires the selection of an equal number of untreated PACs as controls. The amendment would remove language referencing monitoring (pre- and post-treatment, population, and habitat). Replacement language would defer final project design and monitoring to the FWS biological opinion specific to MSO for the project.

  The amendment, which is specific to restricted habitat in pine-oak, would allow for designating less than 10 % of restricted habitat on the Coconino NF as target or threshold (i.e. future nesting and roosting habitat) based on the quality of the habitat. Definitions of target and threshold habitat would be added. It would allow 6,299 acres of habitat to be managed for a low range of 110 - 150 basal area.
- **Amendment 2** would add the desired percentage of interspace within uneven-aged stands to facilitate restoration in goshawk habitat (excluding nest areas), add the interspace distance between tree groups, add language clarifying where canopy cover is and is not measured, allow 28,653 acres to be managed for an open reference condition, and add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- **Amendment 3** would remove the cultural resource standard that requires achieving a “no effect” determination and would add the words “or no adverse effect” to the remaining standard. In effect, management would strive to achieve a “no effect” or “no adverse effect” determination.

Effects of implementing plan amendments

Amendment 1 (Coconino NF): If amendment 1 is implemented, the resulting decreases in CBH, CBD, and CC would have the indirect effect of slightly decreasing crown fire potential for the 18 MSO PACs that would receive mechanical treatments. An additional indirect effect would be to increase the ability of fire managers to implement prescribed fire within PACs because of decreased potential fire behavior and effects. The ability to implement prescribed fire in 56 core areas would decrease potential fire behavior and effects, increasing the potential for desirable fire behavior and effects. If amendment 1 is not implemented on the Coconino NF, these 18 PACs (~10,700 acres) would retain the current forest structure that places them at high risk of high severity fire. Potential fire behavior would make it difficult to implement prescribed fire because of narrow burn windows (weather and fuel conditions that would produce the desired fire effects and behavior). If prescribed fires were implemented on acres adjacent to PACs, or core areas, it is more likely that firelines would need to be created to keep fire out of PACs and/or core areas, producing ground disturbance that would be less likely under the proposed amendment. There would be little effect on emissions, except for a slight decrease in potential emissions in the event of wildfire following mechanical treatments within the PACs.

Amendment 2 (Coconino NF): If amendment 2 is implemented, it would allow 28,653 acres to be managed for an open reference condition. An indirect effect of managing for open conditions would be to have little potential for active crown fire, moving these acres towards the desired conditions. Open conditions would, in the long run, produce fewer emissions because of less litter and debris from trees, and greater herbaceous component to surface fuels, which is a flashier fuel, burning faster and more cleanly quickly than woody fuels. If amendment 2 is not implemented on the Coconino NF, some treatments could be implemented, but would not move these acres as far towards desired conditions as they would be under the amendment.

Amendment 3 (Coconino NF): If amendment 3 is implemented, it would allow fire to be used to meet objectives if it was determined to be the best tool. Additionally, it would allow all significant, or potentially significant inventoried sites that are not considered 'fire sensitive' to be included in burn units. If amendment 3 is not implemented, all significant, or potentially significant inventoried sites within burn units, regardless of if they are considered 'fire sensitive' or not, would be managed for 'no effect' and/or avoidance.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative C are discussed in the following order.

1. Fire behavior is discussed at the treatment area scale
2. Potential fire type is discussed by vegetation type
3. Within Restoration Units and Subunits, fire type is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

When analyzed at the landscape scale, Alternative C would meet the purpose and need and move the majority of the acres towards the desired condition of having potential for less than 10% crown fire as modeled under the conditions that produced the Schultz Fire (Table 70). Non-burnable substrate constitutes ~2% of the treatment area and was not included in the acres shown fire potential fire behavior.

Table 70. Modeled fire type for Alternative C

All acres proposed for treatment	2010	2020
Surface fire (%)	61	94
Passive crown fire (%)	9	3
Active crown fire (%)	28	2

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced by breaking up the vertical and horizontal continuity of canopy fuels, decreasing excessive surface fuel loads of litter and duff, and replacing them with the light, flashy fuels that would be stimulated by post-treatment conditions (Noble 2012). Wildfire behavior would benefit the ecosystems in which it burned, and would not threaten lives, resources, or infrastructure. Air quality impacts (nuisance smoke) could increase some as first and second entry prescribed fires are implemented.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to canopy fuels, would remain lower than existing condition for about 68% of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by the direct effects on canopy fuels, would be expected to be better than the existing condition for 95% of the ponderosa pine, and shows in the mapping of potential fire type as well (Figure 55).

For surface fuel loading, about 52% would be improved from existing conditions, with an additional 41% less than 0.5 ton/acre short of existing forest plan direction. However, this 41% includes the savanna treatments, so CWD would be expected to be on the low side of the acceptable range (because of including savanna in the average).

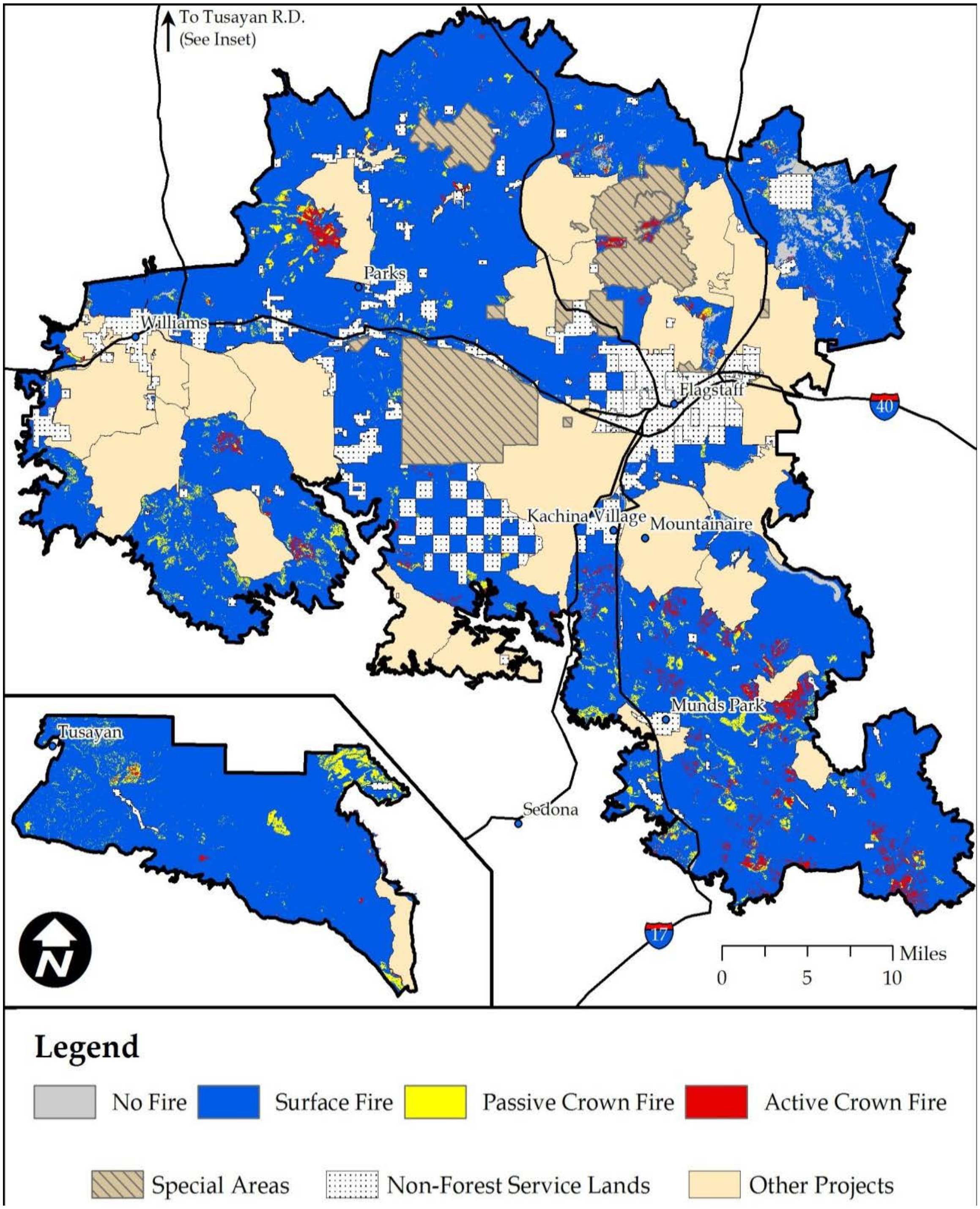

Figure 55. Modeled fire type for Alternative C, 2020

Air quality impacts (indirect effects) could decrease some as the treatment area is in maintenance mode for prescribed fires, producing fewer emissions per acre. Under Alternative C, the horizontal and vertical continuity of canopy fuels are broken up, decreasing the potential for crown fire from 37% of the treatment area to 5% of the treatment area, with potential for active crown fire decreasing from 28% to 2%. Non-burnable substrate constitutes ~1% of the treatment area and was not included in the acres shown fire potential fire behavior (Table 70 and Table 71).

Table 71. Modeled fire type in ponderosa pine habitat for Alt. C. Shaded areas would not meet desired conditions for ponderosa pine.

Vegetation Type		Fire Type	Existing Conditions		Alt. C 2020	
			Acres	%	Acres	%
Ponderosa Pine*	**All Pine****	**Surface**	**311,313**	**61%**	**476,369**	**94%**
		Passive crown	**48,023**	**9%**	**17,323**	**3%**
		Active crown	**143,186**	**28%**	**8,894**	**2%**
	Protected	Surface	17,954	51%	26,953	76%
		Passive crown	3,034	9%	1,896	5%
		Active crown	14,106	40%	6,247	18%
	Target/ Threshold	Surface	4,275	49%	8,260	95%
		Passive crown	922	11%	87	1%
		Active crown	3,482	40%	331	4%
	Restricted	Surface	35,019	53%	57,403	86%
		Passive crown	6,540	10%	8,360	13%
		Active crown	24,756	37%	572	1%
	PFA/ dPFA	Surface	18,400	61%	27,511	92%
		Passive crown	2,903	10%	1,910	6%
		Active crown	8,560	29%	442	1%
	LOPFA	Surface	235,666	64%	356,242	97%
		Passive crown	34,624	9%	5,071	1%
		Active crown	92,282	25%	1,301	0%
Other Vegetation*	Aspen	Surface	1,120	74%	1,207	79%
		Passive crown	135	9%	235	15%
		Active crown	258	17%	71	5%
	Grassland	Surface	41,491	86%	45,679	95%
		Passive crown	3,059	6%	18	0%
		Active crown	1,153	2%	2	0%
	Juniper Woodland	Surface	1,941	83%	2,331	100%
		Passive crown	74	3%	7	0%
		Active crown	320	14%	0	0%
	Oak Woodland	Surface	2,504	77%	3,215	99%
		Passive crown	266	8%	6	0%
		Active crown	466	14%	20	1%
	Pinyon/Juniper	Surface	19,379	83%	22,582	97%
		Passive crown	1,523	7%	343	1%
		Active crown	2,047	9%	43	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area

**Decreased treatment intensity on ~40,000 acres of ponderosa pine would be expected to shift about 1,750 acres from surface fire to passive or active crownfire outside of MSO habitat. There would be potential for an additional ~130 acres previously modeled as passive crownfire to support active crownfire.

Ponderosa Pine

The majority of ponderosa pine acres would meet desired conditions under Alternative C when acres are analyzed at the landscape scale. At the scale of ponderosa pine vegetation, the crown fire risk and effects are identical to Alternative B, with the exception of lower treatment intensity on ~40,000 acres of VSS4, VSS5, and VSS6 stands. In those stands, modeled fire behavior would shift about 1,750 acres from surface fire to crownfire and about 130 acres from passive to potentially active crownfire. When broken out by habitat type, 23% (8,143 acres) of protected habitat in ponderosa pine would still be at risk of crown fire, of which 8% (6,247 acres) would be active crown fire (Table 71). Active crown fire in protected habitat accounts for 70% of the active crown fire in ponderosa pine.

The amount of potential crown fire remaining after proposed treatments would be well within the historic ranges of ponderosa pine in this area. As illustrated by Figure 55, much of the active crown fire that remains following treatment is in Restoration Units 1 and, in most cases, would occur in MSO and goshawk habitat (Table 71).

Pine/Sage

Effects for Pine/Sage would be identical to Alternative B, as discussed on page 148.

Large/old trees

Effects on large and old trees would be identical to those described for Alternative B, page 147.

Aspen

There are 19 more acres of aspen treatments proposed in Alternative B than in Alternative C. Effects would be the same as those described in Alternative B under 'Aspen', page 147.

Gambel Oak

Effects would be identical to those discussed on page 149 in Alternative B under 'Gambel Oak', though there is potential for 49 more acres of Operational Burn. The exception would be for parts of the ~40,000 acres of decreased treatment intensity in which oak would continue to be suppressed. In these areas, large oaks would continue to be at some risk of high severity fire, though decreased somewhat from pre-treatment conditions.

Grasslands

Alternative C proposes to implement mechanical treatments and prescribed fire on 48,195 acres, and prescribed fire only on an additional 488 acres, for a total of 48,683 acres of treatments in grasslands. Desired Conditions would be met at all analysis scales.

Table 72. Modeled fire type in grasslands by Restoration Unit under Alternative C

Grassland RU	Fire Type	Veg type acres	Existing		Alt. C 2020	
			Acres	%	Acres	%
RU1	Surface	8,135	6,131	75%	7,699	95%
	Passive crown		1,340	16%	4	0%
	Active crown		236	3%	0	0%
RU3	Surface	12,772	11,670	91%	12,504	98%
	Passive crown		706	6%	5	0%
	Active crown		167	1%	0	0%
RU4	Surface	22,661	21,080	93%	22,542	99%
	Passive crown		788	3%	5	0%
	Active crown		645	3%	1	0%
RU5	Surface	4,536	2,521	56%	2,842	63%
	Passive crown		222	5%	4	0%

	Active crown		105	2%	1	0%
RU6	Surface	93	89	96%	93	100%
	Passive crown		2	2%	0	0%
	Active crown		1	1%	0	0%

Fire behavior would be similar to what would be expected in healthy grassland units in the treatment area, with the crown fire being passive. For those grassland acres that did burn, effects would be as described under Alternative B on page 150.

Pinyon/Juniper woodland (PJ)

Effects on fire type for PJ under Alternative C are virtually identical to those discussed in Alternative B (Table 73), differing by 6 acres of Operational Burn. Effects are as discussed under Alternative B on page 151. Table 74 displays modeled fire type in pinyon-juniper with a fuels objective.

Table 73. Fire type in all Pinyon/Juniper under Alternative C

Vegetation Type	Fire Type	2010 %/Acres	Alternative C 2020 %/Acres
Pinyon/Juniper	Surface crown fire	83/19,379	98/22,524
	Passive crown fire	7/1,523	2/379
	Active crown fire	9/2,047	0/41

Table 74. Fire type in the Pinyon/Juniper in Restoration Unit 6 (fuels reduction objective)

Vegetation Type	Fire Type	2010 %/Acres	Alternative C 2020 %/Acres
Pinyon/Juniper	Surface crown fire	74/595	100/533
	Passive crown fire	25/132	0/2
	Active crown fire	<2/8	0/0

Restoration Units

When analyzed at the scale of the Restoration Unit, Alternative C would meet desired conditions for fire type. Post-treatment potential for crown fire ranges from 7% in RU1 to 2% in RUs 4 and 5 (Table 75). ”No fire” includes water, rock, roads, cinders, areas of sparse vegetation, and other acres on which there were insufficient fuels to carry fire under the conditions modeled. These acres range from 44 acres (0.11%) in RU6 to 5,725 acres (7.82%) in RU5.

Table 75. Fire type for Alternative C by Restoration Units.

		Fire Acres*			Fire %		
	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	Surface Fire	Passive Crown Fire	Active Crown Fire
Alt. C (2020)	RU 1	142,435	5,264	5,745	92%	3%	4%
	RU 3	139,678	6,914	2,222	93%	5%	1%
	RU 4	161,663	3,012	450	98%	2%	0%

	RU 5	66,141	831	507	90%	1%	1%
	RU 6	41,467	1,912	106	95%	4%	0%
	Total	**551,384**	**17,933**	**9,031**	**94%**	**3%**	**2%**

*Decreased treatment intensity for ~40,000 acres would add potential crownfire on ~1,750 acres, and potential for active crown fire where previous modeling showed potential for passive crown fire on about 130 acres.

Restoration Unit 1

Restoration Unit 1 is of particular concern because Lake Mary is a source watershed for Flagstaff, and fire behavior in this RU could affect an observatory just north of Lower Lake Mary, and Walnut Canyon. There are adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer, as well as the city of Flagstaff to the northwest. Post-treatment modeling shows 7% (11,009 acres) of RU1 would have crown fire potential, of which 4% (5,745 acres) would be active crown fire. A 498 acre control watershed for a research project would not receive any treatment. It would account for 2% (200 acres) of all crown fire in RU1; 3% (176 acres) of the active crown fire in RU1.

Ponderosa pine occupies 144,113 acres in Restoration Unit 1, more than the other Restoration Units. Post-treatment, 8% (10,832 acres) of the ponderosa pine vegetation would have potential for crown fire, of which 4% (5,652) of it would be active crown fire (Table 76).

Table 76. Modeled fire type for RU1 by vegetation and habitat under Alternative C.

RU 1 acres =		154,383	Veg type acres	2010		Alt. C 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**144,113**	**80,257**	**56%**	**132,810**	**92%**
		Passive		**15,784**	**11%**	**5,180**	**4%**
		Active		**47,553**	**33%**	**5,652**	**4%**
	Protected	Surface	29,052	15,020	52%	22,098	76%
		Passive		2,246	8%	1,768	6%
		Active		11,728	40%	5,126	18%
	Target/ Threshold	Surface	4,793	2,236	47%	4,524	94%
		Passive		504	11%	40	1%
		Active		2,042	43%	218	5%
	Restricted	Surface	25,710	12,731	50%	22,479	87%
		Passive		2,601	10%	3,134	12%
		Active		10,348	40%	74	0%
	PFA/ dPFA	Surface	4,670	2,594	56%	4,590	98%
		Passive		518	11%	62	1%
		Active		1,558	33%	17	0%
	LOPFA	Surface	79,889	47,676	60%	79,118	99%
		Passive		9,915	12%	175	0%
		Active		21,877	27%	217	0%
Other Vegetation*	Aspen	Surface	420	241	57%	275	65%
		Passive		40	9%	75	18%
		Active		140	33%	70	17%
	Grassland	Surface	8,135	6,131	75%	7,699	95%
		Passive		1,340	16%	4	0%

		Active		236	3%	0	0%
	Juniper Woodland	Surface	286	236	83%	285	100%
		Passive		12	4%	1	0%
		Active		38	13%	0	0%
	Oak Woodland	Surface	287	195	68%	287	100%
		Passive		62	21%	0	0%
		Active		30	11%	0	0%
	Pinyon/ Juniper	Surface	1,141	897	79%	1,079	95%
		Passive		115	10%	4	0%
		Active		95	8%	23	2%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU1

**Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 175 acres of crownfire in ponderosa pine in RU1. This would not change the percentages.

The pine vegetation type meets desired conditions for fire type. All, or parts of 52 PACs occur in RU1, accounting for 20% (~29,000 acres) of the ponderosa pine. There is no desired fire type for protected habitat which, post-treatment, 24% (has potential for 2% (6,894 acres) of crown fire, of which 18% (5,126) would be active crown fire. Protected habitat would account for 91% of the active crown fire in RU1.

Aspen effects differ from Alternative B by15 acres and were considered to be identical (see discussion under Alternative B in ‘Restoration Unit 1’ on page 147).

Grasslands in Restoration Unit 1, would meet desired conditions for fire type. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to less than 1%, meeting desired conditions for fire type.

Pinyon/Juniper woodland effects differ from Alternative B by 10 acres and were considered to be identical (See discussion Alternative B page 152).

Oak woodland effects differ from Alternative B by 21 acres and were considered identical. See discussion on page 152. Under Alternative C, there would be no crown fire in oak woodland.

Subunits

When considered by the subunit (Table 77), four of the five subunits would meet desired conditions for fire type.

Table 77. Modeled fire type in Restoration Unit 1 subunits by vegetation type for 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative C	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
1-1	**10,170**	**165**	**9,919**	**84**	**1**	**<2%**	**98%**	**1%**	**0%**
Ponderosa Pine*	8,914	113	8,717	84	1	1%	98%	1%	0%
Grassland	567	18	549	0	0	3%	97%	0%	0%
Oak Woodland	173	0	173	0	0	0%	100%	0%	0%
Pinyon-Juniper	515	34	481	0	0	7%	93%	0%	0%
1-2	**8,054**	**70**	**7,840**	**145**	**0**	**1%**	**97%**	**2%**	**0%**
Ponderosa Pine*	6,517	24	6,348	145	0	<1%	97%	2%	0%
Grassland	1,537	45	1,492	0	0	3%	97%	0%	0%

1-3	**39,791**	**414**	**36,958**	**937**	**1,482**	**1%**	**93%**	**2%**	**4%**
Ponderosa Pine*	36,461	103	33,992	922	1,443	0%	93%	3%	4%
Aspen	88	0	35	15	38	0%	40%	17%	43%
Grassland	3,241	310	2,931	0	0	10%	90%	0%	0%
1-4	**18,250**	**18**	**17,453**	**207**	**572**	**0%**	**96%**	**1%**	**3%**
Ponderosa Pine*	17,285	7	16,510	206	562	0%	96%	1%	3%
Grassland	519	11	509	0	0	2%	98%	0%	0%
Oak Woodland	83	0	83	0	0	0%	100%	0%	0%
Pinyon-Juniper	363	0	352	2	10	0%	97%	0%	3%
1-5	**78,119**	**273**	**70,264**	**3,891**	**3,690**	**0%**	**90%**	**5%**	**5%**
Ponderosa Pine*	74,936	225	67,243	3,823	3,644	0%	90%	5%	5%
Aspen	332	0	240	61	32	0%	72%	18%	10%
Grassland	2,270	48	2,218	4	0	2%	98%	0%	0%
Juniper Woodland	286	0	285	1	0	0%	100%	0%	0%
Oak Woodland	32	0	32	0	0	0%	100%	0%	0%
Pinyon-Juniper	262	0	246	3	14	0%	94%	1%	5%

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands since previous modeling would add the potential for crownfire on <1 acre in 1-1 and 1-2; about 2 acres in 1-3 and 1-4, and about 170 acres in 1-5. This would raise crownfire potential in 1-5 to 11%.

Modeled fire type in Subunit 1-5 shows potential for crown fire would be 14% (11,235 acres), of which 9% (4,061 acres) would be active crown fire. The ponderosa pine in Subunit 1-5 has similar numbers, with 14% (10,568 acres) of crown fire, of which 9% (3,564 acres) would be active crown fire. This can be attributed to the presence of all, or parts, of 39 PACs within the Subunit, accounting for 27% of this SU. Crown fire in PACs would account for the majority of crown fire in SU1-5. Grasslands would meet desired conditions in all subunits.

Subunit 1-3 would have a 498 acre control watershed which, for research purposes, would receive no treatment. It would account for 9% (200 acres) of all crown fire in this SU1-3; 12% (176 acres) of the active crown fire in Subunit 1-3.

Restoration Unit 3

Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. Adjacency concerns for fire behavior include Interstates 40 and 17 which are adjacent to RU3 to the north and east, respectively, so that smoke from wildfires would have good potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, Williams, and Kachina Village. Additional concerns include Oak Creek, Oak Creek Canyon, and Sycamore Canyon. Under Alternative C, 6% (9,136 acres), of RU3 would have potential for crown fire, of which 1% (2,222 acres) would be active crown fire. Outside of PACs where there are some contiguous areas of both passive and active crown fire, though the majority of crown fire is scattered passive crown fire. Two control watersheds for research purposes would receive no treatment. They would account for 9% (835 acres) of all crown fire in RU3; 31% (686 acres) of the active crown fire.

<u>Ponderosa pine</u> in RU3 would have potential for 7% (8,992 acres) of crownfire, of which 2% (2,185 acres) would be active crown fire (Table 78). Ponderosa pine, as a veg type, in RU3 would meet desired conditions for fire type (<10% crown fire).

Table 78. Fire type by vegetation type and habitat for Restoration Unit 3

RU 3 acres =		149,715	Veg type acres	2010		Alt. C 2020	
Vegetation Type		Fire Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine	**All Pine***	**Surface**	**129,226**	**72,776**	**56%**	**119,606**	**93%**
		Passive		**12,594**	**10%**	**6,807**	**5%**
		Active		**43,256**	**33%**	**2,185**	**2%**
	Protected	Surface	4,793	2,020	42%	3,563	74%
		Passive		611	13%	127	3%
		Active		2,076	43%	1,020	21%
	Target/ Threshold	Surface	3,899	2,039	52%	3,736	96%
		Passive		481	11%	47	1%
		Active		1,440	37%	113	3%
	Restricted	Surface	38,527	21,085	55%	32,939	85%
		Passive		3,672	10%	5,035	13%
		Active		13,704	36%	498	1%
	PFA/ dPFA	Surface	5,582	2,948	53%	4,931	88%
		Passive		605	11%	499	9%
		Active		2,026	36%	150	3%
	LOPFA	Surface	76,424	44,683	58%	74,436	97%
		Passive		7,288	10%	1,099	1%
		Active		24,010	31%	403	1%
Other Vegetation	Aspen	Surface	201	144	72%	132	65%
		Passive		40	20%	70	35%
		Active		16	8%	0	0%
	Grassland	Surface	12,772	11,670	91%	12,504	98%
		Passive		706	6%	5	0%
		Active		167	1%	0	0%
	Juniper Woodland	Surface	1,851	1,559	84%	1,845	100%
		Passive		49	3%	4	0%
		Active		240	13%	0	0%
	Oak Woodland	Surface	1,633	1,282	79%	1,603	98%
		Passive		75	5%	5	0%
		Active		269	16%	20	1%
	Pinyon/ Juniper	Surface	4,033	3,351	83%	3,987	99%
		Passive		175	4%	24	1%
		Active		501	12%	16	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area in RU3

**Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for a little over 350 acres of crownfire in ponderosa pine in RU1. About 35 acres previously modeled as passive crownfire would have potential for active crownfire. Crownfire potential for ponderosa pine in RU3 would remain at ~7%

<u>Aspen</u> effects in RU3 differ from Alternative B by 6 acres and were considered to be identical. (See discussion under Alternative B in 'Restoration Unit 3' on page 155).

Grasslands would meet desired conditions for fire type under Alternative C. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to less than 1% (5 acres out of over 12,000), meeting desired conditions for fire type.

Pinyon/Juniper woodland effects differ from Alternative B by 11 acres and were considered to be identical (See discussion under Alternative B in 'Restoration Unit 3' on page 155).

Oak woodland effects under Alternative C would be identical to those in Alternative B (See discussion under Alternative B in 'Restoration Unit 3' on page 155). Under Alternative C, there would be no crown fire in oak woodland.

Subunits

All subunits would meet desired conditions for fire type and this scale (Table 79). Subunit 3-5 has the most crown fire potential, with 8% (3,042 acres) of the area having potential for crown fire. Subunit 3-5 has all, or parts of 10 PACs (1,477 acres) accounting for most of the active crown fire. There is potential for small areas of crown fire on slopes >30% in Subunits 3-5 (on the edge of Oak Creek Canyon and Sycamore Canyon), but these areas would be less than ½ acre and would be rare. There is one watershed in each of SUs 3-2 and 3-3 that would function as a 'control' watershed for research. No treatments would occur in either of these. In SU3-2, the control would account for 34% (408 acres) of the crownfire, of which 356 acres would be active crown fire. In SU3-3, the control would account for 14% (427 acres) of the crown fire, of which 330 acres would be active crown fire.

Table 79. Modeled fire type for Restoration Unit 3 subunits by vegetation type for 2020.

		Fire Type (acres)				Fire Type (%)			
Alternative C	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
3-1	**23,145**	**72**	**21,621**	**1,401**	**51**	**<1%**	**93%**	**6%**	**0%**
Ponderosa Pine*	18,805	35	17,361	1,358	51	<1%	92%	7%	0%
Aspen	91	0	54	37	0	0%	59%	41%	0%
Grassland	590	31	558	0	0	5%	95%	0%	0%
Juniper Woodland	907	1	905	2	0	0%	100%	0%	0%
Oak Woodland	845	1	842	2	0	0%	100%	0%	0%
Pinyon-Juniper	1,908	4	1,901	2	0	0%	100%	0%	0%
3-2	**32,726**	**294**	**31,237**	**763**	**433**	**1%**	**96%**	**2%**	**1%**
Ponderosa Pine*	22,885	134	21,597	741	412	1%	94%	3%	2%
Aspen	59	0	38	20	0	0%	66%	34%	0%
Grassland	9,611	160	9,450	1	0	2%	98%	0%	0%
Oak Woodland	172	0	150	1	20	0%	88%	<1%	12%
3-3	**48,434**	**63**	**45,507**	**2,216**	**648**	**0%**	**94%**	**5%**	**1%**
Ponderosa Pine*	44,426	48	41,532	2,199	648	<1%	93%	5%	1%
Aspen	50	0	38	12	0	0%	76%	24%	0%
Grassland	1,353	9	1,344	0	0	1%	99%	0%	0%
Juniper Woodland	873	1	870	2	0	0%	100%	0%	0%
Oak Woodland	232	3	228	0	0	1%	98%	<1%	0%

Pinyon-Juniper	1,500	3	1,496	2	0	0%	100%	0%	0%
3-4	**9,019**	**215**	**8,221**	**188**	**394**	**<3%**	**91%**	**2%**	**4%**
Ponderosa Pine*	8,920	201	8,137	188	394	<3%	91%	2%	4%
Grassland	99	15	84	0	0	15%	85%	0%	0%
Oak Woodland	0	0	0	0	0	0%	100%	0%	0%
3-5	**36,392**	**257**	**33,092**	**2,346**	**696**	**1%**	**91%**	**6%**	**2%**
Ponderosa Pine*	34,190	209	30,979	2,321	680	<1%	91%	7%	2%
Aspen	2	0	2	0	0	0%	100%	0%	0%
Grassland	1,120	48	1,068	3	0	4%	95%	<1%	<1%
Juniper Woodland	70	0	70	0	0	0%	100%	0%	0%
Oak Woodland	384	0	382	2	0	<1%	99%	<1%	0%
Pinyon-Juniper	626	0	590	21	15	0%	94%	3%	<3%

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for crownfire in ponderosa pine on about 91 acres in 3-1 (8%); 38 acres in 3-2 (no change in percent), 201 acres in 3-3 (7%); 5 acres in 3-4 (7%); and 12 acres in 3-5 (no change in percent).

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 10, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires.

Under Alternative C, there would be potential for 2% (3,462 acres) of the RU4 treatment area to burn with crown fire, <1% of which (450 acres) would be active crown fire. Most of the crown fire in RU4 would be in scattered patches, with few areas of contiguous active crown fire greater than about 15 acres, mostly in areas not classified as ponderosa pine. There would be larger contiguous acreages of passive crown fire in PFAs and areas of lower intensity treatments, and some burn only treatments.

Ponderosa pine in RU4 has potential for 4% (5,777 acres) to burn with crown fire, of which 1% (1,416 acres) would be passive crown fire (Table 80).

Aspen effects in RU3 differ from Alternative B by 4 acres and were considered to be identical. (See discussion on page 158).

Grasslands in RU4 would not meet desired conditions for fire type. The addition of mechanical treatments combined with fire shifts potential fire behavior in grasslands to potential for 13%% (2,895 acres) of potential crown fire, of which 4% would be active crown fire. This means the potential for undesirable fire effects and behavior in grasslands is zero.

Pinyon/Juniper woodland effects differ from Alternative B by 6 acres and were considered to be identical (See discussion on page 158).

Oak woodland effects under Alternative C would be identical to those in Alternative B (See discussion on page 158). Under Alternative C, there would be no crown fire in oak woodland.

Table 80. Modeled fire type for Restoration Unit 4 under Alternative C for 2020

RU 4 acres =		165,645	Veg type acres	2010		Alt. C 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	Surface	134,278	83,499	62%	130,482	97
		Passive		10,590	8%	2,969	2
		Active		39,763	30%	449	0
	Protected	Surface	558	379	68%	531	95
		Passive		45	8%	0	0
		Active		134	24%	27	5
	Restricted	Surface	1,576	751	48%	1,379	88
		Passive		196	12%	190	12
		Active		621	39%	0	0
	PFA/ dPFA	Surface	13,484	8,008	59%	12,269	91
		Passive		1,250	9%	1,058	8
		Active		4,221	31%	153	1
	LOPFA	Surface	118,659	74,361	63%	116,304	98
		Passive		9,100	8%	1,721	1
		Active		34,786	29%	269	0
Other Vegetation*	Aspen	Surface	497	403	81%	462	93
		Passive		31	6%	31	6
		Active		59	12%	0	0
	Grassland	Surface	22,661	21,080	93%	22,542	99
		Passive		788	3%	5	0
		Active		645	3%	1	0
	Juniper Woodland	Surface	118	69	59%	115	98
		Passive		4	3%	0	0
		Active		43	36%	0	0
	Oak Woodland	Surface	926	669	72%	923	100
		Passive		90	10%	1	0
		Active		165	18%	0	0
	Pinyon/ Juniper	Surface	7,165	5,855	82%	7,138	100
		Passive		453	6%	0	0
		Active		829	12%	0	0

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area in RU4

**Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 560 acres of crownfire in ponderosa pine in RU4. There would be potential for about 36 acres previously modeled as passive crown fire to be active crown fire. Overall, this would raise the potential for crownfire in RU4 to 3%.

Subunits

At the subunit level (Table 81) SU 4-5, though the smallest SU in the project (6,919 acres), is adjacent to the city of Flagstaff, and has steep topography, so that the second order fire effects (flooding, debris flows, etc.) of high severity fire has good potential to impact neighborhoods and schools. Under Alternative C, 1% (54 acres) of SU 4-5 would have potential for crown fire, of which 12 acres active crown fire. There would be no areas of contiguous crown fire greater than 2 acres in subunit 4-5. In subunit 4-3, there would be areas of contiguous passive crown fire of over 100 acres in burn-only units and/or PFAs. Passive crown fire could become active crown fire if the wind increased, or other conditions, such as fuel moisture, temperature, or humidity deteriorated. However, wind is the most important factor in extreme fire behavior and this was modeled with winds at the 98thile. These areas are surrounded by surface fire.

Table 81. Modeled fire type for Restoration Unit 4 subunits under Alternative C for 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative C	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
4-2	**10,227**	**55**	**9,924**	**215**	**33**	**1%**	**97%**	**2%**	**0%**
Ponderosa Pine*	7,381	15	7,120	214	33	<1%	96%	3%	0%
Aspen	1	0	1	0	0	29%	71%	0%	0%
Grassland	328	19	309	0	0	6%	94%	0%	0%
Juniper Woodland	8	0	8	0	0	0%	100%	0%	0%
Oak Woodland	567	2	564	1	0	<1%	99%	<1%	0%
Pinyon-Juniper	1,941	19	1,922	0	0	1%	99%	0%	0%
4-3	**67,012**	**325**	**64,948**	**1,480**	**259**	**<1%**	**97%**	**2%**	**<1%**
Ponderosa Pine*	55,312	308	53,273	1,472	258	1%	96%	3%	0%
Aspen	230	3	225	3	0	1%	98%	1%	0%
Grassland	6,951	11	6,939	1	1	0%	100%	0%	0%
Juniper Woodland	31	0	31	0	0	0%	100%	0%	0%
Oak Woodland	325	0	325	0	0	0%	100%	0%	0%
Pinyon-Juniper	4,162	2	4,155	5	0	0%	100%	0%	0%
4-4	**81,487**	**137**	**79,928**	**1,305**	**116**	**0%**	**98%**	**2%**	**0%**
Ponderosa Pine*	65,003	54	63,561	1,272	116	0%	98%	2%	0%
Aspen	255	0	228	27	0	<1%	89%	10%	0%
Grassland	15,055	81	14,969	5	0	1%	99%	0%	0%
Juniper Woodland	78	2	76	0	0	3%	97%	0%	0%
Oak Woodland	35	0	35	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,062	0	1,060	1	0	0%	100%	0%	0%
4-5	**6,919**	**2**	**6,863**	**12**	**42**	**0%**	**99%**	**0%**	**1%**
Ponderosa Pine*	6,581	1	6,528	11	42	0%	99%	0%	1%
Aspen	11	0	9	2	0	0%	86%	14%	0%
Grassland	327	2	325	0	0	1%	99%	0%	0%

*Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for crownfire in ponderosa pine on about 18 acres in 4-2 (4%); 330 acres in 4-3 (4%) and 210 acres in 4-4 (3%).

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 mostly on Mount Eldon, immediately upslope and adjacent to northern Flagstaff). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. There are many areas, some larger than 500 acres, in the north and eastern areas of this RU that are cinder substrate, and have no potential for fire. These areas consist of cinder cones, and cinder soils which generally support sparse vegetation. In these areas, active crown fire is less likely because of decreased potential for high intensity surface fire. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

Under Alternative C (Table 82), there would be potential for 2% of RU5 (838 acres) of crown fire, of which 507 would be active. Crown fire is scattered, with the majority of it in small areas on the north side of the Peaks, in PACs on the southwest aspect of the Peaks or the north aspect of Mount Eldon near Schultz Pass.

Table 82. Modeled fire type for Restoration Unit 5 under Alternative C, 2020

RU 5 acres =		73,203		2010		Alt. C 2020	
Vegetation Type		Type	Veg type acres	Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**59,034**	**41,109**	**70%**	**54,034**	**92%**
		Passive		**6,821**	**12%**	**767**	**1%**
		Active		**7,376**	**12%**	**502**	**1%**
	Protected	Surface	859	535	62%	761	89%
		Passive		132	15%	0	0%
		Active		167	19%	75	9%
	Restricted	Surface	606	451	74%	606	100%
		Passive		71	12%	0	0%
		Active		83	14%	0	0%
	PFA/ dPFA	Surface	2,227	1,343	60%	1,949	87%
		Passive		419	19%	114	5%
		Active		325	15%	24	1%
	LOPFA	Surface	55,341	38,780	70%	50,719	92%
		Passive		6,199	11%	652	1%
		Active		6,801	12%	403	1%
Other Vegetation*	Aspen	Surface	403	332	82%	338	84%
		Passive		24	6%	59	15%
		Active		43	11%	1	0%
	Grassland	Surface	4,536	2,521	56%	2,842	63%
		Passive		222	5%	4	0%
		Active		105	2%	1	0%
	Juniper Woodland	Surface	74	67	90%	74	99%
		Passive		7	9%	0	1%
		Active		0	1%	0	0%
	Oak Woodland	Surface	386	349	91%	372	96%
		Passive		20	5%	0	0%
		Active		1	0%	0	0%
	Pinyon/ Juniper	Surface	8,771	7,804	89%	8,481	97%
		Passive		277	3%	1	0%
		Active		393	4%	4	0%

* Nonburnable substrate constitutes about 6% of ponderosa pine and about 8% of the entire treatment unit within RU5

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 14 acres of crownfire in ponderosa pine in RU4. There would be potential for about 36 acres previously modeled as passive crown fire to be active crown fire.

Ponderosa pine would have potential for 2% (1,269 acres) crown fire after treatment, of which 1% (502) would be active crown fire. Ponderosa pine would meet desired conditions.

Aspen effects in RU5 differ from those in Alternative B by 6 acres, and were considered to be identical. See discussion on page 161.

Grasslands in RU4 would meet desired conditions for fire type. Mechanical treatments combined with fire would reduce potential crown fire in grasslands to less than 1% (5 acres out of 4,536), meeting desired conditions for fire type. This means there is no potential for undesirable fire effects and behavior in grasslands.

Pinyon/Juniper woodland effects differ from those in Alternative B by 2 acres, and were considered to be identical. See discussion Alternative B on page 160.

Oak woodland effects would differ from Alternative B by 6 acres. See discussion on under Alternative B, page 160.

Subunits

Subunit 5-2 (Table 83) includes sparsely vegetated cinder cones, as well as areas that sustained second order fire effects from the Schultz Fire. Both subunits in RU5 would meet desired conditions for fire type. There is a PAC north of Chimney Spring, and adjacent to the Schultz Pass road where there would be about 70 acres of active crown fire within ½ mile, and uphill from Schultz Pass road.

Table 83. Modeled fire type in Restoration Unit 5 subunits by vegetation type for 2020.

Alternative C	Acres	Fire Type (acres)				Fire Type (%)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
5-1	**21,341**	**792**	**19,725**	**417**	**406**	**4%**	**92%**	**2%**	**2%**
Ponderosa Pine*	18,040	746	16,532	357	405	4%	92%	2%	2%
Aspen	392	5	328	59	1	1%	83%	15%	<1%
Grassland	1,239	19	1,219	1	0	2%	98%	0%	0%
Oak Woodland	95	0	95	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,574	23	1,551	0	0	1%	99%	0%	0%
5-2	**51,863**	**4,932**	**46,416**	**414**	**101**	**10%**	**89%**	**1%**	**0%**
Ponderosa Pine*	40,994	2,986	37,501	410	97	7%	91%	1%	<1%
Aspen	10	0	10	0	0	0%	100%	0%	0%
Grassland	3,297	1,670	1,623	3	1	51%	49%	0%	0%
Juniper Woodland	74	0	74	0	0	0%	99%	1%	0%
Oak Woodland	291	14	277	0	0	5%	95%	0%	0%
Pinyon-Juniper	7,196	262	6,931	1	3	4%	96%	0%	0%

*Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 3 acres of additional crownfire in ponderosa pine in 5-1, and about 11 acres in 5-2.

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area. Modeled post-treatment fire type shows 4% (1,918 acres) would have potential for crown fire, of which <1% (106 acres) would be active crown fire. Alternative C would meet fire behavior objectives in RU6.

Ponderosa pine in RU6, most active crown fire is in the ponderosa pine vegetation type and mostly in three areas. PFA/dPFA habitat accounts for 97 of the 106 acres of active crown fire (Table 84).

Table 84. Modeled fire type for Restoration Unit 6 under Alternative C, for 2020

RU 6 acres =		43,530	Veg type acres	2010		Alt. C 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**41,189**	**33,673**	**82%**	**39,437**	**96%**
		Passive		**2,233**	**5%**	**1,601**	**4%**
		Active		**5,238**	**13%**	**106**	**0%**
	PFA/ dPFA	Surface	4,050	3,506	87%	3,772	93%
		Passive		111	3%	177	4%
		Active		430	11%	97	2%
	LOPFA	Surface	37,139	30,167	81%	35,665	96%
		Passive		2,123	6%	1,424	4%
		Active		4,808	13%	9	0%
Other Vegetation*	Grassland	Surface	93	89	96%	93	100%
		Passive		2	2%	0	0%
		Active		1	1%	0	0%
	Juniper Woodland	Surface	13	10	79%	11	85%
		Passive		3	21%	2	15%
		Active		0	0%	0	0%
	Oak Woodland	Surface	30	9	30%	29	99%
		Passive		20	68%	0	1%
		Active		1	2%	0	0%
	Pinyon/ Juniper	Surface	2,206	1,472	67%	1,897	86%
		Passive		504	23%	308	14%
		Active		229	10%	0	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU6

**Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 646 acres of crownfire in ponderosa pine in RU4. There would be potential for about 61 acres previously modeled as passive crown fire to be active crown fire. Overall, this would raise the potential for crownfire in RU6 to 6%.

Grasslands in RU4 would meet desired conditions for fire type. The means the potential for undesirable fire effects and behavior in grasslands is less than 1% under conditions modeled.

Pinyon/Juniper woodland effects differ from Alternative B by 10 acres, and were considered to be identical. See discussion under on page 162.

Oak woodland effects under Alternative C are identical to those in Alternative B, with 1 acre difference. See discussion on page 162.

Subunits

Under Alternative C, desired conditions fire type would be met in Subunits 6-2 and 6-3. Subunit 6-4, exceeds desired conditions for fire type, but has decreased by over 10% from existing conditions and is moving towards desired conditions. Much of the passive crown fire in this unit comes from vegetative intergrading with Gambel oak, juniper, and pinyon pine (see Figure 28).

Table 85. Modeled fire type in Restoration Unit 6 subunits by vegetation type for 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative C	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
6-2	**5,551**	**7**	**5,376**	**168**	**0**	**0%**	**97%**	**3%**	**0%**
Ponderosa Pine	5,069	7	4,896	166	0	0%	97%	3%	0%
Pinyon-Juniper	483	0	481	2	0	0%	100%	0%	0%
6-3	**34,109**	**33**	**33,105**	**866**	**105**	**0%**	**97%**	**3%**	**0%**
Ponderosa Pine	32,635	33	31,741	757	105	<1%	97%	2%	0%
Grassland	85	0	85	0	0	0%	100%	0%	0%
Juniper Woodland	13	0	11	2	0	0%	85%	15%	0%
Pinyon-Juniper	1,375	0	1,268	107	0	0%	92%	8%	0%
6-4	**3,870**	**4**	**2,986**	**879**	**1**	**0%**	**77%**	**23%**	**0%**
Ponderosa Pine*	3,484	4	2,801	678	1	<1%	80%	19%	<1%
Grassland	7	0	7	0	0	0%	100%	0%	0%
Oak Woodland	30	0	29	0	0	0%	99%	1%	0%
Pinyon-Juniper	348	0	148	200	0	0%	43%	57%	0%

*Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential crown fire in ponderosa pine on about 646 acres in 6-4 (38%).

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 15, desired openness is an indication of the relative desired post treatment interspace/tree group condition.

Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 168. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 86 for more details).

Canopy characteristics affecting fire behavior

Changes to Canopy Cover (CC), Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are direct effects, though they are not always apparent in the fire behavior data (indirect effects). Post-treatment conditions (2020), under Alternative C show changes in canopy cover significant enough that the treatment area would meet desired conditions (Table 86). Desired conditions for canopy base height (CBH) are 18 feet or higher; desired conditions for canopy bulk density (CBD) are for 0.05 or less. Alternative C would meet desired conditions for CBH and CBD.

Table 86 shows a decrease in CBD and an increase in CBH as a direct effect of treatments. This decreases the potential for crown fire initiation (because CBH is higher), less potential for passive crown fire (because of higher CBH and lower CBD), and less potential for active crown fire (lower CC and lower CBD). Under Alternative C, desired conditions would be met for CBH and CBD for most ponderosa pine. Very Low (PAC Burn Only) and Very Low (Core Areas) would not meet desired conditions.

Figure 56 shows trends for all levels of desired openness. Assumptions are that prescribed fire and mechanical treatments occurred between 2010 and 2020 and no treatments of any kind occurred between 2020 and 2050. In the two least intense treatment types, the initial values (2010) start at the highest (for CBD and CC) and the lowest (CBH). Post-treatment, for those two treatments the increase in canopy cover (CC) from 2010 to 2020 combined with only modest decreases in CBD suggest that conditional Crown fire is still likely in those treatment areas.

Table 86. Modeled trends in canopy characteristics for Alternative C. Shaded cells would not meet desired conditions.

Alt C	CBH* (feet)			CBD* (kg/m3)			CC* (%)			% of pond. pine
Desired Openness	**2010**	**2020**	**2050**	**2010**	**2020**	**2050**	**2010**	**2020**	**2050**	
High	15	28	29	0.061	0.025	0.031	41	21	29	41%
Moderate	15	25	26	0.061	0.030	0.040	43	26	36	24%
Low (Mechanical)	16	26	28	0.063	0.035	0.043	42	28	37	6%
Low (Burn Only)	14	20	25	0.046	0.036	0.037	33	27	32	18%
Very Low (Burn Only)	15	21	26	0.063	0.048	0.049	41	35	39	2%
Very Low (Mechanical)	16	25	30	0.062	0.045	0.047	48	42	50	4%
Very Low (PAC Burn Only)	14	17	23	0.067	0.065	0.064	49	49	53	4%
Very Low/No Proposed Treatments (Core Areas)	14	17	23	0.070	0.068	0.067	51	51	54	1%
No Proposed Treatments	16	18	23	0.049	0.053	0.055	39	43	48	<1%
Weighted Average[4]	15	25	27	0.059	0.032	0.037	41	26	34	

*Decreased treatment intensity on ~40,000 acres of VSS4, VSS5, and VSS6 would result in some shifts in 'High', 'Moderate', and some 'Very Low (Mechanical)'. Expected changes would include increases in CC and CBH, and decreases in CBD. The changes would not be of a magnitude that would be expected to shift the overall weighted averages out of the desired conditions for CBH or CBD.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of the proposed treatments that have indirect effects on fire behavior and effects. General effects for Alternative C are the same as Alternative B, (see discussion on page 166). Under Alternative C, Forest Plan guidelines for CWD (5 – 7 tons/acre) are met for Very Low (Burn Only), Very Low (PAC Burn Only), and Very Low (Core Areas) in 2020, for a total of about 41,000 acres, or 9% of the ponderosa pine. For about 410,000 acres CWD values range from 2.46 to 2.96, too low to meet desired conditions. Alternative C would leave the treatment area deficit in CWD in some areas although, modeling for this project and research (Waltz et al. 2003, Haase and Sackett 2008, Roccaforte et al. 2012) suggest that it would be just a year or two before CWD levels once again met desired conditions (Figure 57). Assumptions for Table 87 include one mechanical treatment and two prescribed fires between 2010 and 2020, and no addition treatments or disturbances of any kind occurred between 2020 and 2050. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD.

Historical values were around 5 tons per acre on the high end for CWD, and less than 2.5 tons/acre for duff (Brown et al 2003) so, assuming ~2.5 for litter, all levels of desired openness except the lowest two would be within the historical range of surface fuel loading in 2020, and would exceed it by 2050.

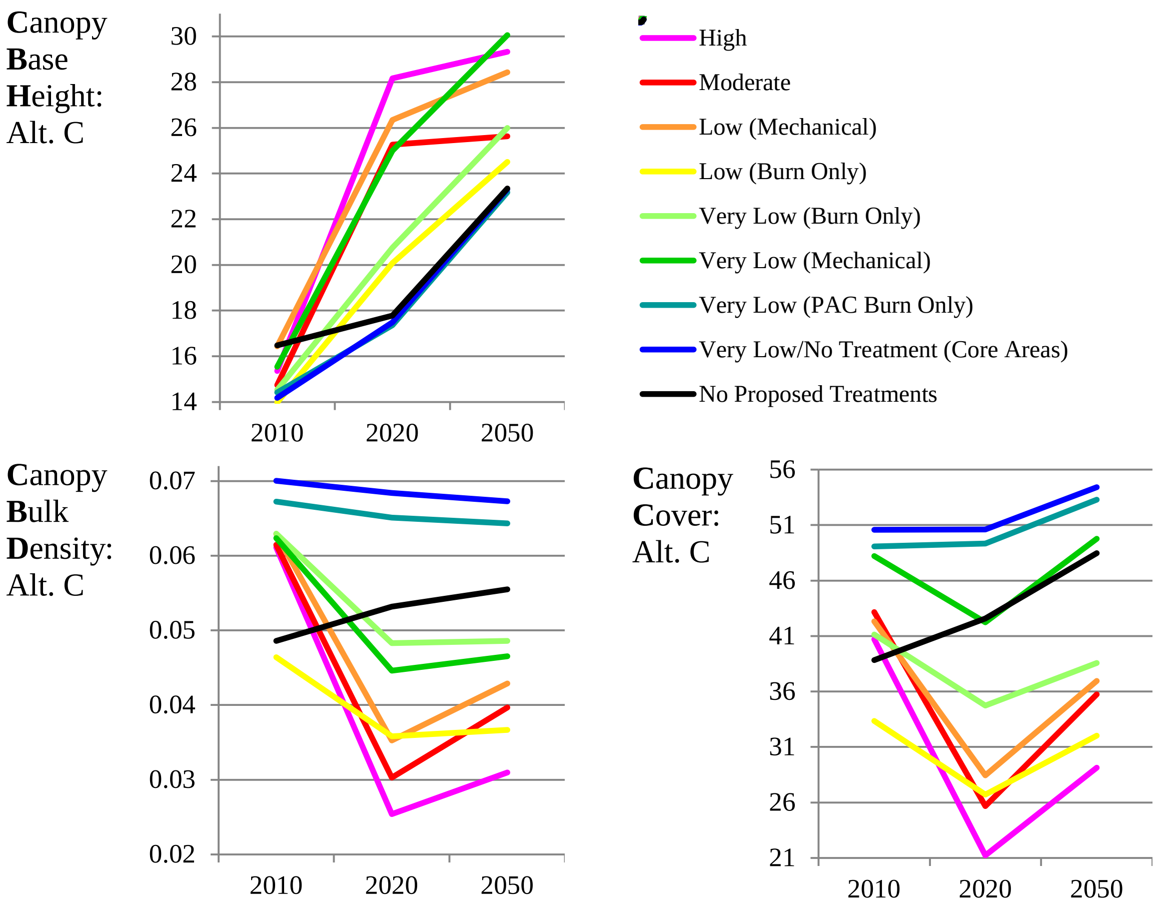

Figure 56. Modeled trends in canopy characteristics under Alternative C.

Surface fuel loading by treatment ability to maintain desired openness

Except for High, total surface fuel loading exceeds pre-treatment levels by 2050, illustrating the role of fire in regulating surface fuel loading. CWD>3” and Duff both increase from 2010 to 2050, litter decreases. By 2050, 48% of ponderosa pine exceeds forest guidelines for CWD>3”.

With duff, litter, and canopy fuels decreased, more sunlight and precipitation would reach the surface, stimulating more vigorous growth of surface vegetation, which would support the low intensity, low severity surface fires to which ponderosa pine is well adapted.

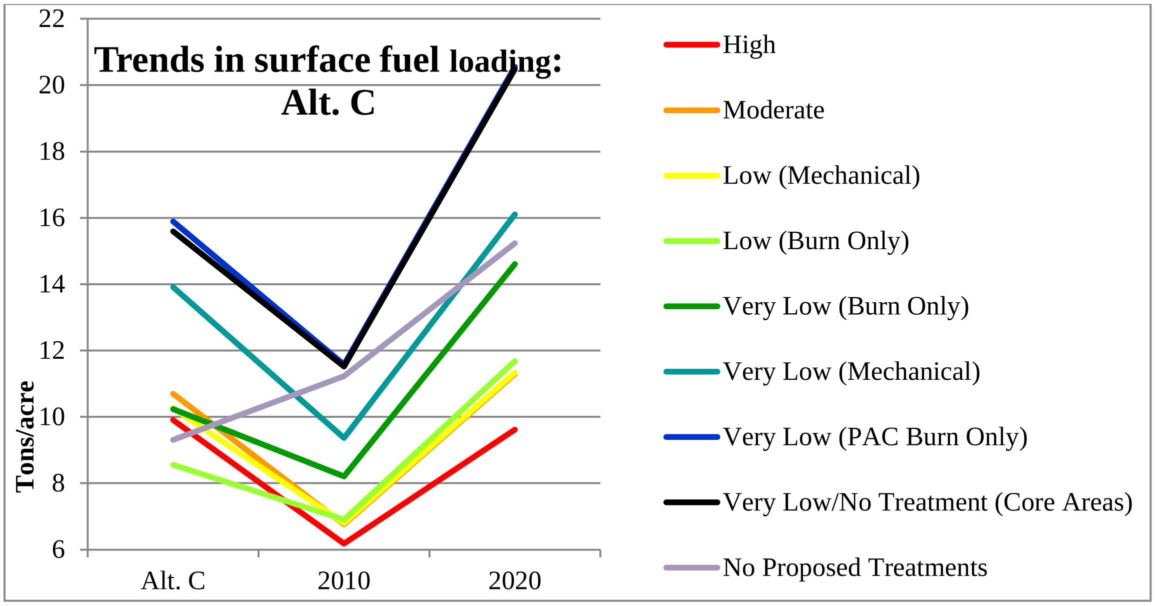

Figure 57. Modeled trends for surface fuel loading for Alternative C.

Table 87. Modeled changes to surface fuel loading for Alternative C.

Desired openness	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			% of pond pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.7	2.7	4.7	3.1	1.3	2.5	3.1	2.2	2.5	9.9	6.2	9.6	41
Moderate	3.7	2.8	5.3	3.9	1.8	3.4	3.1	2.2	2.6	10.7	6.8	11.3	24
Low (Mechanical)	3.8	2.8	5.6	3.2	1.7	3.1	3.3	2.3	2.7	10.3	6.8	11.3	6
Low (Burn Only)	3.2	2.8	6.2	2.5	1.6	2.6	2.9	2.5	2.9	8.6	6.9	11.7	18
Very Low (Burn Only)	3.8	3.2	7.8	3.2	2.0	3.4	3.2	3.0	3.4	10.2	8.2	14.6	2
Very Low (Mechanical)	5.0	2.8	6.0	5.0	2.5	5.4	3.9	4.1	4.7	13.9	9.4	16.1	4
Very Low (PAC Burn Only)	6.0	3.3	8.5	4.8	3.0	6.0	5.1	5.3	6.0	15.9	11.6	20.5	4
No Proposed Treatments (Core Areas)	5.8	3.4	8.5	5.1	3.2	6.3	4.7	4.9	5.7	15.6	11.5	20.5	1
No Proposed Treatments	3.0	3.9	6.5	3.8	4.5	5.1	2.4	2.9	3.6	9.3	11.2	15.2	<1
Weighted Averages[4]	**3.7**	**2.8**	**5.4**	**3.3**	**1.6**	**3.0**	**3.2**	**2.5**	**2.9**	**10.3**	**6.9**	**11.4**	

Surface fuel loading by stand

Figure 58 shows the distribution of fuel loading post-treatment when evaluated at the stand level for 2020. Across most of the treatment area, fuel loading has decreased below 20 tons/acre. There are a few areas that exceed 20, 25, 30, and 35 tons per acre, mostly in RU3 in PACs, a few areas in RU4 and two areas in RU5. Under Alternative C, there would be about 810 acres with surface fuel loading greater than 20 tons/acre, and 1,759 acres in the 15 – 20 tons/acre range. By 2040, there would be 3,531 acres exceeding 20 tons/acre, and 56,674 acres in the 15 – 20 tons/acre range.

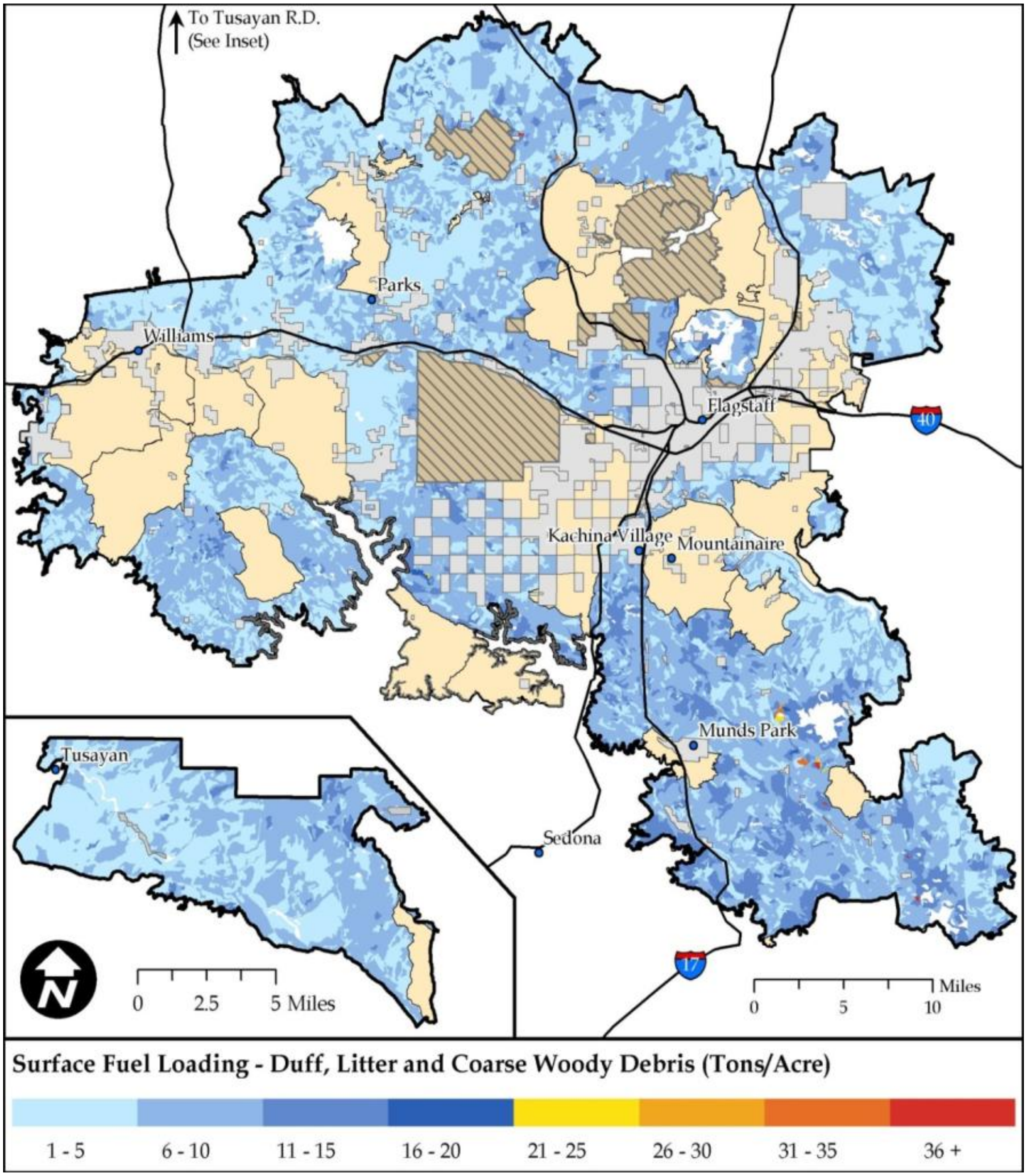

Figure 58. Modeled fuel loading for Alternative C.

Fire Regime/Condition Class

Under Alternative C, Fire Regime/Condition Class (FRCC) would move toward the desired condition of an overall rating of FRCC2 for the treatment area, and having no remaining acres in VCC3. Changes in grasslands are more subtle and, with the exception of woody encroachment, not as obvious because the matrix species dominance (grasses, as opposed to forbs) shifts occur slowly. With no disturbance of any kind (mechanical or fire treatments, wildfire, insects, disease, etc.), some effects of the treatments proposed in Alternative C persist, maintaining an FRCC of 2 after 30 years. Grassland treatments in Alternative C include both mechanical treatments and thinning treatments, which should move the majority of grassland acres out of FRCC3. The proposed treatments would improve the stability of key ecosystem elements. Treatments proposed under Alternative C (Table 88) would shift over 289,000 acres of the ponderosa pine out of VCC3.

Table 88. Fire Regime/Condition Class for Alternative C

VCC – Alt. C	2010		2020		2050	
	Acres	Percent	Acres	Percent	Acres	Percent
1	71,097	14%	137,117	27%	81,254	16%
2	126,960	25%	350,409	69%	248,841	49%
3	309,782	61%	20,314	4%	177,744	35%
Vegetation departure =	66%		38%		69%	
Fire Severity Departure =	74%		40%		33%	
Fire Return Interval Departure =	80%		20%		60%	
FRCC of treatment area =	**3**		**2**		**2**	

Fire Return Interval

The effects of Alternative C (Table 89) are identical to those of Alternative B, except that there are no areas that would not move towards a sustainable, resilient fire regime. See discussion on page 174.

As with Alternative B, this should be interpreted with caution, however, because it is the long term cycle of fire return intervals that regulates a system. Up to two prescribed fires would set the treatment area on a trajectory towards a restored condition, but maintenance fires would continue to be needed to avoid the ecosystem slipping back to an unsustainable condition.

Table 89. Average Fire Return Intervals for Alternative C

Alternative C	# of years averaged	Average annual acres burned	Fire Return Interval over years averaged
Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
2020	20 (2001- 2020)	58,611 (2001- 2020)	10
2050	40 (2001- 2050)	29,306 (2001- 2050)	20

Emissions: Air Quality and Ecological Effects

This alternative would meet the purpose and need, and desired conditions for Air Quality. The effects (indirect) would be almost identical to those in Alternative B, with the exceptions being the additional acres of MSO habitat and grasslands proposed for burning. Most acres in PACs and nest cores would be first entry burns, but all the surface fuel load would not be burned in one entry, so the smoke would be dispersed over time. See discussion on page 171.

Under this alternative, an average of 58,333 acres would need to burn every year, either from wildfire or prescribed fire with a total of 586,110 acres proposed for burning. This Alternative Differs from Alternative B by treating the PACs with prescribed fire. While this would initially produce a greater volume of smoke, in the long run, it would minimize wildfire emissions and effects, and allow prescribed fire to be used in the future with lower emissions.

Ecological effects of smoke

The ecological effects of smoke would be identical to those under Alternative B, except that they would extend to those 5,288 acres that were not proposed for burning under Alternative B and are under Alternative C, mostly PACs and nest areas.

Stream/spring restoration

Effects on stream/spring restoration would be identical to those in Alternative B. See discussion on page 174.

Roads

Road effects would be identical to those in Alternative B. See discussion on page 174.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources would be identical to those in Alternative B. See discussion on page 174.

Alternative D

From a fire ecology perspective, the direct and indirect effects of Alternatives D relate to treatments that include either mechanical thinning or prescribed fire, but only one or the other would occur on any one acre. Alternative D responds to Issue 2 (prescribed fire emissions) by decreasing prescribed fire acres by about 70% when compared to alternative B (proposed action). On average, 40 – 60,000 acres of prescribed fire would be implemented annually across the Forests (within the treatment area). Up to two prescribed fires would be conducted on all acres proposed for burning over the 10-year period. A select number of MSO PACs would be mechanically treated but would not be burned with prescribed fire. All other components of the alternative are the same as described in alternative B.

The Coconino and Kaibab NFs would conduct restoration activities on approximately 563,407 acres over a period of 10 years or until objectives are met. On average, 45,000 acres of vegetation would be mechanically treated annually. Restoration activities would:

- Mechanically cut trees on approximately 384,966 acres. This includes: (1) mechanically treating up to 16-inch dbh within 18 Mexican spotted owl protected activity centers, and, (2) disposing of slash through various methods including chipping, shredding, mastication, and removal of biomass off-site
- Utilize prescribed fire only on approximately 178,441 acres (no mechanical treatments).
- Construct 520 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed).
- Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no new permanent roads would be constructed). Of these miles, approximately 30 miles would be improved to allow for haul (primarily widening corners to improve turn radiuses) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.
- Decommission 726 miles of existing system and unauthorized roads on the Coconino NF.
- Decommission 134 miles of unauthorized roads on the Kaibab NF.
- Restore 74 springs and construct up to 4 miles of protective fencing.
- Restore 39 miles of ephemeral channels.
- Construct up to 82 miles of protective (aspen) fencing.
- Allocate/manage as old growth 40% of ponderosa pine and 77 percent of pinyon-juniper woodland on the Coconino NF, and manage 35% of ponderosa pine and 58% of pinyon-juniper on the Kaibab NF.

Forest Plan Amendments

Three non-significant forest plan amendments would be required on the Coconino NF to implement Alternative D:

- **Amendment 1** would add language to allow mechanical treatments up to 16-inch dbh. to improve habitat structure (nesting and roosting habitat) in 18 MSO PACs. The amendment would remove language that limits PAC treatments in the recovery unit to

10% increments and language that requires the selection of an equal number of untreated PACs as controls. The amendment would remove language referencing monitoring (pre- and post-treatment, population, and habitat). Replacement language would defer final project design and monitoring to the FWS biological opinion specific to MSO for the project.

The amendment, which is specific to restricted habitat in pine-oak, would allow for designating less than 10% of restricted habitat on the Coconino NF as target or threshold (i.e., future nesting and roosting habitat) based on the quality of the habitat. Definitions of target and threshold habitat would be added.

- **Amendment 2** would add the desired percentage of interspace within uneven-aged stands to facilitate restoration in goshawk habitat (excluding nest areas), add the interspace distance between tree groups, add language clarifying where canopy cover is and is not measured, allow 28,952 acres to be managed for an open reference condition, and add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- **Amendment 3** would remove the cultural resource standard that requires achieving a “no effect” determination and would add the words “or no adverse effect” to the remaining standard. In effect, management would strive to achieve a “no effect” or “no adverse effect” determination.

Effects of implementing plan amendments

Amendment 1 (Coconino NF): If amendment 1 is implemented, the resulting decreases in CBH, CBD, and CC would have the indirect effect of slightly decreasing crown fire potential for the 18 MSO PACs that would receive mechanical treatments. If amendment 1 is not implemented on the Coconino NF, these 18 PACs would retain the current forest structure that places them at high risk of high severity fire. If prescribed fire was the proposed treatment on acres adjacent to PACs, it is more likely that some firelines would need to be created to avoid burning, producing ground disturbance that would be less likely under the proposed amendment. There would be little effect on emissions, except for a slight decrease in potential emissions in the event of wildfire following mechanical treatments within the PACs.

Amendment 2 (Coconino NF): If amendment 2 is implemented, it would allow 29,054 acres to be managed for an open reference condition. An indirect effect of managing for open conditions would be to have little potential for active crown fire, moving these acres towards the desired conditions. Open conditions would, in the long run, produce fewer emissions because of less litter and debris from trees, and greater herbaceous component to surface fuels, which is a flashier fuel, burning faster and more cleanly quickly than woody fuels. If amendment 2 is not implemented on the Coconino NF, some treatments could be implemented, but would not move these acres as far towards desired conditions as they would be under the amendment.

Amendment 3 (Coconino NF): If amendment 3 is implemented, it would allow fire to be used to meet objectives if it was determined to be the best tool. Additionally, it would allow all significant, or potentially significant inventoried sites that are not considered ‘fire sensitive’ to be included in burn units. If amendment 3 is not implemented, all significant, or potentially significant inventoried sites within burn units, regardless of if they are considered ‘fire sensitive’ or not, would be managed for ‘no effect’.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative D are discussed in the following order.

1. Fire behavior is discussed at the treatment area scale
2. Potential fire type is discussed by vegetation type
3. Within Restoration Units and Subunits, fire type is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

Alternative D proposes to use a combination of mechanical only treatments and prescribed fire only treatments to meet the purpose and need of the 4FRI and move the treatment area for Alternative D (563,407 acres) toward the desired condition. There would be no acres on which both mechanical and prescribed fire treatments would be implemented.

Operationally, it would be difficult implement fire on all of the 178,753 acres for which it is proposed because of the necessity to lay out burn units in an operationally sound manner. Implementing fire across all the acres proposed for burning would require firelines to be built around burn units that would either necessitate burning acres not analyzed in Alternative D for burning, or blocking additional acres out of burning that are proposed for burning under Alternative D.

This alternative would meet direction in the Forest Service Manual 5100 (page 9) on USFS use of prescribed fire to meet land and resource management goals and objectives. See Alternative B, pg. 145 for details on Forest Service Manual direction.

No use of prescribed fire on 384,966 acres would eliminate many of the ecological role/s of fire that are necessary and beneficial to healthy forests and watersheds in the 4FRI treatment area. Potential for crown fire would decrease on those acres, and the potential for high severity surface effects would increase or stay the same. Fires that did occur in on the 384,966 acres would be wildfires.

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced (indirect effects of proposed treatments) by breaking up the vertical and horizontal canopy fuels (direct effects of proposed treatments). In mechanically treated areas, potential for high severity surface fires would remain the same or increase. In burn only areas, canopy base heights would increase and canopy bulk densities would decrease, decreasing the potential for crown fire, and surface fuel loads of litter and duff would be reduced (all direct effects), and replaced by the light, flashy fuels that would be stimulated by post-treatment conditions (indirect effects), decreasing the potential for high severity surface fire effects (indirect effects). Air quality impacts (indirect effects) could increase some as first and second entry prescribed fires are implemented.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to canopy fuels, would not maintain desired conditions for about 10% of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by changes to canopy fuels and surface fuel loading, would not remain lower than existing condition for any of the ponderosa pine in the treatment area. Air quality impacts (indirect effects) would decrease as the acres are moved in to maintenance mode and fewer emissions per acre are produced by fire.

When analyzed at the scale of the treatment area, Alternative D would move the treatment area towards the desired condition of having potential for less than 10% crown fire as modeled under the conditions that produced the Schultz Fire (Table 90 and Figure 59). Non-burnable substrate constitutes ~2% of the treatment area and was not included in the acres shown fire potential fire behavior.

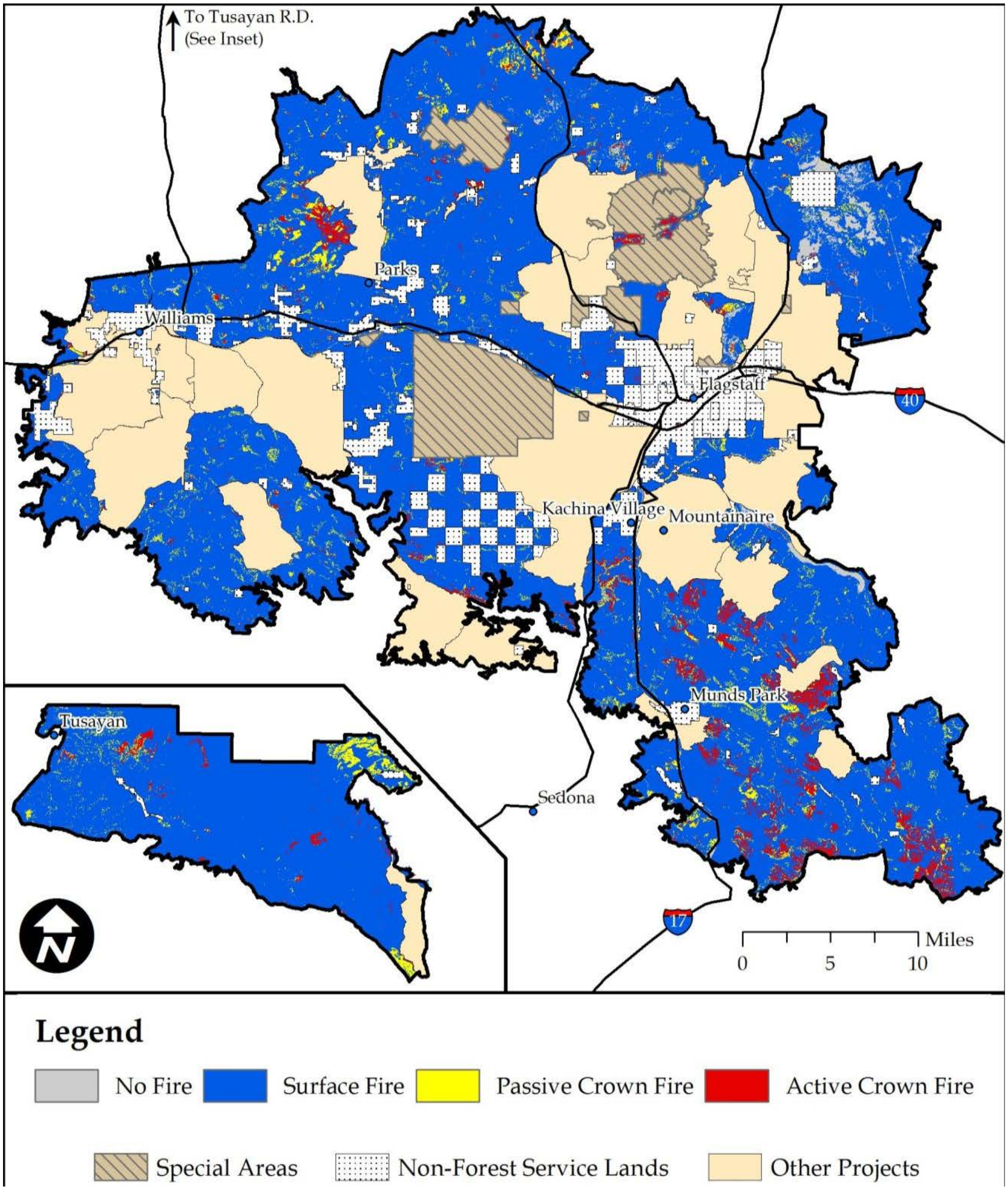

Figure 59. Modeled fire type for Alternative D, 2020

A direct effect of treatments proposed under Alternative D is breaking up the horizontal and vertical continuity of canopy fuels are broken up. The indirect effect of this is to decrease the potential for crown fire from 34% of the treatment area to 7% of the treatment area, with potential for active crown fire decreasing from 25% to 3% (Table 90). Non-burnable substrate constitutes ~1% of the treatment area and was not included in the acres shown fire potential fire type.

Table 90. Modeled fire type for Alternative D

Fire Type	2010 (percent)	2020 (percent)
Surface fire	64	92
Passive crown fire	9	4
Active crown fire	25	3

The amount of potential crown fire remaining after proposed treatments would be within the historic ranges of ponderosa pine in this area. As illustrated in Figure 59, post-treatment active crown fire is scattered across all treatment areas, with the most in Restoration Unit 1 and, in most cases, would occur in MSO and goshawk habitat (Figure 59).

Ponderosa Pine

At the treatment area scale, when considered by vegetation and habitat type, ponderosa pine would meet desired conditions under Alternative D of having potential for crown fire on 6% (32,367 acres), 3% (15,382 acres) of which would be active crown fire (Table 91). Protected habitat would account for 77% of the active crown fire in ponderosa pine across the treatment area, and 42% of all protected habitat.

The direct effects of proposed treatments would decrease the horizontal and vertical continuity of canopy fuels with mechanical treatments, allowing sunlight to reach the surface, increasing surface temperatures, and decreasing dead fuel moisture content at the surface. This, combined with increased surface winds with fewer trees blocking the wind, could increase surface fire intensity, flame length, and rate of spread even if surface fuels were the same before and after canopy treatment (Omi and Martinson 2004; Scott, 2003). Therefore, canopy fuel treatments reduce the potential for crown fire at the expense of slightly increased surface fire behavior (fireline intensity, flame length, and rate of spread). However, critical levels of fire behavior (limits of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires. Although surface fire intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally more controllable (Scott 2003).

Table 91. Modeled fire type for Alternative D by ponderosa pine habitat type.

Vegetation Type		Fire Type	Existing Conditions		Alt. D 2020	
			Acres	Percent	Acres	Percent
Ponderosa Pine*	**All Pine**	**Surface**	**311,313**	**61%**	**470,177**	**92%**
		Passive crown	**48,023**	**9%**	**16,985**	**3%**
		Active crown	**143,186**	**28%**	**15,382**	**3%**
	Protected	Surface	17,954	51%	19,976	55%
		Passive crown	3,034	9%	3,300	8%
		Active crown	14,106	40%	11,820	34%
	Target/ Threshold	Surface	4,275	49%	7,830	90%
		Passive crown	922	11%	372	4%
		Active crown	3,482	40%	473	5%
	Restricted	Surface	35,019	53%	63,149	95%
		Passive crown	6,540	10%	3,080	5%
		Active crown	24,756	37%	96	0%
	PFA/ dPFA	Surface	18,400	61%	28,237	94%

		Passive crown	2,903	10%	1,188	4%
		Active crown	8,560	29%	431	1%
	LOPFA	Surface	235,666	64%	350,985	96%
		Passive crown	34,624	9%	9,044	2%
		Active crown	92,282	25%	2,562	1%
Other Vegetation*	Aspen	Surface	1,120	74%	1,269	82%
		Passive crown	135	9%	163	11%
		Active crown	258	17%	80	5%
	Grassland	Surface	41,491	86%	40,020	91%
		Passive crown	3,059	6%	4,260	4%
		Active crown	1,153	2%	1,361	3%
	Juniper Woodland	Surface	1,941	83%	2,322	99%
		Passive crown	74	3%	3	0%
		Active crown	320	14%	12	1%
	Oak Woodland	Surface	2,504	77%	3,209	99%
		Passive crown	266	8%	9	0%
		Active crown	466	14%	20	1%
	Pinyon/Juniper	Surface	19,379	83%	22,513	97%
		Passive crown	1,523	7%	380	2%
		Active crown	2,047	9%	68	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and about 1% of the entire treatment area

Mechanical treatments can take the forest a long way towards restoration, removing most of the potential for active crown fire, but ponderosa pine forest structure cannot be restored without fire (Figure **60**).

For the most part, accumulations of litter, duff, existing dead/down woody debris, and seedlings and small saplings are not addressed by mechanical thinning. In areas where trees are skidded, yarded and/or the surface is disturbed, surface fuels may be moved around, and may even provide temporary firelines if disturbed to the mineral soil, but litter, duff, seedlings or dead/down wood are not removed by thinning operations. Some saplings may be removed, depending on the particulars of the thinning prescription. Thinning adds varying amounts of woody fuels that break off branches and twigs that are left on site from thinning operations (Fulé et al. 2012), even if most of the thinned material is removed from the site, which could increase surface fire intensity. Species that require the smoke or the heat of a fire to germinate or thrive (Abella et al. 2007, Huffman and Moore 2008, Keeley and Fotheringham 2000, Abella 2006, Abella 2009, Keeley and Fotheringham 2002, Schwilk and Zavala 2012) would decline (indirect effect). For those species, in the long run, their survival would depend on the chance of a wildfire burning in those areas at the appropriate time, severity and frequency (Auld and O'Connell 1991). Another indirect effect of implementing Alternative D would be the decline of natural fire patterns, including the groupy/clumpy arrangements that are natural to the ponderosa pine ecosystems in the treatment area because, although mechanical treatments can reset much of the forest structure, they would not address the smallest size classes or surface fuels. In Figure **60** the top two images are no treatment and mechanical treatment-only.

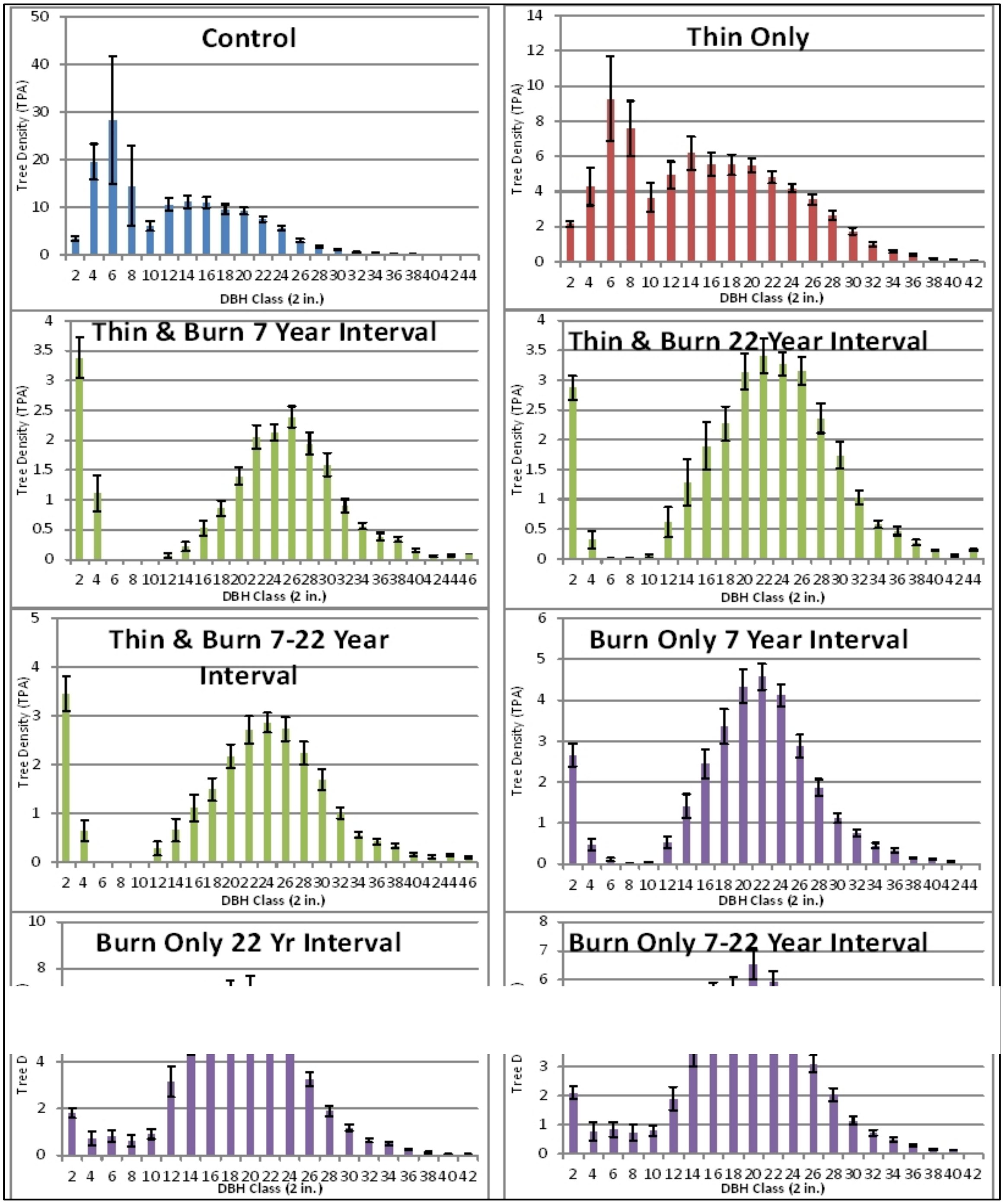

Figure 60. Modeling of project area stands for a variety of treatments and treatment intervals (Hall et al. 2011)

Litter and duff would continue to build up, locking up nutrients, changing soil chemistry, and physically suppressing surface vegetation, decreasing productivity at the surface as well as decreasing species diversity (Moir 1988, Abella et al. 2007, Laughlin et al. 2011). Natural patterns of surface vegetation would continue to deteriorate, as patterns of shrubs and other species adapted to frequent fire continued to shift in response to decreased fire frequencies (Huffman and Moore 2008, Moir 1988).

Pine/Sage

Thinning the pine/sage community in RU6 would allow the sage to expand, which would generally be beneficial to the system. Although little is documented about the dynamics of the system, sage appears to have the capacity to outcompete most other surface vegetation in some places as can be seen in Figure 13 on page 56. Without fire to maintain a shifting mosaic at the surface, it is likely that the woody species (sage and other shrubs) would expand to dominate the surface vegetation until wildfire burned though the area. High severity fire is likely to be lethal to the majority of the sage.

Large/old trees

Throughout the life of this project, direct and indirect effects are likely to result in some large and/or old trees would be damaged or killed by prescribed fire. In this alternative, in areas where prescribed fire would be implemented there would be decreased mortality of old and/or large trees. Over 128,669 acres, prescribed fire would decrease potential fire behavior in the vicinity of old and/or large trees, decreasing the likelihood of lethal damage in the event of a wildfire. Recent research indicates that scorch is one of the primary factors in large and old tree mortality (Jerman et al. 2004), and is influenced by the vertical arrangement of fuels. Old trees, which are more susceptible to dying from fire than younger trees, would have ladder fuels in the immediate vicinity removed before burning whenever possible. Mitigation for trees of particular significance, such as wildlife trees, occupied nest sites, etc., would be completed prior to burning. Ignition techniques or other mitigations would be employed to minimize residence time in deep litter or duff adjacent to old trees whenever possible. Under this alternative, low severity fire would be used in the vicinity of old trees and, to the degree it is practicable, ladder fuels and excessive surface fuel buildups adjacent to old trees would be removed before burning.

Mitigation measures (page 227) are unpredictable, and site specific (Kolb et al. 2007), and some can have negative effects of their own. Raking, for example, can remove fine, live roots in the surface organic layers, which may compound the effects of additional shallow roots being damaged by fire, though it is unlikely to actually kill the tree. Low intensity fire that causes little crown scorch can stimulate resin production in old trees, but may attract bark beetles, increasing tree mortality.

Under Alternative D, 384,966 acres of forested areas would have mechanical treatments. In these areas, potential for active crown fire, and the high severity effects associated with crown fire, would be decreased and would meet desired conditions. When wildfire burned though these acres, surface fuels would have increased (Fulé et al.2012), increasing potential surface fire intensity in these areas. Litter and duff cones that accumulate around the base of old and/or large trees can be lethal to large and/or old trees if they burn under wildfire conditions (Egan 2011). These fuels cannot be effectively treated by mechanical methods across the over 500,000 acres of ponderosa pine proposed for treatment. Old and/or large trees could not often be ‘prepped’ for wildfire as they would be for prescribed fire. Across ~70,000 acres of the treatment area, surface fuel loading would be sufficient that it could be expected to burn with high severity, even with no crown fire, killing most trees in the area. Based on the current average, and assuming no increase in average annual acres burned with wildfires, by 2020, about 64,000 – 144,000 acres within the treatment area could have burned with high severity.

Aspen

Aspen thrives on disturbance, so the 1,227 acres that would receive mechanical treatment would improve as encroaching conifers are removed. The soil disturbance would be likely to stimulate some suckering as well (an indirect effect). It would not be as vigorous as it would if the disturbance was fire, but it would move these acres towards a healthier condition that is more resilient to disturbances such as fire, disease, insects, and drought. There would be no increase in soil temperature or nutrient flush to speed up the growth rate of new sprouts, an adaptation to fire which would help them compete with other surface vegetation that would also increase following treatment. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, both stimulating sprouting and allowing the survival of some large stems.

Those acres that would receive prescribed fire treatments (22 acres) would be expected to sucker vigorously in response to low severity prescribed fire. Dead/down/decadent stems and wood would be partially consumed, and/or topkilled, stimulating vigorous suckering from roots no longer trying to reinvigorate large, decadent stems. In those areas that burn with moderate to high severity, fire would probably top-kill most aspen stems but, in most cases, the clone would respond by vigorous sprouting. In those areas that burned with low severity (wildfire and prescribed fire) aspen would benefit as the fire consumed accumulations of litter and some CWD. Following fire, the decreased surface albedo, decreased shade, and the flush of nutrients would stimulate vigorous sprouting. For those areas with only mechanical treatment, there would be sprouting, though not as vigorous as in areas that were burned. Ungulate grazing would be expected to have an impact on new suckers, so where possible, deterrents would be used.

Gambel Oak

Gambel oak would benefit from the thinning of ponderosa pine overtopping it. Post-treatment fire modeling shows potential for 1% (20 acres) of oak to have active crown fire, with no passive crownfire. Across oak woodland, and pine/oak vegetation, in areas that are thinned but not burned, there would be greater potential for mortality of large and small stems when wildfire did burn across the area because of increased surface fuel loading. Wildfire would be likely to topkill most of the oak, decreasing small stems for a couple of years until suckers matured. At all scales of analysis, desired conditions would be met for fire type in oak woodlands (<10% crown fire).

In the short run it would increase sprouting and small-diameter stems. It is also possible that there would be some mortality of large oak in the prescribed burns, particularly initial entry though, in the long run, it would decrease the risk to large oak. Where Gambel oak was treated with prescribed fire, the effects would be identical to Alternatives B and C, which are described on pages 149 and 208).

Grasslands

Effects for grasslands would be almost identical to Alternative B with 392 fewer acres being treated in Alternative D than in Alternative C. See discussion of fire effects under Alternative B on page 149. Prescribed fires in grasslands would be under ‘Operational Burn’, and would not have restoration objectives associated with them. Treatments proposed for grasslands in Alternative D would move most of the acres towards desired conditions, but would not meet desired conditions at any scale (Table 92). Regardless of the intensity of treatments, where fuels are primarily herbaceous, grasslands would benefit from wildfire or prescribed fire because the intensity at which it could burn, even under extreme conditions, would benefit the system by decreasing woody encroachment, stimulating decadent grasses, shrubs, and forbs, and providing a disturbance to which they are well adapted. Where there is active crown fire, there would be potential for undesirable fire effects such as high burn severity (detrimental soil effects), including killing the existing seed bank and potentially giving invasive plant species a foothold.

Table 92. Modeled fire type in grasslands for Alternative D

Grassland RU	Fire Type	Veg type acres	Existing		Alt. D 2020	
			Acres	%	Acres	%
RU1	Surface	8,135	6,131	75%	6,156	76%
	Passive crown		1,340	16%	1,316	16%
	Active crown		236	3%	235	3%
RU3	Surface	12,772	11,670	91%	11,710	92%
	Passive crown		706	6%	678	5%
	Active crown		167	1%	170	1%
RU4	Surface	22,661	21,080	93%	19,544	86%
	Passive crown		788	3%	2,044	9%
	Active crown		645	3%	851	4%
RU5	Surface	4,536	2,521	56%	2,521	56%
	Passive crown		222	5%	219	5%
	Active crown		105	2%	105	2%
RU6	Surface	93	89	96%	89	96%
	Passive crown		2	2%	3	3%
	Active crown		1	1%	1	1%

Pinyon/Juniper Woodland (PJ)

Fire effects for PJ under Alternative D would be similar to those described in Alternative B on page 151, and for the 535 acres of fuels treatment, effects would be identical to Alternative C. One difference may be in the amount of PJ that is burned under 'Operational Burn'. With only 178,441 total acres of any vegetation type proposed for burning under Alternative D, there would be less need for Operational Burning in PJ to facilitate prescribed fire in ponderosa pine. There are no desired conditions that specify a desired amount of crown fire for PJ.

Restoration Units

When analyzed at the scale of the Restoration Unit, Alternative D would meet desired conditions for fire type in 4 of the 5 Restoration Units (Table 93). "No fire" includes water, rock, roads, cinders, areas of sparse vegetation, and other acres on which there were insufficient fuels to carry fire under the conditions modeled. These acres range from 44 acres (0.11%) in RU6 to 5,738 acres (7.8%) in RU5.

Table 93. Modeled fire type by Restoration Unit for Alternative D.

		Fire Acres			Fire Percent		
	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	Surface Fire	Passive Crown Fire	Active Crown Fire
Alt. D (2020)	RU 1	136,084	6,815	10,569	88%	4%	7%
	RU 3	140,429	5,621	2,764	94%	4%	2%
	RU 4	156,299	6,428	2,275	94%	4%	1%
	RU 5	65,546	1,204	715	90%	2%	1%
	RU 6	41,152	1,733	601	95%	4%	1%

	Total	539,510	21,801	16,924	92%	4%	3%

Total crown fire potential would range from 11% in RU1 to 3% in RU5. The majority of crown fire in RU1 would be in protected habitat, for which there are no desired conditions relating to fire type. See discussion below.

Restoration Unit 1

Restoration Unit 1 would be at greater risk of crown fire than the other Restoration Units. It is of particular concern because the Lake Mary watershed is a source of water for the city of Flagstaff, and is a popular recreation site. There are adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer, as well as the city of Flagstaff to the northwest. Within RU1, there would be potential for 18,693 (12 percent) acres of crown fire, of which 7% (10,660 acres) would be active crown fire. Alternative D would not meet desired conditions for fire type in RU1.

Ponderosa pine would have potential for 11% (15,581 acres) crown fire, of which 7% (10,183 acres) would be active crown fire (Table 94). Within the protected habitat in RU1, 42% (12,248 acres) would be at risk from crown fire, accounting for 72% of all crownfire in RU1.

Aspen occupy 420 acres of RU1. There would be crown fire potential on 31% (131 acres). Alternative D proposes one prescribed fire in 32 acres of aspen. This would be low to moderate severity fire, benefiting the aspen by consuming accumulations of litter and some of the CWD. For 420 acres, mechanical treatment would decrease potential for crown fire by 49 acres. In these areas, there would be sprouting, though not as vigorous as in areas that were burned. Additional effects are described on page 207.

Grasslands in RU1 would have potential for crown fire in 19% (1,551 acres). There would be potential for active crown fire in 3% (235 acres) of RU1 grasslands. Although the grasslands would mostly benefit from wildfires occurring following proposed treatments, Alternative D would not meet desired conditions for fire type in grasslands in RU1. Additional effects are described on page 149 and 208.

Table 94. Modeled fire type by vegetation and habitat type for Restoration Unit 1

RU 1 acres =		154,383	Veg type acres	2010		Alt. D 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**144,113**	**80,257**	**56%**	**128,080**	**89%**
		Passive		**15,784**	**11%**	**5,398**	**4%**
		Active		**47,553**	**33%**	**10,183**	**7%**
	Protected	Surface	29,052	15,020	52%	16,749	58%
		Passive		2,246	8%	2,469	8%
		Active		11,728	40%	9,779	34%
	Target/ Threshold	Surface	4,793	2,236	47%	4,228	88%
		Passive		504	11%	307	6%
		Active		2,042	43%	247	5%
	Restricted	Surface	25,710	12,731	50%	24,222	94%
		Passive		2,601	10%	1,450	6%
		Active		10,348	40%	13	0%

	PFA/ dPFA	Surface	4,670	2,594	56%	4,595	98%
		Passive		518	11%	61	1%
		Active		1,558	33%	13	0%
	LOPFA	Surface	79,889	47,676	60%	78,287	98%
		Passive		9,915	12%	1,111	1%
		Active		21,877	27%	131	0%
Other Vegetation*	Aspen	Surface	420	241	57%	290	69%
		Passive		40	9%	60	14%
		Active		140	33%	71	17%
	Grassland	Surface	8,135	6,131	75%	6,156	76%
		Passive		1,340	16%	1,316	16%
		Active		236	3%	235	3%
	Juniper Woodland	Surface	286	236	83%	273	95%
		Passive		12	4%	1	0%
		Active		38	13%	12	4%
	Oak Woodland	Surface	287	195	68%	258	90%
		Passive		62	21%	9	3%
		Active		30	11%	20	7%
	Pinyon/ Juniper	Surface	1,141	897	79%	1,027	90%
		Passive		115	10%	32	3%
		Active		95	8%	48	4%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU1

Oak woodlands in RU1 would have the potential for 10% (29 acres) crown fire, of which 7% (20 acres) would be active crown fire. Additional effects are described on page 208.

Pinyon/Juniper woodlands crown fire potential in Restoration Unit 1 would decrease to 93 acres (down from 260 in the existing condition). PJ in RU1 is Operational Burning, but would benefit from the prescribed fires that would be implemented. Additional effects that could be expected are described on page 151, under Alternative B.

Subunits

Subunit 1-1 includes Walnut Canyon, is adjacent to Flagstaff and the Pulliam Airport. Following treatments, there would be potential for 1% (513 acres) of crown fire (Table 95), of which 1% (442 acres) would be active crown fire.

Table 95. Modeled fire type in Restoration Unit 1 subunits by vegetation type for 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative D	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
1-1	**10,170**	**157**	**9,499**	**442**	**71**	**2%**	**93%**	**4%**	**1%**
Ponderosa Pine	8,914	109	8,551	235	20	1%	96%	3%	0%
Grassland	567	13	315	194	45	2%	56%	34%	8%
Oak Woodland	173	0	173	0	0	0%	100%	0%	0%
Pinyon-Juniper	515	35	461	14	6	7%	89%	3%	1%
1-2	**8,054**	**61**	**7,801**	**171**	**21**	**1%**	**97%**	**2%**	**0%**

Ponderosa Pine	6,517	24	6,413	79	1	<1%	98%	1%	0%
Grassland	1,537	37	1,388	92	20	<3%	90%	6%	1%
1-3	**39,791**	**424**	**35,780**	**1,436**	**2,150**	**1%**	**90%**	**4%**	**5%**
Ponderosa Pine	36,461	103	33,396	918	2,044	<1%	92%	<3%	6%
Aspen	88	0	52	18	18	0%	59%	20%	21%
Grassland	3,241	322	2,332	501	88	10%	72%	15%	3%
1-4	**18,250**	**16**	**16,377**	**705**	**1,153**	**0%**	**90%**	**4%**	**6%**
Ponderosa Pine	17,285	6	15,563	603	1,113	<1%	90%	3%	6%
Grassland	519	10	409	92	9	<2%	79%	18%	2%
Oak Woodland	83	0	54	9	20	0%	65%	11%	24%
Pinyon-Juniper	363	0	351	2	11	0%	97%	0%	3%
1-5	**78,119**	**257**	**66,627**	**4,061**	**7,174**	**<1%**	**85%**	**5%**	**9%**
Ponderosa Pine	74,936	210	64,158	3,564	7,004	0%	86%	5%	9%
Aspen	332	0	237	42	53	0%	71%	13%	16%
Grassland	2,270	47	1,712	438	74	2%	76%	19%	3%
Juniper Woodland	286	0	273	1	12	0%	95%	<1%	4%
Oak Woodland	32	0	32	0	0	0%	100%	0%	0%
Pinyon-Juniper	262	0	215	16	32	0%	82%	6%	12%

Some of the crown fire would be near, or adjacent to the Country Club area in southeastern Flagstaff, as well as adjacent to or close to Pulliam Airport. About 42% of the grassland area in subunit 1-1 would have potential for crown fire. Subunit 1-3 includes the Lake Mary watershed, a source watershed for the town of Flagstaff. Following treatments proposed in Alternative D, 9% of it (3,586 acres) would have potential for crown fire, 5% of which would be active crown fire. The majority of the active crown fire in Subunit 1-3 is on the south and west sides of the Subunit, furthest away from the lakes and in PACs. Subunit 1-5 contains all, or pasts of, 12 PACs (9,612 acres), which account for the majority of the crown fire in this subunit. Almost all of the active crown fire is in PACs, with passive crown fire scattered throughout the units. Alternative D would meet desired behavior for in all subunits except SU1-5.

Restoration Unit 3

Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. Adjacency concerns for fire behavior include Interstates 40 and 17 which are adjacent to RU3 to the north and east, respectively, so that smoke from wildfires would have good potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, Williams, and Kachina Village. Additional concerns include Oak Creek, Oak Creek Canyon, and Sycamore Canyon. Under Alternative D, there would be potential for crown fire on 6% (8,385 acres) of U3, of which 2% (2,764 acres) would be active crown fire (Table 96). Alternative D would meet desired conditions for fire behavior in RU3. Most of the crown fire is scattered, with more concentrated (though not always contiguous) areas following treatment type boundaries, or drainages and slopes.

Ponderosa pine would have potential for 6% (7,166 acres) of crown fire in RU3, of which 2% (2,579 acres) would be active crown fire. Protected habitat would account for about 67% of the active crown fire in the ponderosa pine in RU3.

Aspen occupy 201 acres in RU3. There would be crown fire potential in 28% (56 acres) of aspen in RU3,which would all be passive crown fire. Additional effects are described on page 207.

Grasslands in RU3 would have potential for crown fire on 6% (848 acres). Table 96 displays fire type by vegetation types, indicating 1% (170 acres of grasslands would have potential for active crown fire. Although the grasslands would mostly benefit from wildfires occurring following proposed treatments, Alternative D would not meet desired conditions for fire type in grasslands in RU3. Additional effects are described on pages 150 and 208.

Oak woodlands would have no potential for crown fire under Alternative D. Additional details on expected effects were described in Alternatives B and C on pages 149 and 208).

Table 96. Modeled fire type for Restoration Unit 3 for 2020

RU 3 acres =		149,715	Veg type	2010		Alt. D 2020	
Vegetation Type		Type	acres	Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**129,226**	**72,776**	**56%**	**121,105**	**94%**
		Passive		**12,594**	**10%**	**4,870**	**4%**
		Active		**43,256**	**33%**	**2,579**	**2%**
	Protected	Surface	4,793	2,020	42%	2,313	48%
		Passive		611	13%	652	14%
		Active		2,076	43%	1,743	36%
	Target/ Threshold	Surface	3,899	2,039	52%	3,602	92%
		Passive		481	11%	66	2%
		Active		1,440	37%	227	6%
	Restricted	Surface	38,527	21,085	55%	36,818	96%
		Passive		3,672	10%	1,570	4%
		Active		13,704	36%	75	0%
	PFA/ dPFA	Surface	5,582	2,948	53%	5,039	90%
		Passive		605	11%	401	7%
		Active		2,026	36%	141	3%
	LOPFA	Surface	76,424	44,683	58%	73,333	96%
		Passive		7,288	10%	2,181	3%
		Active		24,010	31%	393	1%
Other Vegetation*	Aspen	Surface	201	144	72%	146	72%
		Passive		40	20%	56	28%
		Active		16	8%	0	0%
	Grassland	Surface	12,772	11,670	91%	11,710	92%
		Passive		706	6%	678	5%
		Active		167	1%	170	1%
	Juniper Woodland	Surface	1,851	1,559	84%	1,848	100%
		Passive		49	3%	0	0%
		Active		240	13%	0	0%
	Oak Woodland	Surface	1,633	1,282	79%	1,626	100%
		Passive		75	5%	0	0%
		Active		269	16%	0	0%
	Pinyon/ Juniper	Surface	4,033	3,351	83%	3,994	99%
		Passive		175	4%	18	0%
		Active		501	12%	15	0%

* Nonburnable substrate constitutes <1% in ponderosa pine and <1 in the entire treatment area within RU3

Pinyon/Juniper crown fire potential would decrease to 33 acres (down from 676 acres in the existing condition). PJ in RU3 would all be Operational Burning, but would benefit from the prescribed fires that would be implemented. Additional effects that could be expected are described on page 151, under Alternative B.

Subunits

Subunit 3-5 has all, or parts of 10 PACs accounting for most of the active crown fire. There is potential for small areas of crown fire on slopes >30% in Subunits 3-4. Several areas of 2-3 acres like this occur on the edge of James Canyon, and some on the edge of (Kelly Canyon). When evaluated at the Subunit scale, RUs 3-1, 3-2, and 3-3 meet desired conditions for fire type under Alternative D. Subunits 3-4 (14%) and 3-5 (18 percent) would not (Table 97).

Table 97. Modeled fire type in Restoration Unit 3 subunits by vegetation type for 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative D	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
3-1	**23,145**	**58**	**22,124**	**821**	**141**	**<1%**	**96%**	**4%**	**<1%**
Ponderosa Pine	18,805	39	17,895	739	131	0%	95%	4%	1%
Aspen	91	0	62	29	0	0%	68%	32%	0%
Grassland	590	14	513	54	10	2%	87%	9%	2%
Juniper Woodland	907	1	907	0	0	0%	100%	0%	0%
Oak Woodland	845	1	844	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,908	4	1,904	0	0	0%	100%	0%	0%
3-2	**32,726**	**276**	**31,139**	**1,069**	**242**	**1%**	**95%**	**3%**	**<1%**
Ponderosa Pine	22,885	133	21,689	876	188	<1%	95%	4%	1%
Aspen	59	0	44	14	0	0%	76%	24%	0%
Grassland	9,611	143	9,235	179	54	1%	96%	2%	1%
Oak Woodland	172	0	172	0	0	0%	100%	0%	0%
3-3	**48,434**	**75**	**46,200**	**1,554**	**605**	**<1%**	**95%**	**3%**	**1%**
Ponderosa Pine	44,426	59	42,418	1,390	561	<1%	95%	3%	1%
Aspen	50	0	38	12	0	0%	76%	24%	0%
Grassland	1,353	6	1,149	152	45	<1%	85%	11%	3%
Juniper Woodland	873	2	871	0	0	0%	100%	0%	0%
Oak Woodland	232	5	226	0	0	2%	98%	0%	0%
Pinyon-Juniper	1,500	3	1,497	0	0	0%	100%	0%	0%
3-4	**9,019**	**230**	**7,598**	**503**	**688**	**<3%**	**84%**	**6%**	**8%**
Ponderosa Pine	8,920	217	7,551	474	678	2%	85%	5%	8%
Grassland	99	13	47	29	10	14%	47%	29%	10%
Oak Woodland	0	0	0	0	0	0%	100%	0%	0%
3-5	**36,392**	**262**	**33,368**	**1,674**	**1,087**	**<1%**	**92%**	**5%**	**3%**
Ponderosa Pine	34,190	224	31,553	1,392	1,021	<1%	92%	4%	3%
Aspen	2	0	2	0	0	0%	100%	0%	0%
Grassland	1,120	38	766	265	51	3%	68%	24%	5%
Juniper Woodland	70	0	70	0	0	0%	100%	0%	0%
Oak Woodland	384	0	384	0	0	0%	100%	0%	0%
Pinyon-Juniper	626	0	593	18	15	0%	95%	3%	2%

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and I-10, RU4 has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. There are adjacency concerns with Kendrick and Sitgreaves mountains because of steep slopes and potential for high severity fire effects uphill from the treatment area. There would be potential for crown fire on 5% (8,703 acres) of RU4, of which 2% (2,275 acres) would be active crown fire. Alternative D would meet desired conditions for fire type for ponderosa pine in RU4.

Ponderosa pine in RU4 would have potential for active crown fire on 4% (5,777 acres) of RU4, of which 1% (1,416 acres) would be active crown fire (Table 98).Table 98Aspen occupy 497 acres of aspen in RU4. There would be potential for crown fire in 5% (29 acres), of which 7 acres would be active crown fire. Additional effects are described on page 207, and under Alternative B on page 148.

Table 98. Modeled fire type for Restoration Unit 4 under Alternative D, 2020

RU 4 acres =		165,645	Veg type acres	2010		Alt. D 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**134,278**	**83,499**	**62%**	**128,110**	**95%**
		Passive		**10,590**	**8%**	**4,361**	**3%**
		Active		**39,763**	**30%**	**1,416**	**1%**
	Protected	Surface	558	379	68%	381	68%
		Passive		45	8%	46	8%
		Active		134	24%	131	23%
	Restricted	Surface	1,576	751	48%	1,544	98%
		Passive		196	12%	19	1%
		Active		621	39%	8	0%
	PFA/ dPFA	Surface	13,484	8,008	59%	12,675	94%
		Passive		1,250	9%	554	4%
		Active		4,221	31%	250	2%
	LOPFA	Surface	118,659	74,361	63%	113,509	96%
		Passive		9,100	8%	3,741	3%
		Active		34,786	29%	1,029	1%
Other Vegetation*	Aspen	Surface	497	403	81%	465	93%
		Passive		31	6%	22	4%
		Active		59	12%	7	1%
	Grassland	Surface	22,661	21,080	93%	19,544	86%
		Passive		788	3%	2,044	9%
		Active		645	3%	851	4%
	Juniper Woodland	Surface	118	69	59%	116	99%
		Passive		4	3%	0	0%
		Active		43	36%	0	0%
	Oak Woodland	Surface	926	669	72%	924	100%
		Passive		90	10%	0	0%
		Active		165	18%	0	0%
	Pinyon/ Juniper	Surface	7,165	5,855	82%	7,140	100%
		Passive		453	6%	0	0%
		Active		829	12%	0	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area in RU4

Grassland acres in Restoration Unit 4 include Government Prairie, a grassland area of ~20,000 acres, as well as other scattered grasslands units. These grassland areas would be included as Operational Burn. Potential crown fire would be 13% (2,895 acres), of which 4% (851 acres) would be active crown fire. Additional effects are described on page 208 and under Alternative C on page 208.

Oak woodlands would support just 2 acres of modeled crown fire out of a total of 926 acres in the Restoration Unit. This would meet desired conditions for <10% crown fire potential in oak woodlands. Details of expected effects are described on page 208, and under Alternative Be on page 149.

Pinyon/Juniper woodlands would have no potential for crown fire. These areas would be Operational Burn and, post-treatment, would include potential for 7,283 acres of surface fire. Additional effects are described on page 209, and under Alternative B on page 151.

Subunits

At the subunit level (Table 99) SU 4-5, though the smallest SU in the project (6,919 acres), is adjacent to the city of Flagstaff, and has some steep topography, so that the second order (indirect) fire effects of any high severity fires have good potential to impact neighborhoods and schools. Under Alternative D, Subunit 4-5 would have potential for crown fire on 3% of the area (246 acres), of which 2% (146 acres) would be active crown fire. There is a section (1 $mile^2$) immediately west of north flagstaff with scattered active crown fire a little over a mile southwest from a residential area, with forested non-federal land between. The majority of crown fire in RU4 is in Subunit 4-3, on the northwest and north side of the peaks, and west of Sitgreaves. All Subunits in RU4 would meet desired conditions for fire type, though there are multiple areas with contiguous passive crown fire that are greater than 30 acres, and some of active crown fire that are close to 30 acres.

Table 99. Modeled fire type in Restoration Unit 4 subunits under Alternative D, 2020.

Alternative D	Acres	Fire Type (acres)				Fire Type (percent)			
		No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
4-2	**10,227**	**74**	**9,766**	**337**	**49**	**<1%**	**95%**	**3%**	**<1%**
Ponderosa Pine	7,381	21	6,984	329	47	0%	95%	4%	1%
Aspen	1	0	1	0	0	40%	60%	0%	0%
Grassland	328	29	289	8	2	9%	88%	2%	<1%
Juniper Woodland	8	0	8	0	0	0%	100%	0%	0%
Oak Woodland	567	2	565	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,941	22	1,919	0	0	1%	99%	0%	0%
4-3	**67,012**	**325**	**62,082**	**3,364**	**1,241**	**0%**	**93%**	**5%**	**2%**
Ponderosa Pine	55,312	306	52,428	1,872	706	1%	95%	3%	1%
Aspen	230	3	219	2	6	1%	95%	1%	3%
Grassland	6,951	12	4,920	1,490	529	0%	71%	21%	8%
Juniper Woodland	31	0	31	0	0	0%	100%	0%	0%
Oak Woodland	325	0	325	0	0	0%	100%	0%	0%
Pinyon-Juniper	4,162	3	4,159	0	0	0%	100%	0%	0%
4-4	**81,487**	**241**	**77,780**	**2,627**	**839**	**<1%**	**95%**	**3%**	**1%**
Ponderosa Pine	65,003	63	62,318	2,095	528	0%	96%	3%	1%
Aspen	255	0	236	18	1	0%	93%	7%	0%
Grassland	15,055	177	14,054	513	310	1%	93%	3%	2%
Juniper Woodland	78	2	76	0	0	2%	98%	0%	0%
Oak Woodland	35	0	35	0	0	0%	100%	0%	0%

Pinyon-Juniper	1,062	0	1,062	0	0	0%	100%	0%	0%
4-5	**6,919**	**3**	**6,670**	**100**	**146**	**<1%**	**96%**	**1%**	**2%**
Ponderosa Pine	6,581	1	6,380	65	135	0%	97%	1%	2%
Aspen	11	0	9	2	0	0%	82%	18%	0%
Grassland	327	2	281	33	11	1%	86%	10%	3%

Restoration Unit 5

Restoration Unit 5 includes parts of the area burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in parts of this RU. There would be potential for crown fire on 3% (1,919 acres) of RU5, of which 1% (715 acres) would be active crown fire. Alternative D would meet desired conditions for fire type in RU5. RU5 has areas of cinder substrate northeast of Flagstaff, mostly in and around the Doney Park area, and north. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

Ponderosa pine in RU5 would meet desired conditions with potential for crown fire across 3% of its area (1,561 acres), of which 1% (604 acres) would be active crown fire (Table 100). Thirty-five percent of protected habitat (301 acres) would remain at risk of crown fire, 20% (168 acres) of which would be active crown fire.

Table 100. Modeled fire type by vegetation and habitat for Restoration Unit 5, 2020

RU 5 acres =		73,203	Veg type acres	2010		Alt. D 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**59,034**	**41,109**	**70%**	**53,736**	**91%**
		Passive		**6,821**	**12%**	**957**	**2%**
		Active		**7,376**	**12%**	**604**	**1%**
	Protected	Surface	859	535	62%	532	62%
		Passive		132	15%	133	15%
		Active		167	19%	168	20%
	Restricted	Surface	606	451	74%	565	93%
		Passive		71	12%	41	7%
		Active		83	14%	0	0%
	PFA/ dPFA	Surface	2,227	1,343	60%	1,940	87%
		Passive		419	19%	116	5%
		Active		325	15%	25	1%
	LOPFA	Surface	55,341	38,780	70%	50,699	92%
		Passive		6,199	11%	668	1%
		Active		6,801	12%	412	1%
Other Vegetation*	Aspen	Surface	403	332	82%	370	92%
		Passive		24	6%	26	6%
		Active		43	11%	2	0%
	Grassland	Surface	4,536	2,521	56%	2,521	56%
		Passive		222	5%	219	5%
		Active		105	2%	105	2%
	Juniper Woodland	Surface	74	67	90%	74	100%
		Passive		7	9%	0	0%
		Active		0	1%	0	0%

	Oak Woodland	Surface	386	349	91%	371	96%
		Passive		20	5%	0	0%
		Active		1	0%	0	0%
	Pinyon/ Juniper	Surface	8,771	7,804	89%	8,474	97%
		Passive		277	3%	2	0%
		Active		393	4%	5	0%

*Nonburnable substrate constitutes about 6% of ponderosa pine and about 8% of the treatment area within RU5

Aspen occupy 403 acres of aspen in RU5. Six percent (28 acres) of it would retain potential for crown fire, all of which would be passive. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, both stimulating sprouting and allowing the survival of some large stems.

Grassland effects, under Alternative D, would be identical to those in Alternative B. See discussion on page 208, and under Alternative B on page 160.

Oak woodland effects under Alternative D, would be identical to those in Alternative B. See discussion on page 208, and under Alternative B on page 149). Under Alternative D, there would be no potential for crown fire.

Pinyon/Juniper effects, under Alternative D, would be identical to those in Alternative B. See discussion on page 209, and under Alternative B on 151.

Subunits

Both Subunits in RU5 would meet desired conditions for fire type (Table 101). Subunit 5-1, includes a contiguous area of ~180 acres, of which, about 30 acres is upslope and adjacent to Schultz Pass road and on slopes greater than 30 percent. Subunit 5-2 includes much of the youngest, most sparsely vegetated cinder cones, as well as areas that were affected by the second order (indirect) fire effects resulting from the Schultz Fire.

Table 101. Modeled fire type in Restoration Unit 5 subunits under Alternative D, 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative D	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
5-1	**21,341**	**795**	**19,514**	**517**	**514**	**4%**	**91%**	**<3%**	**<3%**
Ponderosa Pine	18,040	747	16,387	412	493	4%	91%	2%	3%
Aspen	392	5	363	23	1	1%	93%	6%	0%
Grassland	1,239	19	1,119	82	19	<2%	90%	7%	2%
Oak Woodland	95	0	95	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,574	24	1,550	0	0	1%	98%	0%	<1%
5-2	**51,863**	**4,943**	**46,031**	**687**	**202**	**10%**	**89%**	**1%**	**0%**
Ponderosa Pine	40,994	2,990	37,349	545	111	7%	91%	1%	<1%
Aspen	10	0	6	3	1	0%	63%	30%	7%
Grassland	3,297	1,672	1,402	137	86	51%	42%	4%	3%
Juniper Woodland	74	0	74	0	0	0%	100%	0%	0%
Oak Woodland	291	15	276	0	0	5%	95%	0%	0%
Pinyon-Juniper	7,196	266	6,924	2	4	4%	96%	0%	0%

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of and adjacent to Grand Canyon National Park. The town of Tusayan is in the northwest corner, and concerns about hazardous wildland fuels to the east of Tusayan. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area. Modeled post-treatment fire type (Table 102) shows potential for crown fire on 5% (1,316 acres) of RU6, of which 1% (601 acres) would be active crown fire. That would exceed the desired condition of <30 contiguous acres of active crown fire. For this reason, Alternative D would not meet desired conditions for fire type in RU6.

Ponderosa pine would have potential for crown fire across 4% (1,999 acres) of RU6, of which 1% (600 acres) would be active crown fire.

Grassland effects under Restoration Unit 6, would be identical to those of Alternative B. See discussion on page 208, and under Alternative B on page 150.

Oak woodlands would have the same effects under Alternative D as under Alternative B. See discussion on page 208 and under Alternative B on page 149.

Pinyon/Juniper treatment acres occupy 2,219 acres. The effects of Alternative D on fire type in Pinyon/Juniper in RU6 differ from those of Alternative B by 9 acres, and were considered identical. See discussion on page 209, and under Alternative B on page 151. Under Alternative D, there would be 9 more acres of passive crown fire. Active crown fire acres would be the same.

Table 102. Fire type by vegetation type for Restoration Unit 6

RU 6 acres =		43,530	Veg type acres	2010		Alt. D 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine**	**Surface**	**41,189**	**33,673**	**82%**	**39,146**	**95%**
		Passive		**2,233**	**5%**	**1,399**	**3%**
		Active		**5,238**	**13%**	**600**	**1%**
	PFA/ dPFA	Surface	4,050	3,506	87%	3,988	98%
		Passive		111	3%	56	1%
		Active		430	11%	2	0%
	LOPFA	Surface	37,139	30,167	81%	35,158	95%
		Passive		2,123	6%	1,343	4%
		Active		4,808	13%	597	2%
Other vegetation types*	Grassland	Surface	93	89	96%	89	96%
		Passive		2	2%	3	3%
		Active		1	1%	1	1%
	Juniper Woodland	Surface	13	10	79%	11	83%
		Passive		3	21%	2	17%
		Active		0	0%	0	0%
	Oak Woodland	Surface	30	9	30%	30	100%
		Passive		20	68%	0	0%
		Active		1	2%	0	0%
	Pinyon/ Juniper	Surface	2,206	1,472	67%	1,877	85%
		Passive		504	23%	329	15%
		Active		229	10%	0	0%

* Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU6

Subunits

As indicated in Table 103, Subunits 6-2 would meet desired conditions for fire type under Alternative D, of less than 10% crown fire in ponderosa pine. Subunit 6-3 meets desired conditions for less than 10% crown fire, but there are two areas of >30 acres of contiguous crown fire, one of which is mostly active crown fire. In Subunit 6-4, there is diverse vegetation in most of the stands showing potential for passive crown fire, including juniper and Gambel oak. Figure 28 shows the structure of the area, with multiple ladder fuels, but open areas between clumps of vegetation, with ponderosa pine as the dominant species. This structure easily promotes passive crown fire, which is responsible for much of the crown fire potential in Subunit 6-4, the majority of which is in Pinyon/Juniper. This would not meet desired conditions for fire type.

Table 103. Modeled fire type in Restoration Unit 6 subunits by vegetation type for 2020

		Fire Type (acres)				Fire Type (percent)			
Alternative D	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
6-2	**5,551**	**7**	**5,365**	**153**	**26**	**<1%**	**97%**	**<3%**	**<1%**
Ponderosa Pine	5,069	7	4,891	144	26	0%	97%	<3%	<1%
Pinyon-Juniper	483	0	473	9	0	0%	98%	2%	0%
6-3	**34,109**	**33**	**32,811**	**693**	**571**	**0%**	**96%**	**2%**	**2%**
Ponderosa Pine	32,635	33	31,454	578	571	0%	96%	2%	2%
Grassland	85	0	82	3	1	0%	96%	3%	1%
Juniper Woodland	13	0	11	2	0	0%	83%	17%	0%
Pinyon-Juniper	1,375	0	1,265	110	0	0%	92%	8%	0%
6-4	**3,870**	**4**	**2,977**	**886**	**3**	**0%**	**77%**	**23%**	**0%**
Ponderosa Pine	3,484	4	2,801	677	3	<%	80%	19%	<%
Grassland	7	0	7	0	0	0%	100%	0%	0%
Oak Woodland	30	0	30	0	0	0%	100%	0%	0%
Pinyon-Juniper	348	0	139	209	0	0%	40%	60%	0%

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 15, desired openness is an indication of the relative desired post treatment interspace/tree group condition. Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 168. Surface fuel loading may produce desirable or undesirable fire effects, depending on the initial loading and the conditions under which it burns (see page 86).

Canopy characteristics affecting fire behavior

Changes to canopy cover (CC), canopy base height (CBH), and canopy bulk density (CBD) are important indicators of potential fire behavior that can display changes that are not always apparent in the fire behavior data. The following figures and tables are classified by treatment type, based on their relative ability to attain a mosaic of interspaces and tree groups (McCusker et al. 2014). Across the landscape, a mosaic at all scales would be well adapted to fire for southwestern ponderosa pine, and would be maintainable by fire alone should that be desired. Immediately post-treatment (2020), all action alternatives show movement towards desired condition significant enough to have met desired conditions for fire behavior in ponderosa pine (see sections above).

Acres that are the most at risk regarding canopy fuel structure that supports crown fire are in

PACs and Core Areas. When CBH and CBD are averaged over all pine vegetation under Alternative D, they meet desired conditions, with an average CBH of 23 feet, and an average CBD of 0.035 kg/m^3 (Table 104).

Table 104. Modeled canopy characteristics under Alternative D. Shaded cells would not meet desired conditions.

Alt D	CBH (feet)			CBD (kg/m3)			CC (%)			% of pine
Desired Openness	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	15	26	27	0.061	0.028	0.036	41	25	35	42
Moderate	15	22	23	0.061	0.035	0.045	43	32	43	24
Low (Mechanical)	16	23	25	0.060	0.042	0.048	41	34	43	5
Low (Burn Only)	14	20	25	0.046	0.036	0.037	33	27	32	18
Very Low (Burn Only)	15	21	26	0.063	0.048	0.049	41	35	39	2
Very Low (Mechanical)	16	23	29	0.062	0.052	0.052	48	45	51	4
Very Low (PAC Burn Only)	14	16	22	0.067	0.067	0.067	49	51	54	4
Very Low/No Proposed Treatments (Core Areas)	14	16	22	0.070	0.071	0.069	51	52	55	1
No Proposed Treatments	16	18	23	0.069	0.069	0.063	43	45	47	<1
Weighted Average[4]	**15**	**23**	**26**	**0.059**	**0.035**	**0.041**	**41**	**30**	**38**	

Under Alternative D, post treatment conditions differ by as much as 10 feet, between 'Very Low' treatments and 'High' treatments. CBH reaches and maintains desired condition for 95% of the ponderosa pine vegetation (excluding PACs and Core Areas which do not have desired conditions for CBH or CBD) though 2050. CBD reaches desired conditions in about 90% of the ponderosa pine, and maintains it through 2050. Note: desired conditions for CBH and CBD do not apply to PACs or Core Areas.

Canopy Cover (CC) decreases with completion of treatments for all but the two lowest intensity treatments ('Very Low (PAC Burn Only' and Very Low/No Proposed Treatments (Core Areas) in which it increases (Figure **61**).

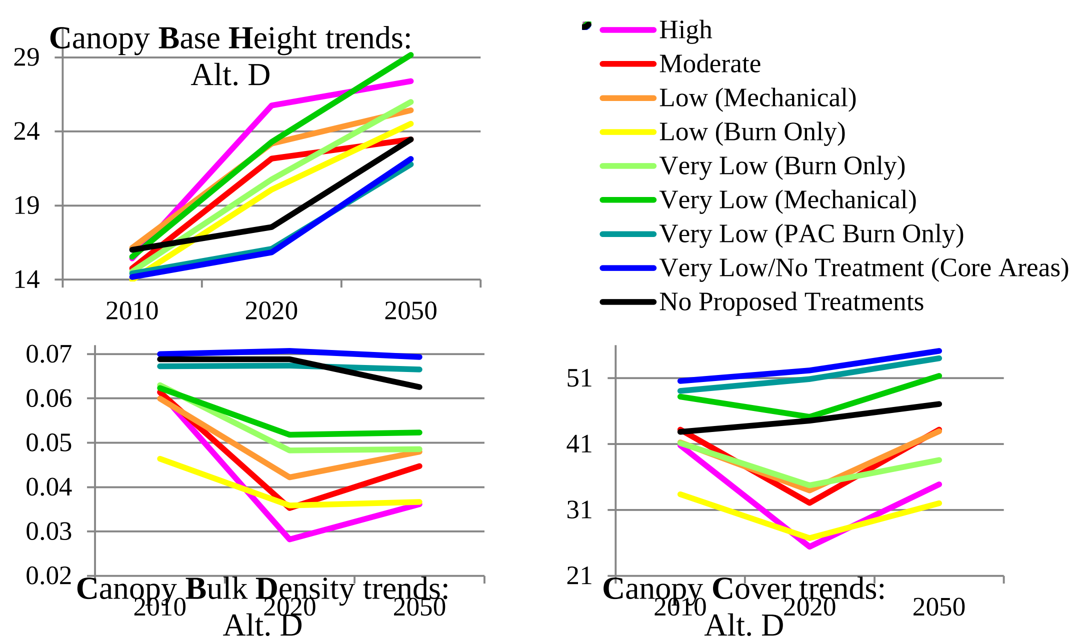

Figure 61. Trends in canopy cover characteristics under Alternative D.

CC stays below pretreatment levels for high and moderate. In this alternative, the lowest two levels of desired openness support canopy characteristics most likely to support crown fire. When CBH is high, if CBD and CC are high enough, it is possible for conditional crown fire to occur, as crown fire moves into a stand from the canopy of an adjacent stand. Crown fire only needs one 'ladder' location to initiate active crown fire. Only in the two highest levels of desired openness does CC stay below pre-treatment levels by 2050. Assumptions are that thinning and two prescribed burns occurred between 2010 and 2020, and no mechanical treatments, wildfire, or prescribed fire occurred between 2020 and 2050.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of proposed treatments that have indirect effects on fire behavior and effects. Litter, duff, and Coarse Woody Debris greater than 3" diameter (CWD>3") contribute to multiple characteristics of a fire regime, including, but not limited to: flammability, surfaced fire intensity, scorch height, flame length, and surface fire effects, and emissions.

They contribute more than other fuels to emissions, particularly CWD and duff. Surface fuels can create high burn severity, and high severity effects to surface biota (roots, seeds, forbs, and other species adapted to low severity fire), as well as producing troublesome emissions. Mechanical thinning alone can contribute significantly to decreasing the potential for crown fire by decreasing and breaking up vertical and horizontal canopy fuel continuity, but does not decrease surface fuel loading (Fulé et al. 2012). General effects are similar in areas that are not burned (see discussion in Alternative B under 'Litter, Duff, and Coarse Woody Debris greater than 3 inches Diameter' on page 168.

Surface fuel loading by treatment ability to maintain desired openness

Under Alternative D, only 'Low (Burn Only), and 'Very Low (Burn Only) would actually include prescribed fire, but the names are kept the same as they indicate the intensity of mechanical treatments that are implemented. As can be seen in, surface fuel loading increases where there are mechanical treatments and, where there is prescribed fire, surface fuel loading decreases, or there is only a very slight increase (Figure **62**). Using 20 tons/acre as the upper end of what might be considered a range of recommended fuel loading, All treated areas would remain below 20 (Table 105). Historical values were around 5 tons per acre on the high end for CWD, and less than 2.5 tons/acre for duff (Brown et al. 2003), none of these treatments decrease to levels that would indicate values within historic ranges (Figure **62** also includes litter).

Table 105 displays modeled changes in surface fuel loading under Alternative D. Assumptions are that one mechanical treatment and two prescribed burns occur between 2010 and 2020, and that there were no additional mechanical treatments, wildfires, or prescribed fires between 2020 and 2050. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD, or recommend surface fuel loading of <20 tons/acre.

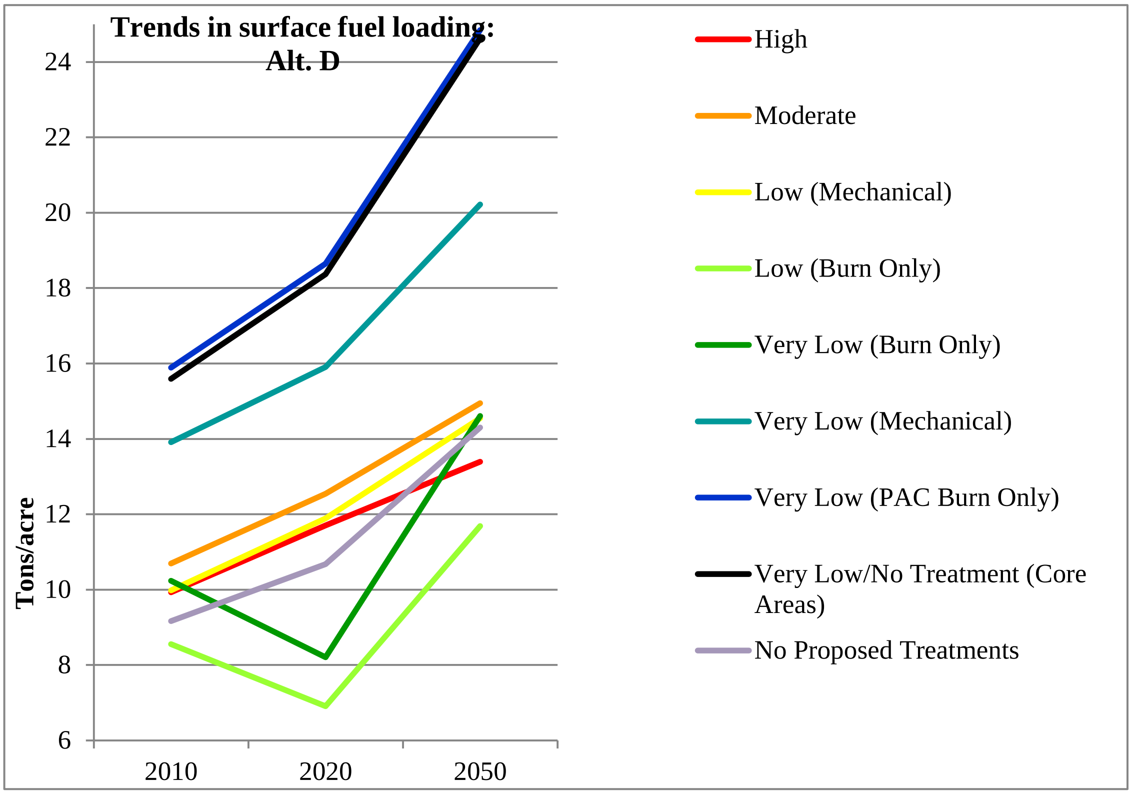

Figure 62. Trends in surface fuel loading under Alternative D.

Table 105. Modeled changes in surface fuel loading under Alternative D

Desired openness	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			% pond pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.7	6.0	6.7	3.1	2.4	3.0	3.2	3.3	3.7	9.9	11.7	13.4	42%
Moderate	3.6	5.8	6.9	3.9	3.4	4.2	3.1	3.3	3.9	10.7	12.5	14.9	24%
Low (Mechanical)	3.6	5.4	6.9	3.2	3.1	3.8	3.2	3.4	3.9	10.0	11.9	14.5	5%
Low (Burn Only)	3.2	2.8	6.2	2.5	1.6	2.6	2.9	2.5	2.9	8.6	6.9	11.7	18%
Very Low (Burn Only)	3.8	3.2	7.8	3.2	2.0	3.4	3.2	3.0	3.4	10.2	8.2	14.6	2%
Very Low (Mechanical)	5.0	6.9	9.7	5.0	4.9	5.5	3.9	4.2	5.0	13.9	15.9	20.2	4%
Very Low (PAC Burn Only)	6.0	7.8	12.5	4.8	5.5	6.1	5.1	5.4	6.2	15.9	18.6	24.8	4%
No Proposed Treatments (Core Areas)	5.8	7.6	12.4	5.1	5.8	6.3	4.7	5.0	5.9	15.6	18.4	24.6	1%
No Proposed Treatments	3.3	4.0	6.7	2.9	3.5	3.8	3.0	3.2	3.8	9.2	10.7	14.3	0%
Weighted Averages	**3.7**	**5.4**	**7.1**	**3.3**	**2.8**	**3.5**	**3.2**	**3.3**	**3.8**	**10.3**	**11.5**	**14.3**	

Surface fuel loading by stand

Figure 63 shows the post-treatment spatial distribution of surface fuel loading by stands. Yellow, orange, and red shades represent areas where surface fuel loading exceeds 20 tons/acre. The majority of those areas are in PACs or PFAs in RU1 and RU3. Under Alternative D, in 2020 there would be about 3,298 acres with surface fuel loading greater than 20 tons/acre and 73,996 acres in the 15 – 20 tons/acre range. By 2040, there would be 19,269 acres exceeding 20 tons/acre, and 152,862 acres in the 15 – 20 tons/acre range. Assumptions are the same as for Table 105.

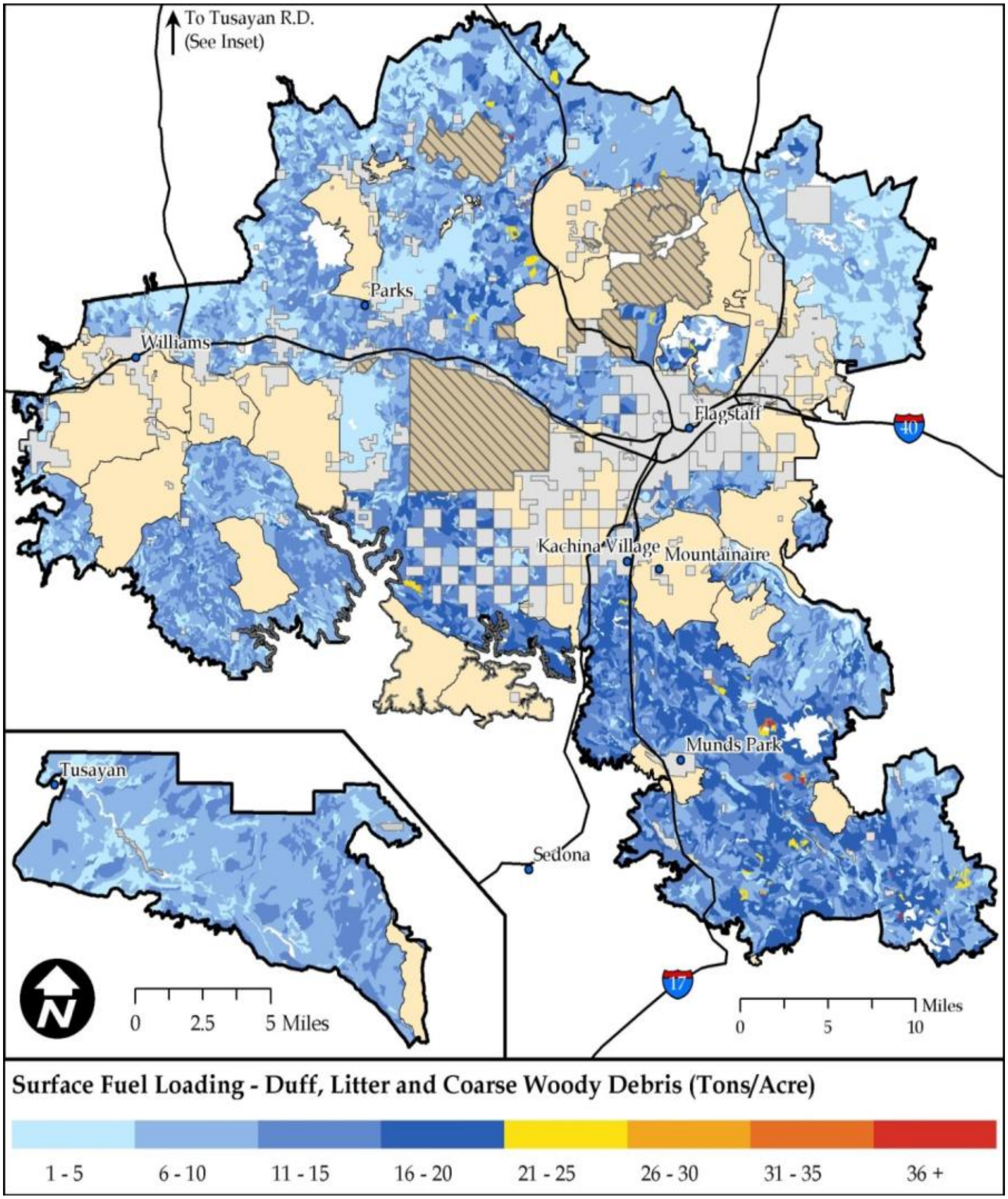

Figure 63. Surface fuel loading under Alternative D

Fire Regime/Condition Class

Under Alternative D, acres of ponderosa pine, in Vegetation Condition Class 3 (VCC) would decrease by over 132,000 acres (Table 106). Modeling results indicate that, after 30 years of no disturbance (following proposed treatments), the 4FRI ponderosa pine area reverts to an FRCC3. Under Alternative D, ponderosa pine in the treatment area would move toward the desired condition of FRCC2, and no acres in VCC3 with the proposed treatments. One of the important variables for determining FRCC is the fire return interval. Across 70% of the treatment area, there would be no prescribed fire. As the fire return interval gets longer, canopies close up and encroachment and ladder fuels make progress so, with disturbance of any kind modeled from 2020 to 2050, there would be a continual shift towards FRCC3.

Acres of grasslands in FRCC1 would decrease in the absence of treatments as woody species continued to encroach and species composition shifted in favor of less fire adapted species. Although treatments in grasslands under Alternative D would only occur as Operational Burning, when prescribed fire is implemented, it would improve the stability of key ecosystem elements. The general deterioration of the stability of key ecosystem components (such as soil) would be expected because so many acres have been encroached upon by trees that are too big to kill with fire.

Table 106. Fire Regime/Condition Class under Alternative D

VCC – Alt. D	2010		2020		2050	
	Acres	Percent	Acres	Percent	Acres	Percent
1	71,097	14%	81,254	16%	45,706	9%
2	126,960	25%	248,841	49%	233,606	46%
3	309,782	61%	177,744	35%	228,528	45%
Vegetation departure =	66%		49%		76%	
Fire Severity Departure =	74%		20%		58%	
Fire Return Interval Departure =	80%		77%		88%	
FRCC of treatment area =	**3**		**2**		**3**	

Unique to Alternative D is the proposal of 384,966 acres of mechanical treatments with no prescribed fire. Mechanical treatments produce surface disturbance, including exposed, disturbed mineral soil. This provides an ideal opportunity for the germination of seedlings, as well as some invasive species. With no prescribed fire in these areas, it can be expected that far more of the seedlings would survive, producing doghair thickets and ladder fuels across large portions of the landscape. This is reflected in the shift from 35% in VCC3 in 2020 to 45% in 2050, and an FRCC from 2 back to 3 as these trees mature.

Fire Return Interval

Fire return intervals (FRI), as described on page 37, are a characteristic of a fire regime, and a coarse measure of the health of a system. This analysis uses running averages of acres treated by planned and unplanned fire. In reality, there would be wide fluctuations in the number of acres treated each year depending on weather, resource availability, public tolerance, funding, and logistics. See discussion under Alternative B under ‘Fire Return Interval’ on page 174.

Under Alternative D, the use of either fire or mechanical treatments is absolute (there are no areas that include both, it can be assumed that, for areas that receive only mechanical treatments, the FRI would be the same as for Alternative A (no treatment) and, for areas that would receive burning, the FRI would be similar to Alternative B.

Post treatment (2020), in burn only areas (178,441 acres, or 30% of the treatment area), the FRI would be about 10 years, on a trajectory towards the desired condition. In areas that would receive only mechanical treatments, the FRI would be 80 years, departing further from desired conditions of being sustainable and resilient.

By 2050, FRI in burn only areas would be about 20 years, departing from the trajectory it was on immediately post-treatment. In areas with only mechanical treatments, the FRI would be 160 years, highly departed from what would be a sustainable, resilient condition.

Table 107 shows the estimated fire return intervals for the proposed treatment area under different alternatives over forty years. Ideally, FRI would average about 10 years, if monitoring indicates that is producing desired results.

Table 107. Fire Return Intervals under Alternative D

Alternative D	# of years averaged (years)	Average annual acres burned	Fire Return Interval over years averaged for entire treatment area
Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
2020 (burn only) 2020 (mechanical only)	20 (2001- 2020)	17,844 (2001- 2020)	34
2050 (burn only) 2020 (mechanical only)	40 (2001- 2050)	8,922 (2001- 2050)	67

Emissions: Air Quality and Ecological Effects

This alternative would meet desired conditions for air quality. Under this alternative, 17,844 acres would need to burn each year to meet a 10 year fire return interval.

There is an inverse relationship between short term and long term smoke impacts to communities. Alternatives that reduce fire treatment also reduce short term smoke impacts, which are indirect effects from prescribed fire. However, alternatives that increase short term smoke impacts would likely reduce longer term impacts because the potential for undesirable wildfire behavior and effects is reduced, including the potential tons/acre of emissions. Uncharacteristic wildfires produce more concentrated and toxic smoke impacts.

Alternative D proposes to treat 384,966 with mechanical thinning treatments only. However, at some point, these acres (as with most acres within the treatment areas) are likely to burn with wildfire. Under those circumstances, there would be with little warning, little control over the smoke, and a great deal more smoke that if prescribed fire was used. Figure 63 shows emissions potential in pounds/acre that would be expected from areas that began with similar fuel loading, but were given different treatments before burning under conditions that would produce extreme fire behavior (details in Appendix F). Columns 2 and 4 represent restoration treatments that include removal of the most flammable surface fuels with prescribed fire – duff, litter and CWD.

Column 1 represents no treatment, and column 3 represents a treatment that only removes the large fuels and canopy fuels (mechanical thinning), and in which surface fuel loading has increased. The error bars show that they are statistically identical. This chart shows only surface fuel emissions, because canopy fuels are only a minor component of most prescribed fire but, when they burn in wildfire, they generally burn up in a short period during the passage of the flaming front.

Alternative D proposes to thin but not burn 70% of the treatment area. That means that about 384,966 acres would produce emissions more like column three, and 178,441 acres (burn only) would be in column two. Emissions from prescribed fires would be still less, though they would occur cyclically.

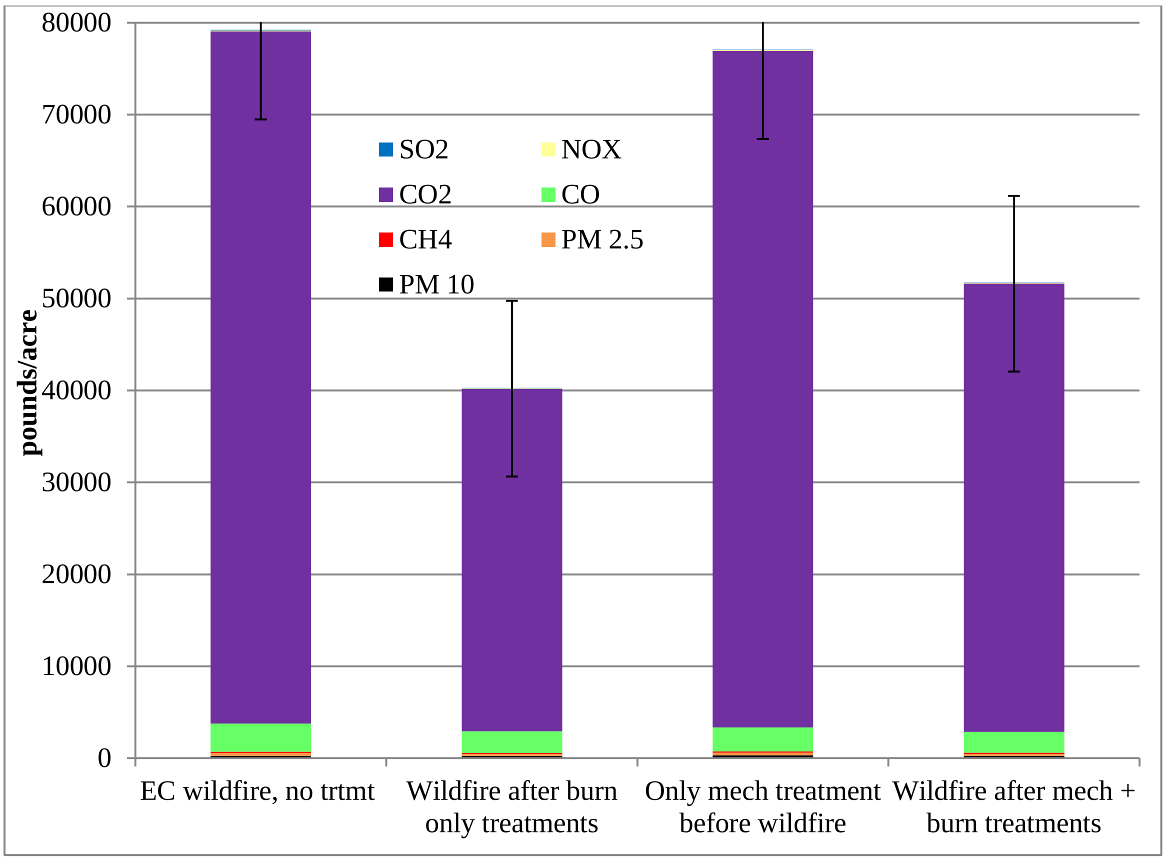

Figure 64. Emissions from surface fuels burning in wildfires after various treatments

Ecological effects of smoke

From an ecological perspective, smoke effects are important to the germination of many native plants (Abella 2006; Abella et al. 2007; Abella 2009; Keeley and Fotheringham 2002; Schwilk and Zavala 2012), and may be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1975; Zimmerman et al. 1987). This Alternative would significantly decrease the area over which smoke could maintain its ecological roles.

Stream/spring restoration

Effects on stream/spring restoration would be identical to those in Alternative B. See discussion on page 174.

Roads

Road effects would be identical to those in Alternative B. See discussion on page 174.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources would be almost identical to those in Alternative B. See discussion on page 174.

Alternative E

From a fire ecology perspective, direct and indirect effects of Alternative E relate primarily to treatments that include using mechanical thinning, prescribed fire, or both to meet the purpose and need of the 4FRI. Alternative E responds to public comments that brought up Issue 5 (Alternatives) by removing all forest plan amendments. On average, 40 – 60,000 acres of prescribed fire would be implemented annually across the Forests (within the treatment area). Up to two prescribed fires[4][6] would be conducted on all acres proposed for burning over the 10-year period. Eighteen MSO PACs would be mechanically treated to 9-inch dbh. No prescribed fire would be utilized within MSO PAC core areas. No acres would be managed for open reference conditions[7]. No treatments would occur within the proposed Garland Prairie RNA. MSO population and habitat monitoring would follow current forest plan direction and the FWS biological opinion. There would be a paired watershed research project implemented, involving six small watershed (smaller than 6th code).

The Coconino and Kaibab NFs would conduct restoration activities on approximately 581,301 acres over a period of 10 years or until objectives are met. On average, 45,000 acres of vegetation would be mechanically treated annually. Restoration activities would:

- Mechanically thin about 431,049 acres including: (1) mechanically treating up to 9-inch dbh within 18 Mexican spotted owl protected activity centers and, (2) disposing of slash through various methods including chipping, shredding, mastication, and removal of biomass off-site.
- Implement prescribed fire on 586,110 acres.
- Utilize prescribed fire only on approximately 177,801 acres (no mechanical treatments).
- Construct 520 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed).
- Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no new permanent roads would be constructed). Of these miles, approximately 30 miles would be improved to allow for haul (primarily widening corners to improve turn radiuses) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.
- Decommission 726 miles of existing system and unauthorized roads on the Coconino NF.
- Decommission 134 miles of unauthorized roads on the Kaibab NF.
- Restore 74 springs and construct up to 4 miles of protective fencing.

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[6] A single prescribed fire may include burning piles and a follow-up broadcast burn. Prescribed fire would be implemented as indicated by monitoring data to augment wildfire acres, with the expectation that desired conditions would require a fire return interval of about 10 years.

[7] Open Reference Condition is defined as forested ponderosa pine areas with mollic integrade soils to be managed as a relatively open forest with trees typically aggregated in small groups within a grass/forb/shrub matrix.

- Restore 39 miles of ephemeral channels.
- Construct up to 82 miles of protective (aspen) fencing.
- Allocate/manage as old growth 40% of ponderosa pine and 77% of pinyon-juniper woodland on the Coconino NF, and manage 35% of ponderosa pine and 58% of pinyon-juniper on the Kaibab NF.

Thinning, whether or not slash was removed from the site, would give managers more control of the amount and timing of emissions. As thinning and first-entry burns were completed, burn windows would expand for larger areas so more burning could occur when ventilation was good. Fewer and healthier trees, as a result of thinning and would be more fire resistant, and understory and surface vegetation would become established. With lower surface fuel loading, and canopy fuels adapted to fire, burn windows would be broader than for initial entry burns. Decision space for managing unplanned ignitions would expand as 4FRI (and other projects) are implemented. Where prescribed fire is proposed, up to two prescribed fires would be implemented (except in aspen where there would be only one). A single prescribed fire may include pile burning months in advance of broadcast burns. Ideally, prescribed fires would occur on an average of every 10 years, depending on yearly fluctuations in climate/weather at different locations within the treatment area. Some areas will have had prescribed fire or wildfire within the last 10 – 15 years, so prescribed fires that are implemented would be maintenance burns. Limitations (wildlife concerns, smoke, funding, resource availability, etc.) may make it difficult to attain an average of a 10 year fire return interval across the proposed treatment area. Burning some areas on a slightly longer return interval may be acceptable (drier areas such as Tusayan) and/or may specifically target to reduce smoke in sensitive receptors as mitigation for prescribed fires.

This alternative would meet direction in the Forest Service Manual 5100 which includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. Objectives of fire management on lands managed by the USFS include:

1. Forest Service fire management activities shall always put human life as the single, overriding priority. The proposed actions of the 4FRI fully support incorporation of the highest standards for firefighter and public safety and are expected to improve and enhance the safety of the public as it relates to wildland fire.

2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement. 4FRI proposes to achieve restoration by restoring ecosystems within the treated area to a condition so that fire, when it occurs, would be beneficial to the ecosystems in which it burns without threatening lives, property, or resources. This would be achieved by fully integrating local industry, mechanical and fire prescriptive treatments, and providing for sustainable supplies of goods, services, and social values though implementation of appropriate fire management activities.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative E are discussed in the following order:

1. Fire behavior is discussed at the treatment area scale

2. Potential fire type is discussed by vegetation type
3. Within Restoration Units and Subunits, fire type is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced by breaking up the vertical and horizontal continuity of canopy fuels, decreasing excessive surface fuel loads of litter and duff (all direct effects), and replacing them with the light, flashy fuels that would be stimulated by post-treatment conditions (second order effects). Wildfire behavior would benefit the ecosystems in which it burned, and would not threaten lives, resources, or infrastructure, except where they are near or downslope from wildlife habitat that could not be treated as intensively as the rest of the treatment area at this time. Air quality impacts (indirect effects) could increase some as prescribed fires are implemented. Decreased treatment intensity on ~40,000 acres of ponderosa pine would mean treatments in those areas would have decreased longevity because already closed or moderately closed canopies close up more quickly than moderately open.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to canopy fuels, would remain lower than existing condition for about 91% of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by changes to surface fuel loading, would remain lower than existing condition for about 60% of the ponderosa pine in the treatment area. Air quality impacts could decrease some as the majority of the treatment area could be managed with maintenance burns, producing fewer emissions per acre. Decreased treatment intensity on ~40,000 acres of ponderosa pine would mean many of those acres would move more rapidly away from desired conditions, and be at high risk of high severity fire.

When analyzed at the scale of the treatment area, Alternative E would meet the purpose and need by moving the project area towards the desired condition of having potential for less than 10% crown fire as modeled under the conditions that produced the Schultz Fire (Table 108) crown fire. Table 108 displays modeled fire type for Alternative E across the entire treatment area. Non-burnable substrates constitute ~1% of the treatment area and were not included in the acres shown fire potential fire behavior.

Table 108. Modeled fire type for Alternative E and Existing Condition

Modeled Fire type	Existing Condition(% area)	Alternative E
No fire	<2	<2
Surface fire	64	94
Passive crown fire	9	3
Active crown fire	25	2

Under Alternative E, the horizontal and vertical continuity of canopy fuels are broken up (direct effect), decreasing the potential for crown fire from 34% of the treatment area to 5% of the treatment area, with potential for active crown fire decreasing from 25% to 2% (indirect effect). Groups would be larger and denser than in Alternative C, though available model are limited in the ability to analyze complex spatial data at the scale of groups and interspaces. It is possible that there would be a bit more crownfire than was modeled. However, even with the additional ~1,750 acres of crownfire that could occur on 40,000 acres where treatment intensity has been decreased, Alternative E would still be expected to meet desired conditions for fire behavior in ponderosa pine. The total amount of potential crown fire remaining after proposed treatments would be well within the historic ranges of ponderosa pine in this area. As illustrated by Figure 65, much of the remaining potential for active crown fire would be in Restoration Units 1 and 3, south of Interstate 40, and east and west of Interstate 17. In most cases, it would occur in MSO and goshawk habitat (Table 109). Non-burnable substrates constitute ~1% of the treatment area and were not included in the acres shown fire potential fire type.

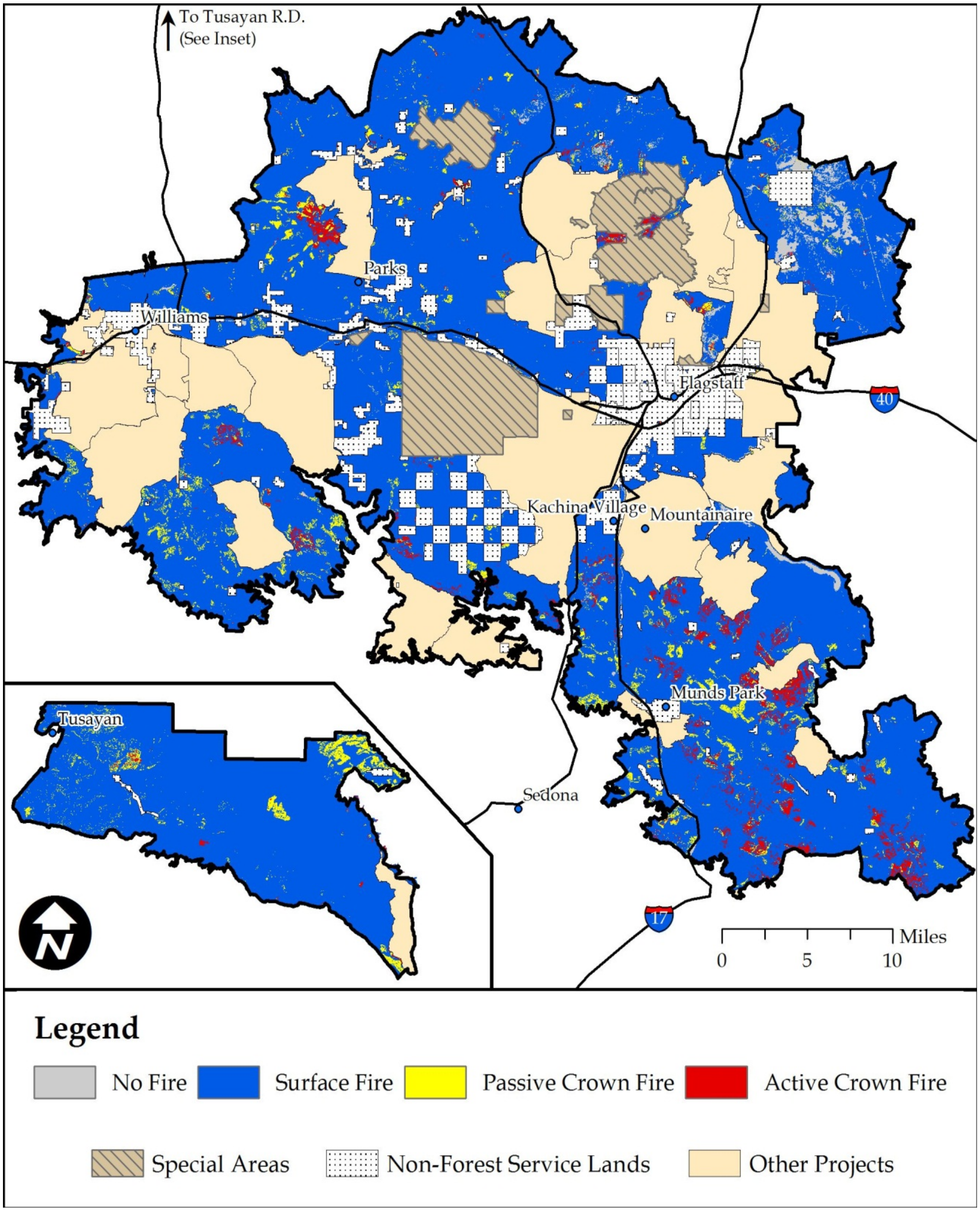

Figure 65. Modeled fire type for Alternative E, 2020

Ponderosa Pine

The majority of ponderosa pine acres would meet desired conditions under Alternative E when acres are analyzed at the landscape scale. At the scale of ponderosa pine vegetation, the crown fire risk and effects are similar to Alternative B, with the exception of lower treatment intensity on ~40,000 acres of VSS4, VSS5, and VSS6 stands. In those stands, modeled fire behavior would shift about 1,740 acres from surface fire to crownfire, and about 130 acres from passive to potentially active crownfire. When broken out by habitat type, 28% (9,669 acres acres) of protected habitat in ponderosa pine would still be at risk of crown fire, of which 24% (8,293 acres) would be active crown fire (Table 109). The active crown fire in protected habitat accounts for ~75% of crownfire in ponderosa pine under Alternative E.

Table 109. Modeled fire type in ponderosa pine by habitat for Alternative E

Vegetation Type		Fire Type	Existing Conditions		Alt. E 2020	
			Acres	%	Acres	%
Ponderosa Pine*	**All Pine****	**Surface**	**311,313**	**61%**	**474,404**	**93%**
		Passive crown	**48,023**	**9%**	**17,002**	**3%**
		Active crown	**143,186**	**28%**	**11,140**	**2%**
	Protected	Surface	17,954	51%	25,429	72%
		Passive crown	3,034	9%	1,289	4%
		Active crown	14,106	40%	8,380	24%
	Target/ Threshold	Surface	4,275	49%	8,293	95%
		Passive crown	922	11%	45	1%
		Active crown	3,482	40%	337	4%
	Restricted	Surface	35,019	53%	57,426	86%
		Passive crown	6,540	10%	8,359	13%
		Active crown	24,756	37%	541	1%
	PFA/ dPFA	Surface	18,400	61%	27,493	92%
		Passive crown	2,903	10%	1,927	6%
		Active crown	8,560	29%	437	1%
	LOPFA	Surface	235,666	64%	355,764	97%
		Passive crown	34,624	9%	5,382	1%
		Active crown	92,282	25%	1,446	0%
Other Vegetation*	Aspen	Surface	1,120	74%	1,186	78%
		Passive crown	135	9%	250	16%
		Active crown	258	17%	78	5%
	Grassland	Surface	41,491	86%	45,685	95%
		Passive crown	3,059	6%	3	0%
		Active crown	1,153	2%	2	0%
	Juniper Woodland	Surface	1,941	83%	2,335	100%
		Passive crown	74	3%	2	0%
		Active crown	320	14%	0	0%
	Oak Woodland	Surface	2,504	77%	3,214	99%
		Passive crown	266	8%	3	0%
		Active crown	466	14%	22	1%
	Pinyon/Juniper	Surface	19,379	83%	22,571	97%
		Passive crown	1,523	7%	345	1%
		Active crown	2,047	9%	45	0%

*Nonburnable substrate constitutes ~1% of ponderosa pine and <2% of the entire treatment area

**Decreased treatment intensity on ~40,000 acres of ponderosa pine would be expected to shift about 1,750 acres from surface fire to passive or active crownfire outside of MSO habitat. There would be ~130 acres previously modeled as passive crownfire that would have potential to support active crownfire.

Pine/Sage

Effects for Pine/Sage would be identical to Alternative B, as discussed on page 148.

Aspen

Fire type differs from Alternative B by just 6 acres, with the number of acres treated being the same. Effects would be the same as those described in Alternative B under ‘Aspen’, page 147.

Gambel Oak

Acres of fire type differ from Alternative B by 16 acres, with Alternative E having 16 more acres of crown fire. Effects would be otherwise identical to those discussed on page 149 under Alternative B under ‘Gambel Oak’. The exception would be for parts of the ~40,000 acres of decreased treatment intensity in which oak would continue to be suppressed. In these areas, large oaks would continue to be at some risk of high severity fire, though decreased somewhat from pre-treatment conditions.

Grasslands

Alternative E proposes to implement mechanical treatments and prescribed fire on 47,915 acres of grassland, and prescribed fire only on an additional 488 acres of grasslands, for a total of 48,403 acres of grassland treatments. Desired Conditions would be met for grasslands under Alternative E (Table 110).

Table 110. Modeled fire type in grasslands by Restoration Unit under Alternative E

Grassland RU	Fire Type	Grassland acres	Existing		Alt. E 2020	
			Acres	%	Acres	%
RU1	Surface	8,135	6,131	75%	7,703	95%
	Passive crown		1,340	16%	0	0%
	Active crown		236	3%	0	0%
RU3	Surface	12,772	11,670	91%	12,513	98%
	Passive crown		706	6%	3	0%
	Active crown		167	1%	2	0%
RU4	Surface	22,661	21,080	93%	22,535	99%
	Passive crown		788	3%	0	0%
	Active crown		645	3%	0	0%
RU5	Surface	4,536	2,521	56%	2,842	63%
	Passive crown		222	5%	0	0%
	Active crown		105	2%	0	0%
RU6	Surface	93	89	96%	93	100%
	Passive crown		2	2%	0	0%
	Active crown		1	1%	0	0%

Pinyon/Juniper Woodlands (PJ)

Effects on fire type for PJ under Alternative E are identical to those discussed in Alternative B (Table 111), differing by 1 acre. Effects are as discussed under Alternative B on page 151. Table 112 displays modeled fire type in pinyon-juniper with a fuels objective.

Table 111. Fire type in all Pinyon/Juniper under Alternative E

Vegetation Type	Fire Type	2010 Percent/Acres	Alternative E 2020 Percent/Acres
Pinyon/ Juniper	No fire	<2/367	<2/356
	Surface crown fire	83/19,379	97/22,571
	Passive crown fire	7/1,523	1/345
	Active crown fire	9/2,047	0/45

Table 112. Fire type in the Pinyon/Juniper in Restoration Unit 6 (fuels reduction objective)

Vegetation Type	Fire Type	2010 Percent/Acres	Alternative E 2020 Percent/Acres
Pinyon/ Juniper	No fire	0/0	0/0
	Surface crown fire	74/595	100/533
	Passive crown fire	25/132	0/2
	Active crown fire	<2/8	0/0

Restoration Units

When analyzed at the scale of the Restoration Unit, Alternative E would meet desired conditions for fire type in four out of five RUs. Post-treatment potential for crown fire ranges from 11% in RU1 to 3% in RU5 (Table 113). ”No fire” includes water, rock, roads, cinders, areas of sparse vegetation, and other acres on which there were insufficient fuels to carry fire under the conditions modeled. These acres range from 44 acres (0.11%) in RU6 to 5,739 acres (7.8%) in RU5.

Table 113. Fire type for Alternative E by Restoration Units.

		Fire Acres*			Fire Percent		
	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	Surface Fire	Passive Crown Fire	Active Crown Fire
Alt. E (2020)	RU 1	141,135	4,680	7,646	91%	3%	5%
	RU 3	139,311	6,977	2,490	93%	5%	2%
	RU 4	161,367	3,198	531	97%	2%	<1%
	RU 5	66,118	832	514	90%	1%	1%
	RU 6	41,463	1,917	106	95%	4%	<1%
	Total	**549,395**	**17,605**	**11,286**	**94%**	**3%**	**2%**

*Decreased treatment intensity on ~40,000 acres would add potential crownfire on ~1,750 acres, and potential for active crown fire where previous modeling showed potential for passive crown fire on about 130 acres.

Restoration Unit 1

Restoration Unit 1 is of particular concern because Lake Mary is a source watershed for Flagstaff, and fire behavior in this RU could affect an observatory just north of Lower Lake Mary, and Walnut Canyon. There are adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer, as well as the city of Flagstaff to the northwest. Post-treatment modeling for Alternative E shows 8% (12,326 acres) of RU1 would have crown fire potential, of which 5% (7,646 acres) would be active crown fire. A 498 acre control watershed for a research project would receive no treatment. This watershed would account for 8% (1,043 acres) of the crown fire, of which 874 acres would be active crown fire.

Ponderosa pine occupies 146,037 acres in Restoration Unit 1, more than the other Restoration Units. Post-treatment, 8% (12,136 acres) of the pine vegetation type would have potential for high severity effects from crown fire, of which 5% (4,596 acres) would be active crown fire (Table 114). The pine vegetation type meets desired conditions for fire type. All, or parts of 52 PACs occur in RU1, accounting for almost 20% (30,000 acres) of the ponderosa pine. There is no desired fire type for protected habitat, of which 26% (8,131 acres) has potential for crown fire, 24% (7,019 acres) of which would be active crown fire. The majority of active crown fire in ponderosa pine in RU1 would be in protected habitat, accounting for over 90% of the crown fire in RU1.

Table 114. Modeled fire type for Restoration Unit 1 by vegetation type for 2020

RU 1 acres =		154,383	Veg type acres	2010		Alt. E 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**144,113**	**80,257**	**56%**	**131,522**	**91%**
		Passive		**15,784**	**11%**	**4,596**	**3%**
		Active		**47,553**	**33%**	**7,540**	**5%**
	Protected	Surface	29,052	15,020	52%	20,862	72%
		Passive		2,246	8%	1,112	4%
		Active		11,728	40%	7,019	24%
	Target/ Threshold	Surface	4,793	2,236	47%	4,556	95%
		Passive		504	11%	16	0%
		Active		2,042	43%	208	4%
	Restricted	Surface	25,710	12,731	50%	22,438	87%
		Passive		2,601	10%	3,190	12%
		Active		10,348	40%	57	0%
	PFA/ dPFA	Surface	4,670	2,594	56%	4,595	98%
		Passive		518	11%	61	1%
		Active		1,558	33%	13	0%
	LOPFA	Surface	79,889	47,676	60%	79,070	99%
		Passive		9,915	12%	216	0%
		Active		21,877	27%	243	0%
Other Vegetation*	Aspen	Surface	420	241	57%	267	63%
		Passive		40	9%	76	18%
		Active		140	33%	77	18%
	Grassland	Surface	8,135	6,131	75%	7,703	95%
		Passive		1,340	16%	0	0%
		Active		236	3%	0	0%
	Juniper Woodland	Surface	286	236	83%	286	100%
		Passive		12	4%	0	0%

		Active		38	13%	0	0%
	Oak Woodland	Surface	287	195	68%	282	98%
		Passive		62	21%	2	1%
		Active		30	11%	3	1%
	Pinyon/ Juniper	Surface	1,141	897	79%	1,076	1%
		Passive		115	10%	5	0%
		Active		95	8%	25	0%

*Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the treatment area within RU1

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 175 acres of crownfire in ponderosa pine in RU1. This would not change the percentages. Decreased intensity on stands previously modeled as savanna treatments would add an additional

Aspen - effects differ from Alternative B by 7 acres and were considered to be identical (see discussion under Alternative B in 'Restoration Unit 1' on page 147).

Grasslands in Restoration Unit 1, would meet desired conditions for fire type. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to 1 percent, meeting desired conditions for fire type. Additional effects are described under Alternative C on page 208.

Pinyon/Juniper woodland effects differ from Alternative B by 1 acre and were considered to be identical (See discussion Alternative B page 152).

Oak woodland effects differ from Alternative B by 18 acres and were considered identical. See discussion on page 152. Under Alternative E, there would be no crown fire in oak woodland.

Subunits

When considered by the subunit (Table 115), four of the five subunits meet desired conditions for fire type. Modeled fire type in Subunit 1-5 shows potential for crown fire would be 10%t (8,338 acres), of which 6% (4,885 acres) would be active crown fire. There would be potential for crown fire in 11% (8,223 acres) of the ponderosa pine in SU1-5, of which 6% (4,883 acres) would be crown fire. This can be attributed to the presence of all, or parts, of 39 PAC within the Subunit. Crown fire in the PACs accounts for the majority of fire in this Subunit.

Subunit 1-3 would have a 2,291 acre control watershed which, for research purposes, would receive no treatment. It would account for 36% of the crown fire in this subunit (1,043 acres). It is about three miles down the drainage to Upper Lake Mary, though the majority of the area is less than a 5% slope, and all is less than 10%.

Table 115. Modeled fire type in RU1 subunits by vegetation type for Alternative E.

Alternative E	Acres	Fire Type (acres) No Fire	Surface	Passive	Active	Fire Type (%) No Fire	Surface	Passive	Active
1-1	**10,170**	**164**	**9,908**	**94**	**4**	**2%**	**97%**	**1%**	**0%**
Ponderosa Pine*	8,914	111	8,707	93	3	1%	98%	1%	0%
Grassland	567	18	549	0	0	3%	97%	0%	0%

Oak Woodland	173	0	173	0	0	0%	100%	0%	0%
Pinyon-Juniper	515	35	479	1	0	7%	93%	0%	0%
1-2	**8,054**	**68**	**7,809**	**168**	**9**	**1%**	**97%**	**2%**	**0%**
Ponderosa Pine*	6,517	24	6,316	168	9	0%	97%	3%	0%
Grassland	1,537	44	1,493	0	0	3%	97%	0%	0%
1-3	**39,791**	**416**	**36,466**	**808**	**2,101**	**1%**	**92%**	**2%**	**5%**
Ponderosa Pine*	36,461	103	33,504	793	2,061	0%	92%	2%	6%
Aspen	88	0	33	16	39	0%	37%	18%	45%
Grassland	3,241	313	2,928	0	0	10%	90%	0%	0%
1-4	**18,250**	**17**	**17,429**	**157**	**648**	**<1%**	**96%**	**<1%**	**4%**
Ponderosa Pine*	17,285	6	16,492	153	634	0%	95%	1%	4%
Grassland	519	11	508	0	0	2%	98%	0%	0%
Oak Woodland	83	0	77	2	3	0%	94%	<3%	<4%
Pinyon-Juniper	363	0	351	2	11	0%	97%	0%	3%
1-5	**78,119**	**257**	**69,523**	**3,453**	**4,885**	**<1%**	**89%**	**4%**	**6%**
Ponderosa Pine*	74,936	211	66,503	3,390	4,833	0%	89%	5%	6%
Aspen	332	0	233	61	38	0%	70%	18%	12%
Grassland	2,270	46	2,224	0	0	2%	98%	0%	0%
Juniper Woodland	286	0	286	0	0	0%	100%	0%	0%
Oak Woodland	32	0	32	0	0	0%	100%	0%	0%
Pinyon-Juniper	262	0	246	3	14	0%	94%	1%	5%

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands since previous modeling would add the potential for crownfire on <1 acre in 1-1 and 1-2; about 2 acres in 1-3 and 1-4, and about 170 acres in 1-5. This would not change crown fire potential in any SU.

Restoration Unit 3

Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. Adjacency concerns for fire behavior include Interstates 40 and 17 which are adjacent to RU3 to the north and east, respectively, so that smoke from wildfires would have good potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, Williams, and Kachina Village. Additional concerns include Oak Creek, Oak Creek Canyon, and Sycamore Canyon. 7% (9,467 acres) of RU3 would have potential for crown fire, of which 2% (2,490 acres) would be active crown fire (Table 116).

Table 116. Modeled fire type by vegetation type and habitat for RU3 under Alternative E.

RU 3 acres =		149,715	Veg type acres	2010		Alt. E 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**129,226**	**72,776**	**56%**	**119,223**	**92%**
		Passive		**12,594**	**10%**	**6,880**	**5%**
		Active		**43,256**	**33%**	**2,455**	**2%**
	Protected	Surface	4,793	2,020	42%	3,308	69%
		Passive		611	13%	165	3%
		Active		2,076	43%	1,239	26%
	Target/ Threshold	Surface	3,899	2,039	52%	3,737	96%
		Passive		481	11%	28	1%
		Active		1,440	37%	129	3%
	Restricted	Surface	38,527	21,085	55%	33,006	86%
		Passive		3,672	10%	4,974	13%

		Active		13,704	36%	484	1%
	PFA/ dPFA	Surface	5,582	2,948	53%	4,931	88%
		Passive		605	11%	500	9%
		Active		2,026	36%	150	3%
	LOPFA	Surface	76,424	44,683	58%	74,240	97%
		Passive		7,288	10%	1,213	2%
		Active		24,010	31%	455	1%
Other Vegetation*	Aspen	Surface	201	144	72%	125	62%
		Passive		40	20%	76	38%
		Active		16	8%	0	0%
	Grassland	Surface	12,772	11,670	91%	12,513	98%
		Passive		706	6%	3	0%
		Active		167	1%	2	0%
	Juniper Woodland	Surface	1,851	1,559	84%	1,848	100%
		Passive		49	3%	0	0%
		Active		240	13%	0	0%
	Oak Woodland	Surface	1,633	1,282	79%	1,607	98%
		Passive		75	5%	0	0%
		Active		269	16%	19	1%
	Pinyon/ Juniper	Surface	4,033	3,351	83%	3,994	99%
		Passive		175	4%	18	0%
		Active		501	12%	15	0%

*Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU1

**Decreased treatment intensity for some VSS4, VSS5, and VSS6 stands would add the potential for about 350 acres of crownfire in ponderosa pine in RU1. About 35 acres previously modeled as passive crownfire would have potential for active crownfire. Crownfire potential for ponderosa pine in RU3 would remain at ~7%.

Outside of PACs where there are few contiguous areas of passive or active crown fire, the majority of crown fire is scattered passive crown fire. Two control watersheds for research purposes would receive no treatment. They would account for 9% (838 acres) of all crown fire in RU3; 28% (694 acres) would be active crown fire.

<u>Ponderosa Pine</u> would have potential for crown fire across 7% (9,335 acres) in RU3 (Table 78). About 50% of the active crown fire in ponderosa pine in RU3 would be in protected habitat.

<u>Aspen</u> effects in RU3 under Alternative E would be identical to Alternative B (wee discussion under Alternative B in 'Restoration Unit 3' on page155).

<u>Grasslands</u> would meet desired conditions for fire type under Alternative C. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to less than 1% (5 acres out of over 12,000), meeting desired conditions for fire behavior. Additional effects are described under Alternative C on page 208.

<u>Oak woodland</u> effects under Alternative E would be identical to those in Alternative B (See discussion under Alternative B in 'Restoration Unit 3' on page 155). Under Alternative C, there would be potential for crown fire in <1% (19 acres) of oak woodland.

Pinyon/Juniper woodland effects differ from Alternative B by 19 acres and were considered to be identical (See discussion under Alternative B in ‘Restoration Unit 3’ on page155).

Subunits

All subunits would meet desired conditions for fire type at this scale (Table 79). Subunit 3-5 has the most crown fire potential, with 9% (3,106 acres) of the unit having potential for crown fire. Subunit 3-5 has all, or parts of, 11 PACs accounting for most of the active crown fire. There is potential for small areas of crown fire on slopes >30% in Subunits 3-5 (on the edge of Oak Creek Canyon and Sycamore Canyon), but these areas would be less than ½ acre and would be rare. There is one watershed in each of SUs 3-2 and 3-3 that would function as a ‘control’ watershed for research. No treatments would occur in either of these. In SU3-2, the control would account for 32% (411 acres) of the crownfire, of which 359 acres would be active crown fire. In SU3-3, the control would account for 15% (427 acres) of the crown fire, of which 334 acres would be active crown fire.

Table 117. Modeled fire type for RU3 subunits by vegetation type under Alternative E.

		Fire Type (acres)				Fire Type (percent)			
Alternative E	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
3-1	**23,145**	**70**	**21,589**	**1,432**	**55**	**<1%**	**93%**	**6%**	**0%**
Ponderosa Pine*	18,805	39	17,319	1,392	55	<1%	92%	7%	0%
Aspen	91	0	51	40	0	0%	56%	44%	0%
Grassland	590	25	565	0	0	4%	96%	0%	0%
Juniper Woodland	907	1	907	0	0	0%	100%	0%	0%
Oak Woodland	845	1	844	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,908	4	1,904	0	0	0%	100%	0%	0%
3-2	**32,726**	**289**	**31,157**	**790**	**490**	**<1%**	**95%**	**<3%**	**1%**
Ponderosa Pine*	22,885	133	21,518	764	470	1%	94%	3%	2%
Aspen	59	0	37	22	0	0%	62%	38%	0%
Grassland	9,611	155	9,450	3	2	2%	98%	0%	0%
Oak Woodland	172	0	153	0	19	0%	89%	0%	11%
3-3	**48,434**	**77**	**45,447**	**2,091**	**819**	**0%**	**94%**	**4%**	**2%**
Ponderosa Pine*	44,426	59	41,472	2,077	819	0%	93%	5%	2%
Aspen	50	0	36	14	0	0%	71%	29%	0%
Grassland	1,353	9	1,344	0	0	1%	99%	0%	0%
Juniper Woodland	873	2	871	0	0	0%	100%	0%	0%
Oak Woodland	232	5	226	0	0	2%	98%	0%	0%
Pinyon-Juniper	1,500	3	1,497	0	0	0%	100%	0%	0%
3-4	**9,019**	**233**	**8,101**	**264**	**421**	**<3%**	**90%**	**<3%**	**5%**
Ponderosa Pine*	8,920	218	8,017	264	421	2%	90%	3%	5%
Grassland	99	15	83	0	0	16%	84%	0%	0%
Oak Woodland	0	0	0	0	0	0%	100%	0%	0%
3-5	**36,392**	**268**	**33,017**	**2,400**	**706**	**<1%**	**91%**	**7%**	**<2%**
Ponderosa Pine*	34,190	219	30,897	2,382	691	1%	90%	7%	2%
Aspen	2	0	2	0	0	0%	100%	0%	0%
Grassland	1,120	49	1,071	0	0	4%	96%	0%	0%
Juniper Woodland	70	0	70	0	0	0%	100%	0%	0%
Oak Woodland	384	0	384	0	0	0%	100%	0%	0%

Pinyon-Juniper	626	0	593	18	15	0%	95%	3%	2%

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for crownfire in ponderosa pine on about 171 acres in 3-1 (8%); 38 acres in 3-2 (6%), 93 acres in 3-3 (no change in percent); 5 acres in 3-4 (no change in percent); and 168 acres in 3-5 (no change in percent).

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 10, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires.

Under Alternative E, there would be potential for crown fire on <3% (3,729 acres) of RU4, of which <1% (531 acres) would be active crown fire. There would be contiguous acreages of passive crown fire in PFAs and areas of lower intensity treatments, and some burn only treatments.

Ponderosa pine in RU4 has potential for 2% (3,691 acres) to burn in crown fire, of which <1% (530 acres) would be active crown fire (Table 80).

Aspen effects in RU3 differ from Alternative B by 3 acres and were considered to be identical. (See discussion on page 158).

Grasslands in RU4 would meet desired conditions for fire type. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to surface fire. Additional effects are described under Alternative C on page 208.

Oak woodland effects under Alternative E would be identical to those in Alternative B (see discussion on page 158). Under Alternative E, there would be no crown fire in oak woodland under modeled conditions.

Pinyon/Juniper woodland effects under Alternative E would be identical to those in Alternative B (see discussion on page 158).

Table 118. Modeled fire type by vegetation and habitat for RU 4 under Alternative E.

RU 4 acres =		165,645	Veg type acres	2010		Alt. E 2020	
Vegetation Type		Type		Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**134,278**	**83,499**	**62%**	**130,195**	**97%**
		Passive		**10,590**	**8%**	**3,161**	**2%**
		Active		**39,763**	**30%**	**530**	**0%**
	Protected	Surface	558	379	68%	503	90%
		Passive		45	8%	11	2%
		Active		134	24%	43	8%
	Restricted	Surface	1,576	751	48%	1,376	87%
		Passive		196	12%	195	12%
		Active		621	39%	0	0%
	PFA/ dPFA	Surface	13,484	8,008	59%	12,253	91%
		Passive		1,250	9%	1,072	8%
		Active		4,221	31%	154	1%

	LOPFA	Surface	118,659	74,361	63%	116,063	98%
		Passive		9,100	8%	1,883	2%
		Active		34,786	29%	332	0%
Other Vegetation*	Aspen	Surface	497	403	81%	457	92%
		Passive		31	6%	37	7%
		Active		59	12%	0	0%
	Grassland	Surface	22,661	21,080	93%	22,535	99%
		Passive		788	3%	0	0%
		Active		645	3%	0	0%
	Juniper Woodland	Surface	118	69	59%	116	99%
		Passive		4	3%	0	0%
		Active		43	36%	0	0%
	Oak Woodland	Surface	926	669	72%	924	100%
		Passive		90	10%	0	0%
		Active		165	18%	0	0%
	Pinyon/ Juniper	Surface	7,165	5,855	82%	7,140	100%
		Passive		453	6%	0	0%
		Active		829	12%	0	0%

*Nonburnable substrate constitutes <1% of ponderosa pine and <1% of the entire treatment area within RU4

**Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 560 acres of crownfire in ponderosa pine in RU4. There would be potential for about 36 acres previously modeled as passive crown fire to be active crown fire. Overall, this would raise the potential for crownfire in RU4 to 3%.

Subunits

At the subunit level (Table 119) SU 4-5, though the smallest SU in the project (6,919 acres), is adjacent to the city of Flagstaff, and has steep topography, so that the second order fire effects (flooding, debris flows, etc.) of high severity fire has good potential to impact neighborhoods and schools. Under Alternative E, 1% (54 acres) of SU 4-5 would have potential for crown fire, of which 12 acres would be active crown fire. In subunit 4-3, there would be areas of contiguous passive crown fire of over 100 acres in burn-only units and/or PFAs. Passive crown fire could become active crown fire if the wind increased, or other conditions, such as fuel moisture, temperature, or humidity deteriorated. However, these areas are surrounded by surface fire.

Table 119. Modeled fire type for Restoration Unit 4 subunits under Alternative E for 2020.

		Fire Type (acres)				Fire Type (percent)			
Alternative E	**Acres**	**No Fire**	**Surface**	**Passive**	**Active**	**No Fire**	**Surface**	**Passive**	**Active**
4-2	**10,227**	**69**	**9,894**	**232**	**32**	**1%**	**97%**	**2%**	**0%**
Ponderosa Pine*	7,381	21	7,097	232	32	<1%	96%	3%	<1%
Aspen	1	0	1	0	0	40%	60%	0%	0%
Grassland	328	24	304	0	0	7%	93%	0%	0%
Juniper Woodland	8	0	8	0	0	0%	100%	0%	0%
Oak Woodland	567	2	565	0	0	0%	100%	0%	0%

Pinyon-Juniper	1,941	22	1,919	0	0	1%	99%	0%	0%
4-3	**67,012**	**325**	**64,801**	**1,593**	**293**	**<1%**	**97%**	**2%**	**<1%**
Ponderosa Pine*	55,312	306	53,122	1,591	293	<1%	96%	3%	<1%
Aspen	230	3	224	3	0	1%	98%	1%	0%
Grassland	6,951	12	6,939	0	0	0%	100%	0%	0%
Juniper Woodland	31	0	31	0	0	0%	100%	0%	0%
Oak Woodland	325	0	325	0	0	0%	100%	0%	0%
Pinyon-Juniper	4,162	3	4,159	0	0	0%	100%	0%	0%
4-4	**81,487**	**152**	**79,810**	**1,360**	**164**	**0%**	**98%**	**2%**	**0%**
Ponderosa Pine*	65,003	63	63,449	1,328	164	0%	98%	2%	0%
Aspen	255	0	223	32	0	0%	87%	13%	0%
Grassland	15,055	88	14,966	0	0	1%	99%	0%	0%
Juniper Woodland	78	2	76	0	0	2%	98%	0%	0%
Oak Woodland	35	0	35	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,062	0	1,062	0	0	0%	100%	0%	0%
4-5	**6,919**	**3**	**6,862**	**12**	**42**	**0%**	**99%**	**0%**	**1%**
Ponderosa Pine	6,581	1	6,528	10	42	0%	99%	0%	1%
Aspen	11	0	9	2	0	0%	82%	18%	0%
Grassland	327	2	325	0	0	1%	99%	0%	0%

*Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential for crownfire in ponderosa pine on about 330 acres in 4-3 (no percent change) and 210 acres in 4-4 (3%).

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 mostly on Mount Eldon, immediately upslope and adjacent to northern Flagstaff). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. There are many areas, some larger than 500 acres, in the north and eastern areas of this RU that are cinder substrate, and have no potential for fire. These areas consist of cinder cones, and cinder soils which generally support sparse vegetation. In these areas, active crown fire is less likely because of decreased potential for high intensity surface fire. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

Under Alternative E, there would be potential for crown fire on 2% (1,346 acres) of RU5, of which 514 would be active crown fire. Crown fire is scattered, with the majority of it in small areas on the north side of the Peaks, in PACs on the southwest aspect of the Peaks or the north aspect near Schultz Pass on Mount Eldon.

Ponderosa pine in RU5 would have potential for crown fire across 2% (1,279 acres), of which 1% (509 acres), would be active crown fire. Ponderosa pine would meet desired conditions for fire type in RU5.

Aspen effects in RU5 would be identical to those in Alternative B. See discussion on page 161.

Table 120. Modeled fire type for Restoration Unit 5 under Alternative E, 2020

RU 5 acres =	73,203	Veg type	2010		Alt. E 2020	
Vegetation Type	Type	acres	Acres	% Veg Type	Acres	% Veg Type

Ponderosa Pine*	**All Pine****	**Surface**	**59,034**	**41,109**	**70%**	**54,020**	**92%**
		Passive		**6,821**	**12%**	**770**	**1%**
		Active		**7,376**	**12%**	**509**	**1%**
	Protected	Surface	859	535	62%	755	88%
		Passive		132	15%	1	0%
		Active		167	19%	79	9%
	Restricted	Surface	606	451	74%	606	100%
		Passive		71	12%	0	0%
		Active		83	14%	0	0%
	PFA/ dPFA	Surface	2,227	1,343	60%	1,943	87%
		Passive		419	19%	115	5%
		Active		325	15%	22	1%
	LOPFA	Surface	55,341	38,780	70%	50,717	92%
		Passive		6,199	11%	654	1%
		Active		6,801	12%	408	1%
Other Vegetation*	Aspen	Surface	403	332	82%	337	84%
		Passive		24	6%	61	15%
		Active		43	11%	0	0%
	Grassland	Surface	4,536	2,521	56%	2,842	63%
		Passive		222	5%	0	0%
		Active		105	2%	0	0%
	Juniper Woodland	Surface	74	67	90%	74	100%
		Passive		7	9%	0	0%
		Active		0	1%	0	0%
	Oak Woodland	Surface	386	349	91%	371	96%
		Passive		20	5%	0	0%
		Active		1	0%	0	0%
	Pinyon/ Juniper	Surface	8,771	7,804	89%	8,474	97%
		Passive		277	3%	2	0%
		Active		393	4%	5	0%

*Nonburnable substrate constitutes about 6% of ponderosa pine and about 8% of the treatment area within RU5

**Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 14 acres of crownfire in ponderosa pine in RU4. There would be potential for about 36 acres previously modeled as passive crown fire to be active crown fire. There would be no change in the percent crownfire potential.

Grasslands in RU4 would meet desired conditions for fire type. Mechanical treatments combined with fire would remove the potential crown fire in grasslands under modeled conditions, meeting desired conditions for fire type. Additional effects are described under Alternative C on page 208.

Oak woodland effects under Alternative C would be identical to those in Alternative B. See discussion on under Alternative B, page 160.

Pinyon/Juniper woodland effects would be identical to those in Alternative B. See discussion Alternative B on page 160.

Subunits

Subunit 5-2 (Table 121) includes sparsely vegetated cinder cones, as well as areas that sustained second order fire effects from the Schultz Fire. Both subunits in RU5 would meet desired conditions for fire type. There is an area on the northwest side of Mt. Eldon (in Schultz Pass) with about 70 acres of mostly contiguous active crown fire of which about 20 acres are on 30 – 40 slopes. This area is adjacent to and uphill from the Schultz Pass road.

Table 121. Modeled fire type in RU5 subunits by vegetation type for 2020

		Fire Type (acres)				Fire Type (percent)			
Alternative E	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
5-1	**21,341**	**794**	**19,719**	**417**	**410**	**4%**	**92%**	**2%**	**2%**
Ponderosa Pine*	18,040	747	16,526	357	410	4%	92%	2%	2%
Aspen	392	5	327	61	0	<2%	83%	15%	0%
Grassland	1,239	18	1,221	0	0	1%	99%	0%	0%
Oak Woodland	95	0	95	0	0	0%	100%	0%	0%
Pinyon-Juniper	1,574	24	1,550	0	0	<2%	98%	0%	<1%
5-2	**51,863**	**4,945**	**46,399**	**415**	**104**	**10%**	**89%**	**1%**	**0%**
Ponderosa Pine	40,994	2,988	37,494	413	100	7%	91%	1%	<1%
Aspen	10	0	10	0	0	0%	100%	0%	0%
Grassland	3,297	1,676	1,621	0	0	51%	49%	0%	0%
Juniper Woodland	74	0	74	0	0	0%	100%	0%	0%
Oak Woodland	291	15	276	0	0	5%	95%	0%	0%
Pinyon-Juniper	7,196	266	6,924	2	4	4%	96%	0%	0%

*Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 3 acres of additional crownfire in ponderosa pine in 5-1, and about 11 acres in 5-2.

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area. Modeled post-treatment fire type shows 5% (2,023 acres) would have potential for crown fire, of which <1% (106 acres) would be active crown fire. Alternative E would meet fire type objectives in RU6.

Ponderosa pine in RU6, would have potential for 4% crownfire, most of which would be passive crown fire, and mostly in three areas. PFA/dPFA habitat accounts for 98 of the 106 acres of active crown fire (Table 84).

Grasslands in RU4 would meet desired conditions for fire type. The addition of mechanical treatments combined with fire would remove the potential for any crown fire on 93 acres of grassland in RU6, meeting desired conditions for fire type. Additional effects are described under Alternative C on page 208.

Pinyon/Juniper woodland effects would be identical to those in Alternative B. See discussion under on page 162.

Oak woodland effects under Alternative E are identical to those in Alternative B. See discussion on page 162.

Table 122. Modeled fire type for Restoration Unit 6 under Alternative E, for 2020

RU 6 acres =	43,530	Veg type	2010	Alt. E 2020

Vegetation Type		Type	acres	Acres	% Veg Type	Acres	% Veg Type
Ponderosa Pine*	**All Pine****	**Surface**	**41,189**	**33,673**	**82%**	**39,444**	**96%**
		Passive		**2,233**	**5%**	**1,595**	**4%**
		Active		**5,238**	**13%**	**106**	**0%**
	PFA/ dPFA	Surface	4,050	3,506	87%	3,770	93%
		Passive		111	3%	179	4%
		Active		430	11%	98	2%
	LOPFA	Surface	37,139	30,167	81%	35,674	96%
		Passive		2,123	6%	1,416	4%
		Active		4,808	13%	8	0%
Other Vegetation*	Grassland	Surface	93	89	96%	93	100%
		Passive		2	2%	0	0%
		Active		1	1%	0	0%
	Juniper Woodland	Surface	13	10	79%	11	83%
		Passive		3	21%	2	17%
		Active		0	0%	0	0%
	Oak Woodland	Surface	30	9	30%	30	100%
		Passive		20	68%	0	0%
		Active		1	2%	0	0%
	Pinyon/ Juniper	Surface	2,206	1,472	67%	1,886	86%
		Passive		504	23%	320	14%
		Active		229	10%	0	0%

*Nonburnable substrate constitutes <1% in ponderosa pine and <1% in the entire treatment area within RU6

**Decreased intensity in some VSS4, VSS5, and VSS6 stands would add the potential for about 646 acres of crownfire in ponderosa pine in RU4. There would be potential for about 61 acres previously modeled as passive crown fire to be active crown fire. Overall, this would raise the potential for crownfire in RU6 to 6%.

Subunits

Under Alternative E, desired conditions fire type would be met in Subunits 6-2 and 6-3. Subunit 6-4, exceeds desired conditions for fire type in ponderosa pine, though all of the fire, as modeled, would be passive crown fire. Much of the passive crown fire would be in areas such as shown in Figure 28 (pg. 82), where juniper, Gambel oak, and ponderosa pine all intergrade.

Table 123. Modeled fire type in RU6 subunits by vegetation/habitat type under Alt. E.

		Fire Type (acres)				Fire Type (percent)			
Alternative E	Acres	No Fire	Surface	Passive	Active	No Fire	Surface	Passive	Active
6-2	**5,551**	**7**	**5,377**	**167**	**0**	**0%**	**97%**	**3%**	**0%**
Ponderosa Pine	5,069	7	4,896	166	0	0%	97%	3%	0%
Pinyon-Juniper	483	0	481	1	0	0%	100%	0%	0%
6-3	**34,109**	**33**	**33,107**	**864**	**104**	**0%**	**97%**	**3%**	**0%**
Ponderosa Pine	32,635	33	31,746	752	104	<1%	97%	2%	<1%
Grassland	85	0	85	0	0	0%	100%	0%	0%
Juniper Woodland	13	0	11	2	0	0%	83%	17%	0%
Pinyon-Juniper	1,375	0	1,266	109	0	0%	92%	8%	0%
6-4	**3,870**	**4**	**2,979**	**886**	**1**	**<1%**	**77%**	**23%**	**<1%**
Ponderosa Pine*	3,484	4	2,803	677	1	<1%	80%	19%	<1%
Grassland	7	0	7	0	0	0%	100%	0%	0%

Oak Woodland	30	0	30	0	0	0%	100%	0%	0%
Pinyon-Juniper	348	0	139	209	0	0%	40%	60%	0%

*Decreased treatment intensity in some VSS4, VSS5, and VSS6 stands would add the potential crown fire in ponderosa pine on about 646 acres in 6-4 (38%).

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 15, desired openness is an indication of the relative desired post treatment interspace/tree group condition.

Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 168. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 86 for more details).

Canopy characteristics affecting fire behavior

Changes to Canopy Cover (CC), Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are direct effects, though they are not always apparent in the fire behavior data (indirect effects). Post-treatment conditions (2020), under Alternative E show changes in canopy cover significant enough that the treatment area would meet desired conditions (Table 124). Desired conditions for canopy base height (CBH) are 18 feet or higher; desired conditions for canopy bulk density (CBD) are for 0.05 or less. Alternative E would meet desired conditions for CBH and CBD.

Table 124. Modeled trends in canopy characteristics for Alternative E.

Alt E	CBH (feet)*			CBD (kg/m3)*			CC (%)*			% of pond. pine
Desired Openness	**2010**	**2020**	**2050**	**2010**	**2020**	**2050**	**2010**	**2020**	**2050**	
High	15	28	28	0.064	0.027	0.035	43	23	32	36%
Moderate	15	25	26	0.062	0.030	0.040	43	26	36	23%
Low (Mechanical)	16	26	28	0.063	0.035	0.043	42	28	37	6%
Low (Burn Only)	14	20	25	0.045	0.035	0.036	32	26	31	24%
Very Low (Burn Only)	15	21	26	0.063	0.048	0.049	41	35	39	2%
Very Low (Mechanical)	16	23	29	0.062	0.054	0.055	48	46	52	4%
Very Low (PAC Burn Only)	14	17	23	0.067	0.065	0.064	49	49	53	4%
Very Low/No Proposed Treatments (Core Areas)	14	16	22	0.070	0.071	0.069	51	52	55	1%
No Proposed Treatments	16	18	23	0.050	0.054	0.056	39	43	48	0%
Weighted Average4	**15**	**24**	**26**	**0.059**	**0.034**	**0.039**	**41**	**27**	**35**	

*Decreases in treatment intensity to ~40,000 acres of VSS4, VSS5, and VSS6 would result in some shifts in 'High', 'Moderate', and some 'Very Low (Mechanical))'. Changes would be increases in CC and CBH, and decreases in CBD. The changes would not be of a magnitude that would be expected to shift the overall weighted averages out of the desired conditions for CBH or CBD. There would be some increased potential for crownfire.

Table 124 shows a decrease in CBD and an increase in CBH as a direct effect of treatments. This decreases the potential for crown fire initiation (because CBH is higher), less potential for passive crown fire (because of higher CBH and lower CBD), and less potential for active crown fire (lower CC and lower CBD. Under Alternative E, desired conditions would be met for CBH and CBD when stands are averaged by treatment type. Very Low (PAC Burn Only) and Very Low/ No treatment (Core Areas) do not have desired conditions for canopy characteristics related to fire behavior, but it is worth noting that neither of them would have met desired conditions.

Figure **66** shows trends for all levels of desired openness. Assumptions are that prescribed fire and mechanical treatments occurred between 2010 and 2020 and no treatments or disturbances of any kind occurred between 2020 and 2050. In the two least intense treatment types, the initial values (2010) start high (for CBD and CC) and low (CCBH). Post-treatment, for those two treatments, the increase in CC from 2010 to 2020, combined with only modest decreases in DBD suggest that conditional crown fire is still likely in areas treated at those treatment intensities.

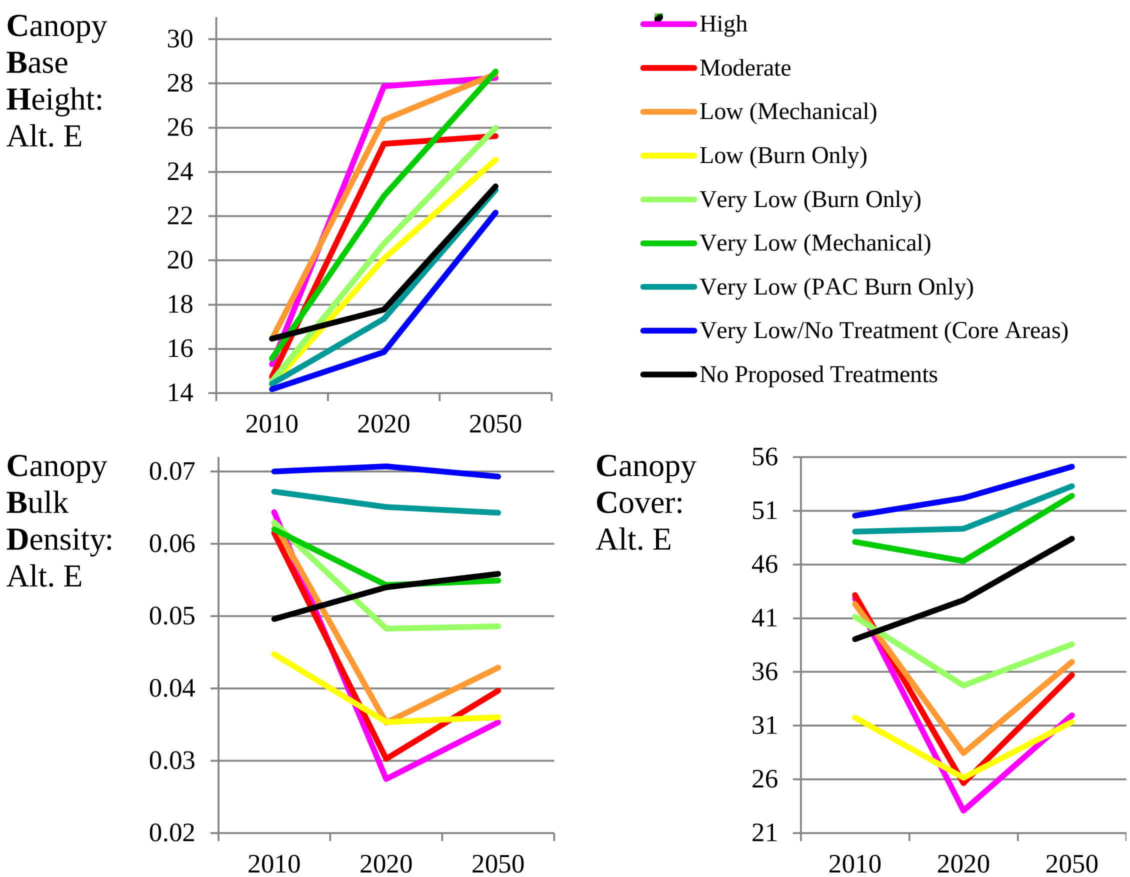

Figure 66. Modeled trends in canopy fuels under Alternative E.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of proposed treatments that have indirect effects on fire behavior and effects.

Surface fuel loading by treatment ability to maintain desired openness

General effects for Alternative E are the same as Alternative B, (see discussion on page 168). Under Alternative E, Forest Plan guidelines for CWD (5 – 7 tons/acre) would be met only on those acres not proposed for treatment outside of core areas (~1% of the ponderosa pine). For the rest of the ponderosa pine, CWD values would range from 2.7 to 4.7, lower than desired conditions. Alternative E would leave the treatment area deficit in CWD in some areas although, modeling for this project and research (Waltz et al. 2003) suggest that it would be just a year or two before CWD levels once again met desired conditions (Table 125). Assumptions include mechanical treatments and prescribed burning occurred between 2010 and 2020 and that no treatments of any kind took place between 2020 and 2050. Assumptions for Table 125 include one mechanical treatment and two prescribed fires between 2010 and 2020, and no addition treatments or disturbances of any kind between 2020 and 2050. Except for 'High', total surface fuel loading increases to above 2010 levels by 2050. Shaded cells exceed recommendations for surface fuel loading, or forest plan guidelines of 5-7 tons/acre for CWD.

Table 125. Modeled changes to surface fuel loading under Alternative E.

Desired openness	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			% pond. pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.9	2.9	5.0	3.3	1.4	2.7	3.3	2.3	2.6	10.5	6.7	10.3	36
Moderate	3.7	2.8	5.2	3.9	1.7	3.4	3.1	2.2	2.6	10.7	6.8	11.3	23
Low (Mechanical)	3.8	2.8	5.6	3.2	1.7	3.1	3.3	2.3	2.7	10.3	6.8	11.3	6
Low (Burn Only)	3.0	2.7	6.0	2.3	1.5	2.5	2.7	2.4	2.8	8.0	6.6	11.3	24
Very Low (Burn Only)	3.8	3.2	7.8	3.2	2.0	3.4	3.2	3.0	3.4	10.2	8.2	14.6	2
Very Low (Mechanical)	5.0	4.7	8.1	5.0	3.8	5.8	3.9	4.1	4.9	13.8	12.6	18.8	4
Very Low (PAC Burn Only)	6.0	3.3	8.5	4.8	3.0	6.0	5.1	5.3	6.0	15.9	11.6	20.5	4
No Proposed Treatments (Core Areas)	5.8	7.6	12.4	5.1	5.8	6.3	4.7	5.0	5.9	15.6	18.4	24.6	1
No Proposed Treatments	3.0	3.9	6.6	3.8	4.4	5.0	2.5	2.9	3.6	9.3	11.2	15.2	0
Weighted Averages[4]	**3.7**	**3.0**	**5.7**	**3.3**	**1.7**	**3.1**	**3.2**	**2.5**	**2.9**	**10.3**	**7.3**	**11.8**	

Figure 67 shows trends in surface fuel loading, with duff, litter, and canopy fuels decreased, more sunlight and precipitation would reach the surface, stimulating more vigorous growth of surface vegetation, which would support the low intensity, low severity surface fires to which ponderosa pine is well adapted.

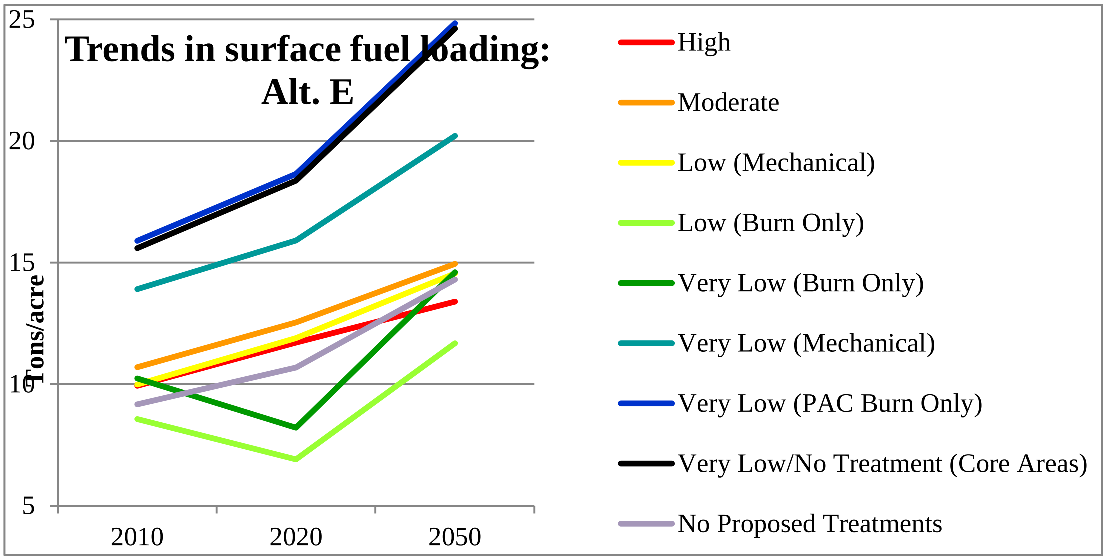

Figure 67. Modeled changes to surface fuel loading (duff + litter + CWD>3").

Surface fuel loading by stand

Figure 58 shows the distribution of fuel loading post-treatment (2020). Across most of the treatment area, fuel loading has decreased below 20 tons/acre. There are a few areas that exceed 20, 25, 30, and 35 tons per acre, mostly in RU3 in PACs, a few areas in RU4 and two areas in RU5. Under Alternative E, there would be about 1,579 acres with surface fuel loading greater than 20 tons/acre, and 7,495 acres in the 15 – 20 tons/acre range. By 2040, there would be 8,005 acres exceeding 20 tons/acre, and 57,048 acres in the 15 – 20 tons/acre range.

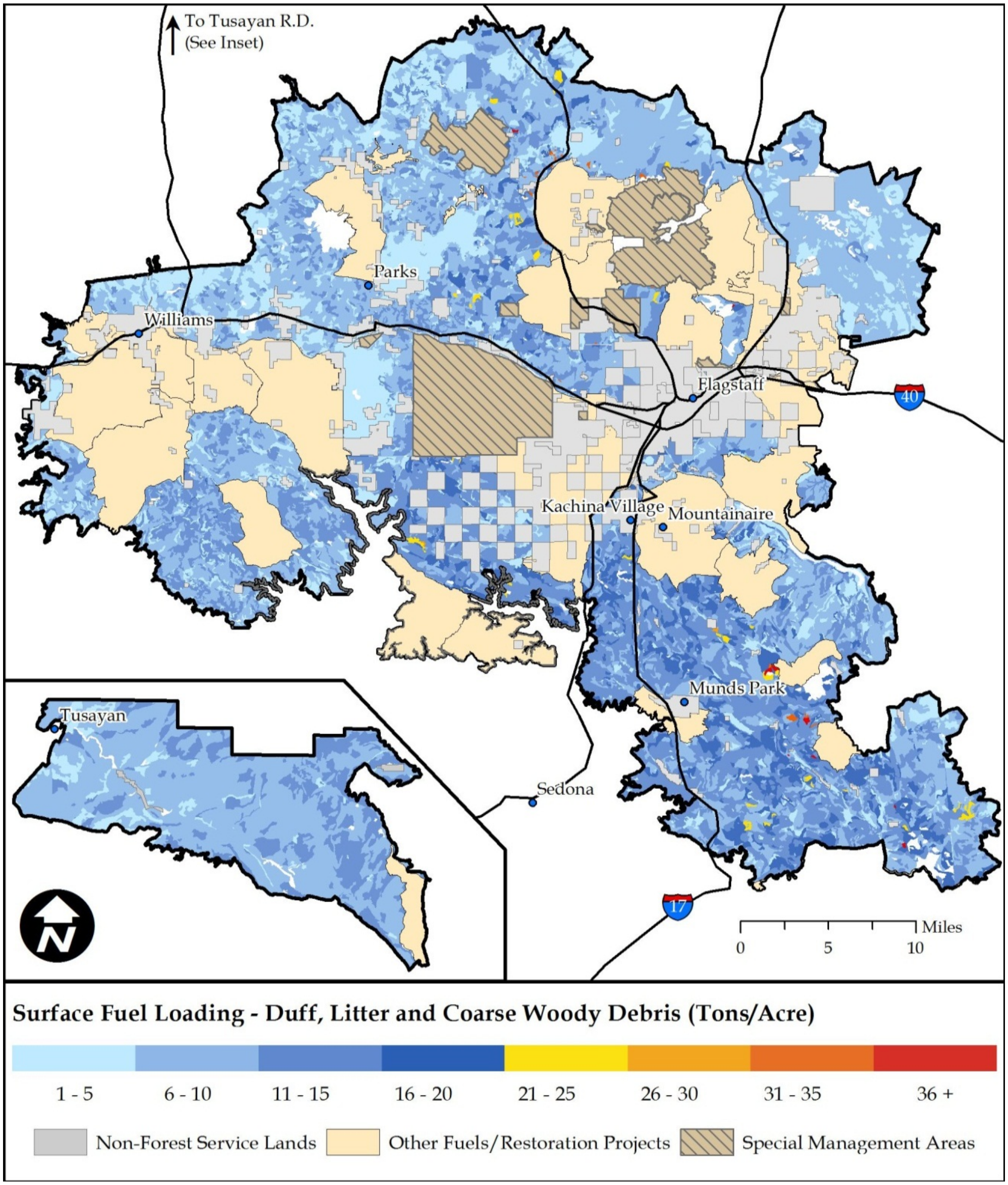

Figure 68. Modeled fuel loading for Alternative E (duff + litter + CWD>3")

Fire Regime/Condition Class

Under Alternative E, Fire Regime/Condition Class (FRCC) would meet the desired post-treatment condition of FRCC2, and would be moving towards having no acres in VCC3. Modeled results indicate that, 30 years after treatment, the treatment area remains in FRCC2, and VCC acres remain below the post-treatment level (2010). Effects to grasslands would be identical to Alternative B. Treatments proposed under Alternative E (Table 126) would move over 270,000 acres of ponderosa pine out of FRCC3, and increase acres of FRCC1 by over 25,000 acres.

Table 126. Fire Regime/Condition Class for Alternative E

VCC – Alt. E	2010		2020		2050	
	Acres	Percent	Acres	Percent	Acres	Percent
1	71,097	14%	111,725	22%	55,862	11%
2	126,960	25%	370,722	73%	248,841	49%
3	309,782	61%	25,392	5%	203,136	40%
Vegetation departure =	66%		43%		74%	
Fire Severity Departure =	74%		40%		50%	
Fire Return Interval Departure =	80%		20%		60%	
FRCC of treatment area =	**3**		**2**		**2**	

Fire Return Interval

The effects of Alternative E (Table 127) would be similar to those of Alternative B, except that there are no areas that would not move towards a sustainable, resilient fire regime. See discussion on page 174.

As with Alternative B, this should be interpreted with caution, however, because it is the long term cycle of fire return intervals that regulates a system. Up to two prescribed fires would set the treatment area on a trajectory towards a restored condition, but maintenance fires would continue to be needed to avoid the ecosystem slipping back to an unsustainable condition.

Table 127. Average Fire Return Intervals for Alternative E

Alternative E	# of years averaged	Average annual acres burned	Fire Return Interval over years averaged
Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
2020	20 (2001- 2020)	58,611 (2001- 2020)	10
2050	40 (2001- 2050)	29,306 (2001- 2050)	20

Air Quality

This alternative would meet the purpose and need, and desired conditions for Air Quality. The effects (indirect) would be almost identical to those in Alternative B, with the exceptions being the additional acres of MSO habitat and grasslands proposed for burning. Most acres in PACs and nest cores would be first entry burns, but the surface fuel load would not all be burned in one entry, so the smoke would be dispersed over time. See discussion on page 171.

Under this alternative, an average of 58,611 acres would need to burn every year, either from wildfire or prescribed fire with a total of 586,110 acres proposed for burning.

Ecological effects of smoke

The ecological effects of smoke would be identical to those under Alternative C, except in core areas that would be excluded from burning.

Stream/spring restoration

Effects on stream/spring restoration would be identical to those in Alternative B. See discussion on page 174.

Roads

Road effects would be identical to those in Alternative B. See discussion on page 174.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources would be identical to those in Alternative B. See discussion on page174.

Climate Change

Based on current projections, the primary regional-level effects of climate change that are expected to affect fire regimes in the Southwest include:

- warmer temperatures
- decreasing precipitation
- decreased water availability with increased demand
- increased extreme disturbance events, such as insect outbreaks or widespread drought (Williams et al. 2010).

Changes in key climate variables affect the seasonality of hydrologic regimes and the length of the fire season. In the west, fire season has increased by 78 days since the mid-1980s (Westerling et al. 2006). Disturbance, such as uncharacteristically severe fire, facilitates the introduction and spread of invasive species, which increase extinction risks for native species and disrupt ecosystem processes and functions. Native species' constitute the fuels that exist in the historic fire regimes, so effects to native species affect fire regimes. These effects challenge the objectives of: reducing risk to communities and natural resources from uncharacteristically severe wildfires; reducing adverse impacts from invasive species; and restoring and maintaining healthy watersheds and diverse habitats. The changing climate is already altering species ranges and has the potential to alter ecosystem structure in the future.

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. Although current conditions, with dense forest stands can sequester more carbon than open forests, shrublands, or grasslands, 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 fifteen years after the fire (Figure 69). Savage and Mast (2005) showed that these conditions can persist for decades.

High severity fire in ponderosa pine forests releases large quantities of CO_2 to the atmosphere (Figure **70**). The emissions below are associated with ponderosa 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 **70** displays modeled emissions from a VSS4 stand with no mechanical treatment prior to burning.

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). They found that while the treatment initially produced a 30% reduction in the carbon held in 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 cause conditions that support uncharacteristic fire and insect outbreaks to become even more prevalent in the western United States. 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.

Figure 69. Top - Fifteen years after the Horseshoe Fire (photo from November 2011); Bottom – healthy ponderosa pine forest

Restoration treatments (e.g. thinning, 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 (North et al. 2009; 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 result from uncharacteristic stand replacing fires (Hurteau et al. 2011) exacerbated by a changing climate and denser forests if left untreated. 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 (Figure **71**).

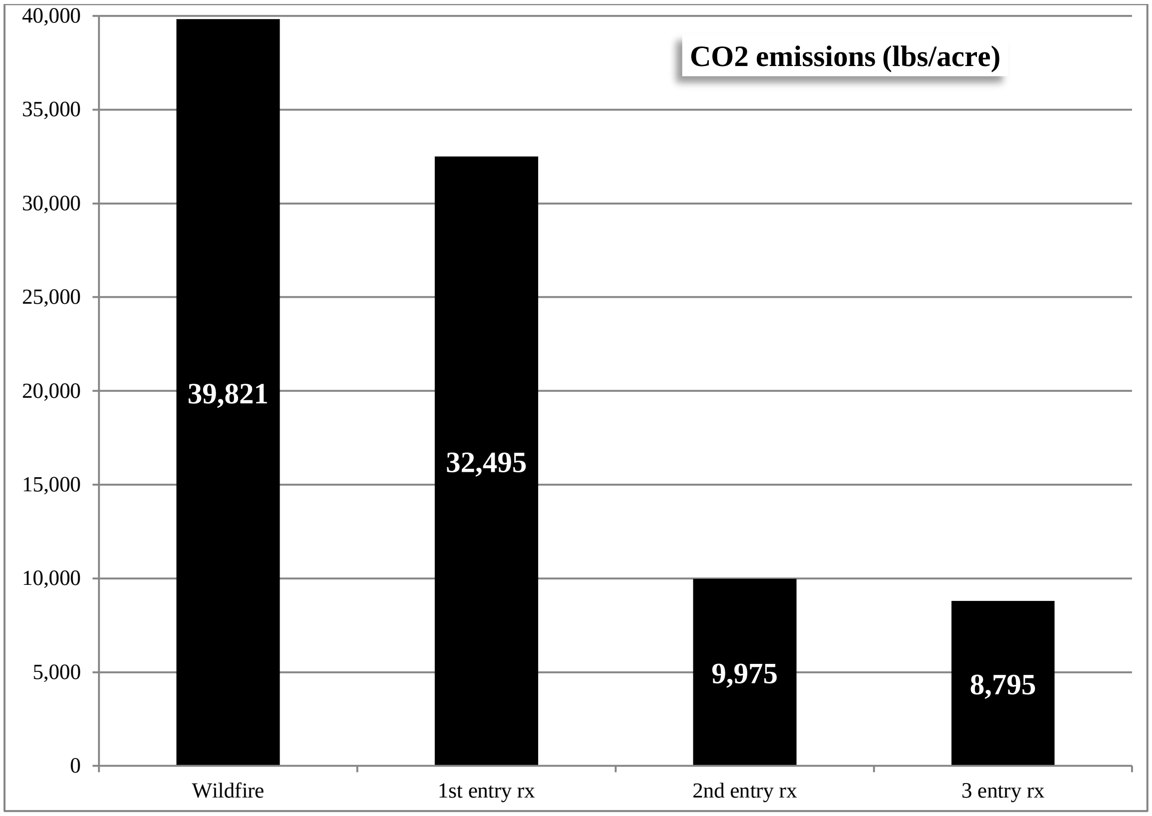

Figure 70. Modeled CO2 emission potential of a typical untreated stand

Figure **71** displays carbon storage per acre comparing a no action 'baseline' scenario with 10 and 20 year fire return intervals in a ponderosa pine forest of northern Arizona (adapted from Woods et al. 2012).

In the long term (e.g.100 years) the action alternatives would create more resilient forests, less prone to stand replacing events and subsequently able to store more carbon by an increased availability of live trees, longer lived wood products (in the form of large trees), and energy products created from resulting slash which are used in place of fuels (North and Hurteau 2011, Sorenson et al. 2011, Woods et al. 2012). Not all forest products sequester carbon equally. For example, products with longer on average lifespans (e.g. houses), have a greater potential to store carbon than short lived products such as fence posts. 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 sequestering carbon (Ryan et al.2010). Thoughtful incorporation of carbon effects in landscape scale planning should help implementation of 4FRI actions improve the ability of the project area to store carbon in a stable condition.

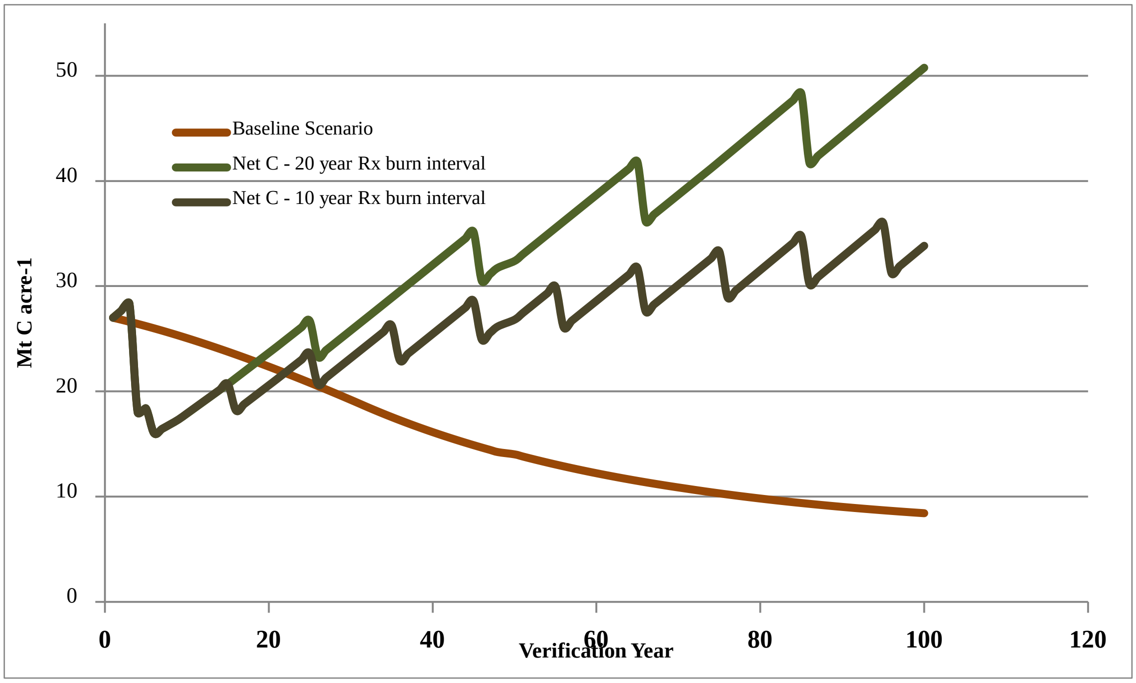

Figure 71. Modeled carbon sequestration with no treatment, and with 10 and 20 year treatment intervals (Woods et al. 2012).

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 sequesters 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 (e.g. wildfires, insects, disease), allowing natural disturbances (e.g. Low-severity surface fires) to play their essential roles

Cumulative Effects – All alternatives

Spatially, cumulative effects of projects and wildfires were evaluated within the Project Area (~989,764 acres), the South Rim of the Grand Canyon National Park, and the Coconino NF (Figure 72).

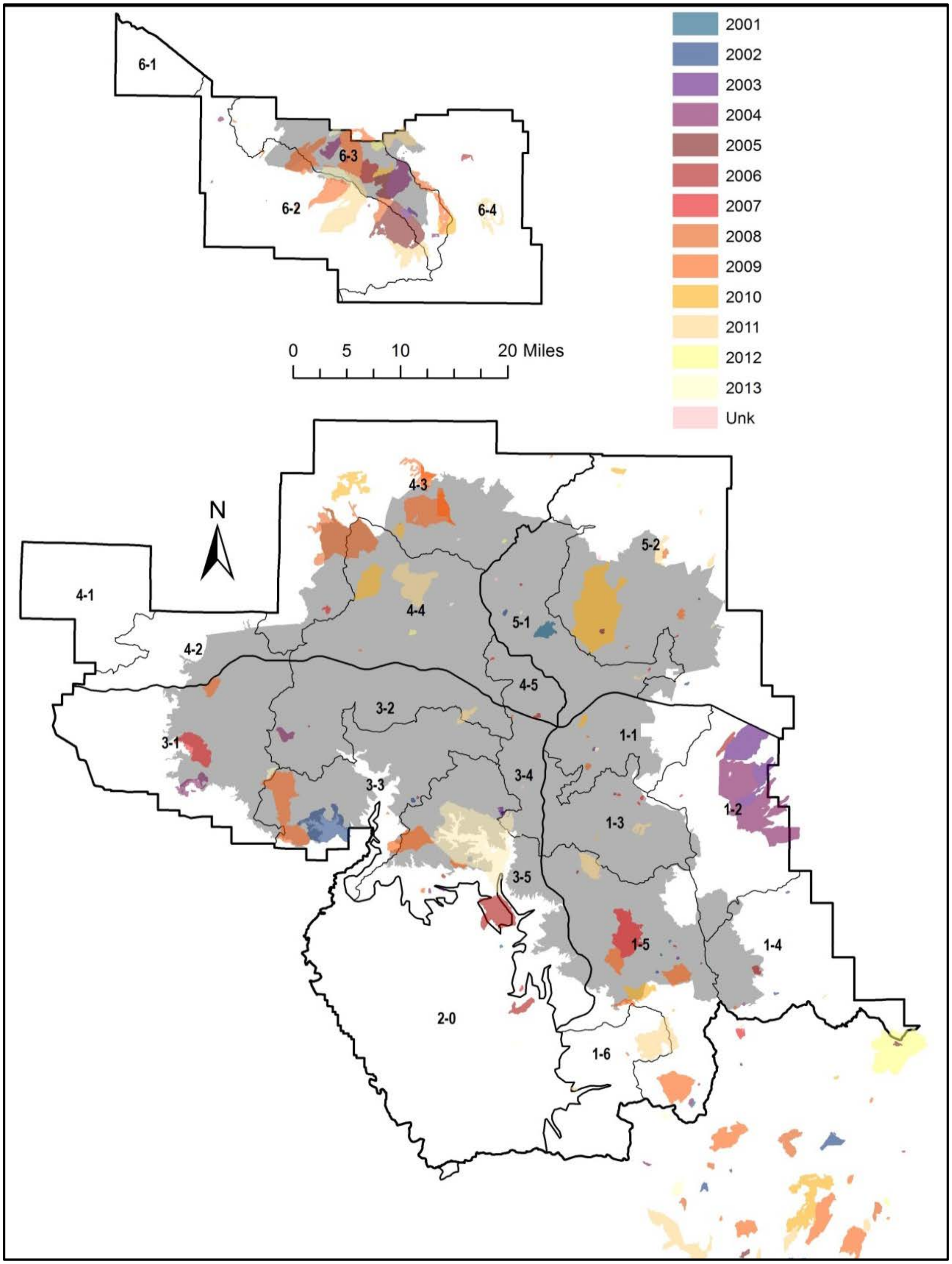

Figure 72 shows wildfires in/near the analysis area from 2001 – 2013.

The treatment area in RU6 and the treatment area in the four contiguous Restoration Units to the south of RU6 (1, 3, 4, and 5) are separated by a little over 23 miles, so projects and wildfires affecting Restoration Unit 6 (RU6) or the Southern EIS area (SEIS) are discussed separately. For the SEIS, the effects of wildfires and other project are considered for ~15 miles south and west of the Project Area because prevailing winds during fire season generally have a western, southwestern, or southerly component to them, so fires coming from those directions have better potential to burn into the project area that fires further away or in other directions. The USFS and the National Interagency Fire Center define 'large fires' as at least 300 acres in grass or shrub fuels, or at least 100 acres in timber (USDA 2014a). All fires included occurred from 2001 through 2013 and are at least 100 acres. The Slide Fire occurred in May of 2014, and was added because it that burned in (~8,000 acres) and adjacent to (~13,000 acres) the area proposed for treatment.

The effects of past treatments and wildfires within the area shown in Figure 72 could affect if and how wildfires burn into the treatment area. Vegetation/fuels in treated/burned areas are more likely to produce surface fires, which are easier to manage and are likely to produce effects that are beneficial to the ecosystems.

Cumulative effects include the effects of wildfire and vegetation management activities (mechanical treatments, prescribed fire and road decommissioning) on fire behavior and fire effects, including air quality. The time frame considered is about 10 years in the future at which time the majority of the actions proposed will have been completed. Assumptions include that about 33% of acres burned in wildfires managed primarily for suppression and less than 1% of acres burn in prescribed fire, or fires specifically managed as Wildfire Use Fire (prior to 2009) are high severity unless more specific data are available.

For the Environmental Consequences and Affected Environment analyses, canopy characteristics and surface fuel loading were evaluated for assessing movement towards desired conditions because they are indicators of potential fire behavior and effects, including air quality, and are used for modeling potential fire behavior. Fire Regime/Condition Class, Vegetation Condition Class, and Fire Return Interval were also used as coarse indicators of the departure of the treatment area from desired conditions. However, estimating fire return intervals (needed to calculate FRCC) for a single project here would not be a good comparison with what was calculated for the entire 4FRI treatment area because of the difference in scale. Specific data are not available for many other projects. However, the intent of considering canopy characteristics and surface fuel loading was to evaluate potential fire behavior and effects and potential air quality impacts. For projects included in this cumulative effects analysis, the treatments and the project objectives were considered as they relate to fire behavior and effects and air quality.

Cumulative Effects –Past Vegetation Management Activities and Wildfires

Restoration Unit 6 (RU6)

Vegetation treatments and wildfires near, adjacent to, and within the project area have contributed to shaping the existing vegetation conditions for the treatment area with prescribed fire and/or mechanical treatments. There are 8 projects which were completed near, adjacent to, or within the project area in RU6 that have affected potential fire behavior and effects in the treatment area (Table 128). Three additional projects were considered, but eliminated from analysis because of incomplete data.

Within RU6, near, adjacent to, or within the treatment area, there are about 50,000 acres on which projects were completed within the last 10 years that included mechanical thinning and/or prescribed burning and have, or may, affect potential fire behavior and effects within the treatment area. The Scott and Hull projects totaled a little over 10,000 acres in one block in the eastern and northeastern part of the treatment area within RU6. Both projects included thinning and prescribed fire, which would decrease the potential for crown fire for areas downwind, adjacent, or upslope. The Scott project was pre-commercial thinning in 2001 and, as such, decreased the potential for high intensity/high severity fire. On the west side, there are about 10,000 acres of vegetation projects which surround the airport and the town of Tusayan to the east and north, as well as being adjacent to the Grand Canyon Railroad and less than four miles from Grand Canyon Village. Objectives of these projects include fuels reduction, maintenance burning, recreating historic stand conditions in PJ (mixed severity), and reducing the risk of stand replacement fire and the rate of spread, intensity, and severity of wildfires that do occur.

Table 128. Estimated acres of past vegetation management activities potentially affecting 4FRI proposed treatments for RU6

Restoration Unit 6		Acres	
Project Name	**Year***	**Thinning**	**Broadcast burn**
Hull		876	876
X Fire	2009	140	0
O'Connell	<2009	500	0
Moqui Antelope Habitat Improvement	2006	2,990	2,990
Long Jim	2005	913	1,175
Russell	2013	0	400
Scott	2001	721	9,434
Ten X	2004	1,780	700
Topeka	2004	1,100	1,100
Tusayan West	2001	549	850
Tusayan East	2002	2,600	2,600
Tusayan South	2000	1,970	1,970
Tusayan South/Boggy Tank	2000	0	2,948
Upper Basin Burn Project	2000	0	1,884
Grand Canyon NP prescribed fires (South Rim)	2001 - 2013	527	22,253
	Total	**14,666**	**50,900**
	****Footprint acres =**	**50,500**	

****'Footprint acres' includes only the largest footprint of a project. For example, for the Scott Project 721 acres were thinned and 9,434 were burned. The footprint of the project would be 9,434 acres.**

Many of the wildfires that burned within RU6 in the last 10 years were managed primarily for resource objectives (as opposed to being managed primarily for suppression), and produced primarily low severity effects (Table 129). Data from the Rapid Assessment of Vegetation Condition After Wildfire database (RAVG) showed that the Miller fire (managed primarily for suppression) burned with only 3% (89 acres) high severity. The X-Fire, burned with almost 70% high severity, but little of it was in ponderosa pine and, for some of the area it burned in, high severity fire is part of the natural fire regime. Using the RAVG numbers, and assuming 33% high severity for those that were managed primarily for suppression, and 0.01% high severity for those managed primarily for resource benefit, there would have been about 983 acres that burned at high severity in RU6, in the last 10 years. In these high severity areas, there was some mortality of large and old trees. There is wide variability in the severity of wildfire effects, depending on the condition of the forests when they burn, and environmental conditions at the time of the burn.

All of the projects listed in Table 128 have decreased the potential for active crown fire and crown fire initiation on acres thinned (14,666), and the potential for crown fire initiation, and high severity effects from surface fire on about 50,900 acres of prescribed fire, and about 52,422 acres of wildfire. Across the project area other projects have affected vegetation in similar ways to those described under the alternatives, though there are some variations in treatments, particularly older fuels treatments. Past mechanical and prescribed fire treatments decreased the potential for crown fire by breaking up the vertical and horizontal continuity of canopy fuels. Prescribed fire and low severity wildfires further decreased the potential for crown fire, by removing additional ladder fuels, decreasing canopy bulk density, and raising canopy base height. Maintenance burning and wildfires decreased surface fuel loading in most areas burned, decreasing the potential intensity of subsequent fires.

Table 129. Wildfires in Restoration Unit 6.

Fire Name	Year	Acres
Antelope*	2003	244
Horse*	2003	153
Camp 36*	2004	3,052
Transfer*	2004	1,058
Mudersbach*	2005	7,260
North*	2005	1,315
West*	2006	1,925
Bar*	2006	193
Newt*	2008	770
Twenty-two*	2008	1,255
X	2008	2,030
Anderson*	2009	1,238
Indian	2009	619
Miller	2009	3,160
Rae	2009	1,392
Ruby	2009	4,107
Scott	2010	458
Tank	2010	945
Wash	2010	197
Grand Canyon NP (south rim)	2011-2013	5,508
Armstrong	2011	2,500
Parallel	2011	4,346
Lower	2011	2,002
Skinner	2011	1,439
Woodbridge	2011	1,762
Grand	2012	450
Halfway	2013	250
Skinner	2013	1,463
Grand Canyon NP (south rim)	2001 - 2010	684
Grand Canyon NP (south rim)*	2001 – 2010	647
Total Acres = 52,422		

***Managed primarily for resource objectives.**

Where wildfires and treatments as described above are close to, or adjacent to treatments proposed in the action alternatives (B, C, D, and E), they would augment the moderating effect the change in fuel structure would have on wildfires moving though the area by increasing the acres where high severity fire effects would not be supported. These areas may also augment the potential size and locations of burn units for the action alternatives because the moderated fire behavior in burned and/or thinned areas would allow prescribed fire to be implemented with broader burn windows and higher intensity fire (if desired) while still meeting control and resource objectives.

The combined effects of these projects and the wildfires that have burned in and near the SEIS have created a mosaic of stand conditions across much of RU6, and adjacent areas. These projects and wildfires have moved all of the treatment area in RU6 and adjacent areas closer to the Historic Range of Variation, in addition to decreasing the potential size and severity of wildfires in areas within and adjacent to the proposed treatment areas.

Air Quality

Past treatments and wildfires have decreased the potential emissions by removing canopy fuels, mostly from thinning on 14,666 acres, but some from wildfire and prescribed fire. Low severity fire would have consumed surface fuels, further decreasing potential for emissions on about 35,000 acres. Where wildfires burned with high severity (~1,300 acres in and adjacent to the project area), fine canopy fuels (needles and small twigs) were consumed leaving tree stems and branches, some of which have fallen and are now Coarse Woody Debris which have the potential to smolder for days, or weeks. From 2001 through 2013, Grand Canyon National Park implemented prescribed fire on about 40,000 acres within the Colorado River Airshed. Over 22,000 acres were on the South Rim (Grand Canyon National Park), while the Tusayan Ranger District (Kaibab National Forest) completed a little over 50,000 acres of prescribed burning. For RU6 the completion of this many acres contributes to a widespread lowering of potential ignitions per acre from both wildfire and prescribed fire for all alternatives, increasing the number of acres that could be burned while meeting desired conditions for air quality.

Southern EIS Area (SEIS)

There are over forty projects which were completed near, adjacent to, or within the SEIS (Table 130) that would have potential to affect fire behavior and effects in the treatment area for all alternatives. An additional seven projects were considered, but eliminated from analysis because of incomplete data. Three others (Blue Ridge Fire Risk, Fossil Creek, and Victorine) were not included because their location makes it unlikely they would affect, or be affected by proposed treatments.

There are about 117,517 acres of forest and savanna, and 65,713 acres of grasslands on which projects have been implemented within the last 10 years that included mechanical thinning and/or prescribed burning and have affected, or could affect potential fire behavior and effects in the proposed treatment area.

Table 130. Past vegetation activities within or close to the project area of the SEIS.

SEIS: 2001 - 2013 non-grassland vegetation treatments	Acres*	Acres	
Project	Year	Thinning	Broadcast burn
APS Power line	2007	167	0
APS Hazard Tree Removal	2003	0	315
Arboretum WUI	2000	602	602
Bald Mesa WUI	2005	457	4,451
Bill Williams Cap	2009	10	1
Blue Ridge 69kV	2005	50	1,300
Camp Navajo Army Depot	2011	1,213	0
City	2005	8,667	12,400

City of Flagstaff Forest Treatment Activities	2011-2013	1,065	1,594
Clover High (385 acres all within the 'City' project)	2004	385	0
Dogtown	2004	6,029	6,029
Doney Park 69kV	2005	9	0
Eastside	2006	7,599	19,977
Elden	2006	193	0
Eldon	2002	200	200
Elk Park	2007	1,800	3,500
Flag Tank	2007	22	36
Frenchy	2003	9,319	9,319
Government Mountain/Coleman	2005	75	0
IMAX	2002	1,595	6,358
Kachina Village	2003	3,801	2,147
Kendrick	2005	2,835	2,835
Lake Mary	2005	1,845	1,400
Little Draw Aspen	2009	107	0
Mormon Lake	2005	1,820	1,820
Mormon Mountain (thinning around towers)	2007	11	0
Munds Park	2009	990	2,950
Pineaire	2004	602	645
Potato Hill	2003	637	0
Rocky Park	2001	5,651	7,800
Skunk Canyon	2005	0	831
Slate Mountain	2010	2,250	0
Twin	2005	1,400	1,400
Valley	2005	0	10,245
Williams Follow-up Mistletoe	2004	368	0
Williams High Risk	2001	756	756
Woody Ridge	2004	7,987	11,184
	Total =	**70,517**	**110,095**
****Footprint Acres = 117,618**			

SEIS - 2001 - 2010 grassland* vegetation treatments	**Acres**	**Treatment Type**	
Project	**Year**	**Thinning**	**Broadcast burn**
Anderson Mesa	2003	0	800
Apache Maid Grassland Restoration	2004	54,528	0
Dogtown	2004	480	480
Eastside	2006	220	220
Garland Prairie	2005	500	0
IDA Grassland	2008	1,800	1,800
Lake Mary	2005	1,845	3,245
Rocky Park	2001	200	200
Slate Mountain	2010	2,250	0
South Williams Prescribed Burn #51	2005	0	290
Twin	2005	1,400	1,400
	Total =	**63,223**	**8,435**
****Footprint Acres = 65,713**			

***Grassland acres were counted only if the objectives specifically mention 'grassland' and acres of 'grasslands' treated can be estimated from the available information.**

****'Footprint acres' includes only the largest footprint of a project. For example, for the Woody Ridge Project**

7,987 acres were thinned and 11,184 were burned. The footprint of the project would be 11,184 acres.

Within and adjacent to the southeastern part of the project area, including parts of RU1, there is an almost continuous block of 8 project implemented between 2001 and 2013 that lower chance of active crown fire or high severity surface fire effects than in areas that have not been treated. In forested habitat, these projects range from 14,500 acres of prescribed fire and 1,800 acres of thinning, to 54,000 acres of thinning and 800 acre of prescribed fire in grasslands. In RU3 and RU1, adjacent to I-17, a series of treatments from south of Kachina Village and north to the lower slopes on the southwest side of Mt. Humphries were treated between 2000 and 2004. The northernmost of these treatments includes some experimental treatments (Fort Valley) that were not full treatments. These areas have grown back somewhat and, though there are still few ladder fuels in much of the area because of thinning, canopies have grown, allowing potential for undesirable fire behavior and effects. More recent treatments south of Munds Park (Rocky Park, 2009) decreased the potential for undesirable fire behavior and effects, particularly as they could affect Munds Park. Fuels projects north and south of I-40, surround the communities of Williams, and mitigate potential effects to Bellemont and Parks. North of I-40 and west of the Peaks, scattered large projects up to 4,500 acres break up fuels on a landscape level, though there are large areas untreated between the projects. East of the peaks, north and south of I-40 is a large fuels reduction project with almost 8,000 acres of mechanical treatments, and over 20,000 acres of prescribed fire.

These large treatments across the project area would slow down the rate of spread for large fires (Finney et al. 2006). Thinning along power lines creates a linear feature that helps protect the power lines in the event of a wildfire, and limits the number of starts caused by power lines (Figure 73). Developed two track roads in the thinned areas could be used as firelines for low intensity fires, facilitating subsequent prescribed fire treatments.

Figure 73. Powerline corridor in Restoration Unit 1 (April 2011)

Wildfires from 2001 to 2010 burned about 151,782 acres within the Southern portion of the project area. Several of the wildfires that burned within the SEIS in the last 10 years were managed primarily for resource objectives (as opposed to being managed primarily for suppression), and produced primarily low severity effects (Table 131). Data from the Rapid Assessment of Vegetation Condition After Wildfire database (RAVG) showed that the Eagle Rock fire (managed primarily for suppression) burned with only 48% (1,661 acres) high severity; the Schultz Fire burned with almost 56% (7,886 acres) high severity; the Taylor fire burned with 23% (794 acres) high severity, the Slide fire burned with about 14% high severity, (~3,000 acres), and the Birdie fire burned with 7% (387 acres) high severity. Using those numbers and, for the rest of the fires, assuming 66% low severity for the rest that were managed primarily for suppression, and 99% low severity for those managed primarily for resource benefit, there would have been about 46,607 acres (~31) that burned at high severity between 2001 and 2010. There is wide variability in the severity of wildfire effects, depending on the condition of the forests when they burn, and environmental conditions at the time of the burn. In general, severity ranges from 20% to 45% of acres burned in wildfires managed primarily for suppression, depending on the conditions at the time of the burn.

Table 131. Large wildfires in or near the southern portion of the project area from 2001 – 2014.

SEIS					
Fire Name	**Year**	**Acres**	**Fire Name**	**Year**	**Acres**
Leroux	2001	1,200	Cross	2009	7,718
Gov. Prairie	2001	751	Independence	2009	1,370
Five Mile	2002	376	July 4TH Complex	2009	3,084
Packrat	2002	2,800	Point	2009	1,295
Springer	2002	874	Raptor	2009	1,922
Tram	2002	197	Rattle Ridge	2009	403
Trick	2002	5,550	Real	2009	1,545
Fry	2003	179	Red	2009	2,203
Lizard	2003	5,270	Reservoir	2009	156
Mormon	2003	2,725	Taylor	2009	3,545
Jacket	2004	17,219	Tucker	2009	2,600
Morgan	2004	670	Twin	2009	908
Webber	2004	1,400	Wildhorse	2009	13,790
Wildsteer	2004	1,220	89 Mesa	2010	523
Bull Run	2005	885	Bravo	2010	3,254
Tater	2005	150	Eagle Rock	2010	3,474
Brins	2006	4,317	Hardy	2010	3,026
February	2006	150	Hobble	2010	2,395
Kennedy	2006	191	Juniper	2010	470
Knife	2006	560	Ranger	2010	2,200
La Barranca	2006	800	Schultz	2010	15,075
Pomeroy*	2006	260	Tag	2010	355
Sawmill	2006	300	Tuba	2010	363
Towel	2006	237	Weir	2010	1,600
Woody	2006	106	Beale	2011	5,096
Bargaman	2007	320	Beef	2011	358
Birdie	2007	5,016	Bolt	2011	1,790
Dutch*	2007	3,148	Engineer	2011	601
Radio*	2007	175	Fly	2011	896
Black	2008	225	International	2011	320
Late	2008	140	Kehl	2011	187
Lost Eden	2008	1,500	Lava	2011	220
Marteen*	2008	10,789	Rocky	2011	4,990
Oak*	2008	473	Sandrock	2011	4,600

Oh	2008	180	Scout	2011	775
Poor Farm	2008	140	Canyon	2012	8,716
Yeager	2008	470	Rabbit	2012	125
Bear	2009	350	Egypt	2013	501
Bow	2009	2,940	Mud	2013	308
Brady	2009	4,000	Wildhorse	2013	102
Cinder Hills	2009	256	Slide	2014	21,277
		Total acres =	**202,645**		

***Managed primarily for resource objectives as opposed to being managed primarily for suppression.**

The combined effects of the projects listed in Table 130, and the wildfires listed in Table 131, have decreased the potential for undesirable fire behavior and effects on about 134,000 acres of mechanical treatments, and the potential for crown fire initiation, and high severity effects from surface fire on ~120,000 acres of prescribed fire, and ~181,000 acres of wildfire. This applies to all alternatives. As with RU6, the combined effects of these projects and the wildfires that have burned in and near the SEIS have created a mosaic of stand conditions across much of the treatment area, and adjacent areas, decreasing the potential for undesirable fire behavior and effects. The scattered large blocks of treatments with decreased fire behavior potential would slow down a large wildfire and decrease the severity of its effects.

Air Quality

As with RU6, past treatments and wildfires have decreased the current potential for emissions in areas that burned with low to moderate severity. The cumulative effects of prescribed fires in on the Coconino, Kaibab, and Prescott National Forests over the last 12 years has resulted in one exceedence of NAAQS on one monitor for one day for $PM_{2.5}$ in Flagstaff in 2007. Past treatments and wildfires have decreased the potential emissions by removing canopy fuels, mostly from thinning on about 134,000 acres, and by increased canopy base height from wildfire and prescribed fire. Low severity fire would have consumed surface fuels, further decreasing potential for emissions on about 300,000 acres of prescribed fire and wildfire combined. In some areas of high severity fire, canopy fuels were consumed leaving tree stems and branches which, once they fall and become Coarse Woody Debris, have the potential to smolder for days, or weeks.

Cumulative Effects – Current and Foreseeable Vegetation Management Activities

Restoration Unit 6 (RU6)

Table 132 lists approximate acres of seven projects within RU6 that are implementing mechanical and prescribed fire treatments (as of 2011) or are foreseeable and likely to impact fire behavior and effects within the proposed treatment area for all alternatives. The estimated annual acres of prescribed fire and low severity fire from the South Rim of Grand Canyon National Park are included (23,000 acres), based on trends and averages of the last 10 years. The effects are similar to what was described under RU6 in the previous section, 'Past Vegetation Management Activities and Wildfires' (page 260), though the locations of some projects are different, as are the acres. On the eastern side of the treatment area in RU6, there are acres adjacent to, and overlapping past treatments, as well as an additional 3,000 acres east of the treatment area. Large areas that can moderate fire behavior can be effective at slowing down wildfires, decreasing the potential for undesirable effects and behavior. An additional treatment west of the Tusayan Airport would help protect the airport and the town of Tusayan for a period of time by extending the treated area further around the airport, as well as further mitigation fire behavior adjacent to the Grand Canyon railroad and the potential for a fast moving wildfire to burn into the park.

Table 132. Current and foreseeable vegetation management activities in Restoration Unit 6

Restoration Unit 6		Acres	
Project Name	**Year**	**Thinning**	**Broadcast burn**
10X Pre-Commercial	Current	0	700
Airport Fuels	Current	2,961	2,961
Long Jim	Current	0	1,300
Russell	Current	5,000	8,000
Tusayan East	Current	0	2,600
Watts Vegetation Project (w/grassland acres)	2014	3,000	3,000
Grand Canyon NP fire (estimated wildfire and rx)	2014	311	23,000
	Total	13,052	41,461
		****Footprint acres =**	**42,641**

****'Footprint acres includes only the largest footprint of a project. For example, for the Russell Project, there would be 5,000 acres thinned and 8,000 burned. The footprint of the project would be the 8,000 acres.**

Air Quality

Prescribed fires implemented for the projects listed in Table 132 would comply with the regulations and requirements of the Arizona Department of Environmental Quality (ADEQ), as would prescribed fires within Grand Canyon National Park. There are ~21,423 acres of prescribed burns planned in RU6, and Grand Canyon National Park by 2020. There is potential for both the Colorado River Airshed and the Little Colorado River Airshed to be impacted by fires occurring within RU6 and Grand Canyon National Park. It is likely that similar burn windows would be needed for many of the fires in the park and parts of RU6.

Southern EIS Area (SEIS)

There are about 275,667 acres of mechanical treatments and 299,524 acres of prescribed fire ongoing or planned that could impact fire behavior and effects within the proposed treatment area for all alternatives (Table 133). Surrounding the community of Flagstaff is a block of projects which include over 45,000 acres of mechanical treatments and over 65,000 acres of prescribed fire. In addition to past projects surrounding the community of Williams, an additional ~17,700 acres of mechanical treatments and ~32,000 acres of prescribed fire are being implemented and planned. Adjacent to the southern border of RU1, ~60,000 acres are being planned for both prescribed fire and mechanical treatments. These ongoing projects would augment the effectiveness of past projects designed to minimize the potential for high severity fire near and/or in Williams and surrounding homes. Ongoing maintenance thinning along power lines creates linear features that help protect the power lines in the event of wildfire, and limits the number of starts caused by power lines (see Figure 73). Developed two track roads in the thinned areas could be used as firelines for low intensity fires. In higher intensity fires, there thick smoke can create a path for electricity to arc from the power lines to something or someone nearby. The Flagstaff Watershed Protection Project is proposing a Forest Plan amendment to the Coconino Forest Plan that would allow mechanical treatments in PACs, and to a greater level than had previously been allowed under the existing Coconino Forest Plan. This would further augment the effects of treatments proposed under the 4FRI because it would lower the potential fire intensity and severity in areas adjacent to the area proposed for treatment in the 4FRI. This, along with all other adjacent areas proposed for mechanical treatments and/or prescribed fire, would increase the flexibility of land managers when they lay out prescribed fire units because of larger areas with lowered potential for high intensity/severity fire.

Table 133. Current and foreseeable vegetation management activities in the SEIS

SEIS - Current & Foreseeable Vegetation Projects (forested)		Acres	
Project	Year	Thinning	Broadcast burn
A-1 Mountain	2012	0	8,274
Arboretum	Current	0	602
Aspen Restoration Project	2012	402	402
Bill Williams Mtn Restoration	2012	11,650	15,200
Camp Navajo (entire project is within DOD AZ ARNG)	2013	1,903	140
Clint's Well Forest Restoration	2013	12,912	16,467
Community Tank	2011	185	185
City	2005	600	600
Community Tank	2011	865	865
Coulter Experimental Forest	Current	800	800
DOD AZ ARNG	2012	17,049	17,049
Dogtown	Current	1,700	1,700
Eastside	2006	7,819	20,197
East Clear Creek	Current	1,562	4,700
Elk Park Fuels	Current	4,700	6,400
Flagstaff Watershed Protection Project	Current	10,543	10,543
Frenchy Vegetation/Fuels Management	2003	2,790	6,529
GFFP	2012	535	535
Grapevine Canyon Wind Project; ROW and Switchyard	2012	9	0
Hart Prairie	Current	9,815	9,815
Jack Smith/Schultz Fuel Reduction & Forest Health	2007	2,000	2,000
Juan Tank Japanese Brome Management	2014	0	12,133
KA	Current	1,050	1,050
Kachina Village Forest Health Project	2003	3,801	2,147
Mahan-Landmark	2012	33,747	33,747
Marshall	2012	7,120	2,580
McCracken	2012	15,262	17,337
Mormon Lake	Current	568	2,388
Mountainaire HFRA Project	2006	13,363	15,109
Munds Park	Current	0	2,950
Pomeroy	Current	1,740	1,740
Power lines, oil and gas lines, natural gas/FERC, meter sites, gas compression and substation sites forestwide	Current	27,344	0
Sandvig Young 69KV	2011	78	535
Skunk Canyon Prescribed Fire Fuel Reduction	2006	0	831
Slate Mountain	2010	2,250	0
South Williams Prescribed Burn #51	Current	0	290
Tornado Rehab (salvage, not really thinning)	2011	18,756	0
Turkey/Barney	2012	17,835	17,835
Twin	Current	0	1,400
Upper Beaver Watershed Fuels Reduction	2012	15,807	31,162

Upper Beaver Creek	2010	1,562	4,700
Western Area Power Admin	2012	4,584	0
Wing Mtn.	2013	9,561	10,138
Woody Ridge	Current	7,987	11,184
Wupatki, Sunset Crater and Walnut Canyon NM	Current	1,104	2,956
	Total =	271,358	295,215
	*****Footprint Acres =**	356,115	

SEIS - Current & Foreseeable Vegetation Projects (grasslands*)		Acres	
Project or wildfire	**Year**	**Thinning**	**Broadcast burn**
Marshall	2012	3,680	3,680
Wing Mtn.	2012	629	629
	Total =	4,309	4,309
	****Footprint Acres =**	4,309	

***Grassland acres were counted only if the objectives specifically mention 'grassland' and acres of 'grassland' treated can be estimated from the available information.**

****'Footprint acres' includes only the largest footprint of a project. For example, for the Russell Project, there would be 5,000 acres thinned and 8,000 burned. The footprint of the project would be the 8,000 acres.**

Across the project area other projects have affected vegetation in similar ways to those described under the action alternatives, though there are some variations in treatments. Current, ongoing, and reasonably foreseeable management activities including mechanical and prescribed fire treatments would decrease the potential for crown fire by breaking up the vertical and horizontal continuity of canopy fuels. Overall, for all the action alternatives, the combined effects of current, ongoing, and reasonably foreseeable management activities would augment the effects of proposed treatments to decrease the potential size and severity of wildfires. These areas also may augment the potential size of burn units, and increase the flexibility of locating burn units, because the moderated fire behavior in burned and/or thinned areas adjacent to potential burn units would allow prescribed fire to be implemented with broader burn windows and higher intensity fire while still meeting control and resource objectives.

Air Quality

Emissions from ~300,000 acres of prescribed fire would be managed in compliance with regulations and requirements of the Arizona Department of Environmental Quality (ADEQ). There is potential for air quality impacts to the Peaks and Sycamore Canyon Wilderness areas, the Colorado River Airshed, the Little Colorado River Airshed, and the Verde River Airshed from fires occurring in the SEIS.

Cumulative Effects – Alternative A

Alternative A would continue to maintain 586,110 acres with increasing potential for high severity fire effects and behavior, though the effects would be mitigated to some degree by past wildfires and projects, and current and reasonably foreseeable projects, and any beneficial wildfires that may occur in the future. Alternative A would not contribute to improving the structure, composition, and patterns within the area proposed for treatment. Within the area considered for cumulative effects for Fire Ecology and Air Quality, there would be some improvement from the projects listed above, which includes about 288,719 acres of mechanical treatments and 340,685 acres of prescribed fire in current and foreseeable projects (Table 133 and Table 132). However, the effects would be much less with no 4FRI treatment because of less spatial continuity between treatments than would be created with any of the action alternatives. It would not put the ponderosa pine forests, or the vegetative communities that are cohorts of ponderosa pine on trajectories towards being resilient or sustainable. The treatment area would continue to become less adapted to fire, increasing the potential for undesirable fire behavior and effects when wildfires do occur. When fires did occur, many would have potential for extreme fire behavior and could produce large areas of high severity, which could extend well outside of the treatment area. Many fires starting within the untreated project area would have potential to spread outside of the treatment area. Extreme fire behavior would put lives, property, infrastructure, and natural resources at risk. Post-fire effects would also extend well beyond the perimeters of the fire, and would include such effects as flooding, sedimentation, decreased water quality and quantity, decreased soil productivity, and other effects of fires burning out of their natural range of variation. In effect, Alternative A would produce the effects described for an area much larger than the area proposed for treatment in the action alternatives.

Air Quality

Air quality would be unaffected by prescribed fire from the treatment area, but would be affected by prescribed fires from projects listed in Table 132 and Table 133. Emissions from 300,000 acres of prescribed fire from current, ongoing, and reasonably foreseeable projects would be managed in compliance with regulations and requirements of the Arizona Department of Environmental Quality (ADEQ). Wildfires occurring in the untreated areas would produce more emissions in areas that were not treated than in areas that were treated, and could augment the effects of prescribed fires (from current and foreseeable projects) on air quality. Areas with potential for impact would be the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Grand Canyon National Park, Sycamore Canyon Wilderness Area.

Cumulative Effects – Alternatives B, C, and E

Treatments proposed in Alternative B would move 583,330 more acres toward desired conditions for fire behavior and effects across the project area. When considered with past wildfires, and past, current, ongoing, and reasonably foreseeable management activities, would augment the effects of proposed treatments on large (project area), mid (Restoration Unit), and small (Subunit) scales, creating mosaics at all scales of potential fire behavior and effects, dominated by low severity fire. The proposed treatments would fill in most of the acres between past, current, ongoing, and foreseeable management activities, creating a more cohesive, contiguous, restored landscape across the project area.

Treatments proposed in Alternative C would move 586,110 more acres, and Alternative E would move 403,218 acres towards desired conditions for fire behavior and effects across the project area. Most of the effects would be identical to Alternative B, with the exception of PACS and grasslands that would be treated under alternatives C and E, further augmenting the cumulative effects of the proposed actions and past wildfires, and past, current, ongoing, and reasonably foreseeable management activities. Under Alternative C, there would be additional acres treated in core areas, and more intense treatments in some PACs, further augmenting treatments from other projects near, or adjacent to the 4FRI areas proposed for treatment.

When the acres above are combined with past mechanical treatments (~148,000 acres), past prescribed fire (~167,710 acres) and current and foreseeable mechanical (288,719) and prescribed fire (340,685 acres), the mosaic that would be created would include large, contiguous areas of forests and grasslands that would be in a condition to be resilient to natural disturbances, including wildfire. Potential fire behavior and effects across the landscape included in the cumulative effects analysis area for Fire Ecology and Air Quality would be expected to be beneficial and desirable.

Air Quality

All prescribed fires would be implemented in compliance with ADEQ regulations and requirements as well as forest plan direction to meet legal standards and provide for public safety. Emissions from prescribed fires proposed in Alternatives B, C, and E would utilize many of the same burn windows that the ~300,000 acres of current, ongoing, and reasonably foreseeable prescribed fire projects would use. However, the increased acres of prescribed fire would allow more flexibility for implementation, and may make it possible to burn more acres at once with the same impacts. Areas with potential for impact would be the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Grand Canyon National Park, Sycamore Canyon 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 quality impacts.

Cumulative Effects – Alternative D

Treatments proposed in Alternative D would move 563,407 more acres toward desired conditions for fire behavior and effects across the project area. The proposed treatments would fill in most of the acres between past, current, ongoing, and foreseeable projects, creating a more cohesive restored landscape across the project area. Under Alternative D, 384,966 acres would not be treated with prescribed fire, so they would not move as far toward desired conditions, and some areas would retain potential for undesirable fire behavior and effects as surface fuel loading increased following thinning, increasing the potential intensity of surface fires.

Air Quality

Restoration Unit 6 (RU6) is adjacent to the Grand Canyon National Park, one of the most heavily visited national parks in the United States, as well as being a Class 1 airshed. Burn windows for the burns proposed in the action alternatives would be the similar to those for the current, ongoing, and reasonably foreseeable future actions. The potential for undesirable air quality impacts from prescribed fire would be the same as other alternatives because all prescribed fires are regulated by the same laws regarding allowed emissions. Areas with potential for impact would be the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Grand Canyon National Park, Sycamore Canyon Wilderness Area. In most of the area that was thinned and not burned (384,966 acres), there would be potential for greater wildfire emissions from increased surface fuel loading. When combined with emissions from current, ongoing, and reasonably foreseeable management actions, there would be potential for greater air quality impacts when wildfires burned in these areas than in areas that had been previously treated with prescribed fire. That could result in fewer acres of desirable fire (because NAAQs are sometimes too close to the limit for additional permits to be issued for prescribed fire or to allow a wildfire to be managed for something other than full suppression).

Cumulative effects - Climate change – All Alternatives

Climate change is expected to result in extreme weather conditions, with more extreme droughts and higher temperatures, making conditions for undesirable fire and insect outbreaks even more prevalent in the western United States. As a part of current, ongoing, and reasonably foreseeable management actions, there would be up to ~300,000 acres of prescribed fire and ~275,000 acres of mechanical thinning adjacent to, or near to, the 4FRI treatment areas. 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.

Comparison of Alternatives

This report analyzed the effectiveness of five alternatives for modifying composition, pattern, and structure as a means of restoring healthy ecological function to ponderosa pine, specifically in regards to fire ecology and air quality. All action alternatives are expected to reset the current trajectory of areas proposed for treatment towards greater sustainability and resilience. Aspen, grasslands, oak communities, and some pinyon/juniper communities associated with ponderosa pine are included. Restoring historic fire regimes plays both direct and indirect roles in achieving or maintaining desired conditions for these vegetation communities. All action alternatives move the 4FRI proposed treatment area toward desired conditions. Differences between them are discussed below, and summarized at the end of this section.

Fire Behavior

Table 134, shows modeled fire type for all alternatives and the existing condition. Alternative C produces the most acres of surface fire, followed by Alternatives E and B. Alternatives D has the least of the action alternatives, followed by Alternative A.

Passive crown fire is less of a concern than active but, when other variables are close, it is worth considering passive crown fire in the context of both severity and its potential to become active crown fire under worse conditions. Passive crown fire does not produce the same magnitude of negative effects as active crown fire because those areas that are burned with high severity are smaller, discontinuous and, in an ecological context, can help maintain forest structure and spatial patterns across the landscape, or maintain/improve grassland structure.

Desired condition for ponderosa pine is to have potential for less than 10% crown fire under the conditions modeled. Table 136 shows the difference in crown fire in ponderosa pine between alternatives. The change from existing conditions to post-treatment conditions in the action alternatives results primarily from: 1) mechanical treatments breaking up the vertical and horizontal continuity of canopy fuels; 2) mechanical treatments and prescribed fire raising canopy base heights; and 3) prescribed fire consuming surface fuels, and decreasing the potential intensity of subsequent fires.

Alternative C shows a little more crownfire potential than Alternative B because of 2,320 acres of crown fire from three control watersheds in the paired watershed research study (which is not proposed in Alternative B).

Modeled differences in fire behavior between Alternatives E and B are not as apparent as would be the case because of limitations in the resolution of the modeling. The inclusion of a forest plan amendment that allows more interspace would produce less, or smaller, areas of active crown fire in B than in E.

Surface Fuel Loading

There are no desired conditions for total surface fuel loading, but 20 tons/acres is a reasonable recommendation for average maximum surface fuel loading for the area of this analysis (see discussion on page 30). Historic levels were estimated to be 5 - 20 tons/acre for CWD alone. As shown in

Figure 75 and **Figure 74**, Alternatives B, C, and E would move the most acres towards recommended levels of surface fuel loading. Alternative E would slightly more acres with surface fuel loading of 15 – 20 tons/acre and greater than 20 tons/acre. Alternative D would leave about 4 times the acres of surface fuel loading >20 tons/acre than Alternative C.

Table 134. Modeled fire types for existing condition for all alternatives by Restoration Unit for the entire treatment area.

		Fire Acres			Fire Percent		
	RU	**Surface Fire**	**Passive Crown Fire**	**Active Crown Fire**	**Surface Fire**	**Passive Crown Fire**	**Active Crown Fire**
Existing Condition	RU 1	87,958	17,352	48,091	57%	11%	31%
	RU 3	90,781	13,639	44,449	61%	9%	30%
	RU 4	111,574	11,956	41,503	67%	7%	25%
	RU 5	52,182	7,370	7,918	71%	10%	11%
	RU 6	35,253	2,763	5,469	81%	6%	13%
	Total	**377,748**	**53,080**	**147,432**	**64%**	**9%**	**25%**
Alt. A (2020)	RU 1	85,639	16,450	51,355	55%	11%	33%
	RU 3	90,371	12,941	45,500	60%	9%	30%
	RU 4	111,515	10,968	42,643	67%	7%	26%
	RU 5	51,458	6,447	9,558	70%	9%	13%
	RU 6	37,120	2,768	3,596	85%	6%	8%
	Total	**376,102**	**49,575**	**152,652**	**64%**	**8%**	**26%**
Alt. B (2020)	RU 1	140,266	6,650	6,550	91%	4%	4%
	RU 3	139,502	7,551	1,767	93%	5%	1%
	RU 4	160,272	3,688	1,041	97%	2%	1%
	RU 5	65,806	1,048	613	90%	1%	1%
	RU 6	41,460	1,919	106	95%	4%	0%
	Total	**547,306**	**20,855**	**10,079**	**93%**	**4%**	**2%**
Alt. C (2020)	RU 1	142,435	5,264	5,745	92%	3%	4%
	RU 3	139,678	6,914	2,222	93%	5%	1%
	RU 4	161,663	3,012	450	98%	2%	0%
	RU 5	66,141	831	507	90%	1%	1%
	RU 6	41,467	1,912	106	95%	4%	0%
	Total	**551,384**	**17,933**	**9,031**	**94%**	**3%**	**2%**
Alt. D (2020)	RU 1	136,084	6,815	10,569	88%	4%	7%
	RU 3	140,429	5,621	2,764	94%	4%	2%
	RU 4	156,299	6,428	2,275	94%	4%	1%
	RU 5	65,546	1,204	715	90%	2%	1%
	RU 6	41,152	1,733	601	95%	4%	1%
	Total	**539,510**	**21,801**	**16,924**	**92%**	**4%**	**3%**
Alt. E. (2020)	RU 1	141,135	4,680	7,646	91%	3%	5%
	RU 3	139,311	6,977	2,490	93%	5%	2%
	RU 4	161,367	3,198	531	97%	2%	0%
	RU 5	66,118	832	514	90%	1%	1%
	RU 6	41,463	1,917	106	95%	4%	0%
	Total	**549,395**	**17,605**	**11,286**	**94%**	**3%**	**2%**

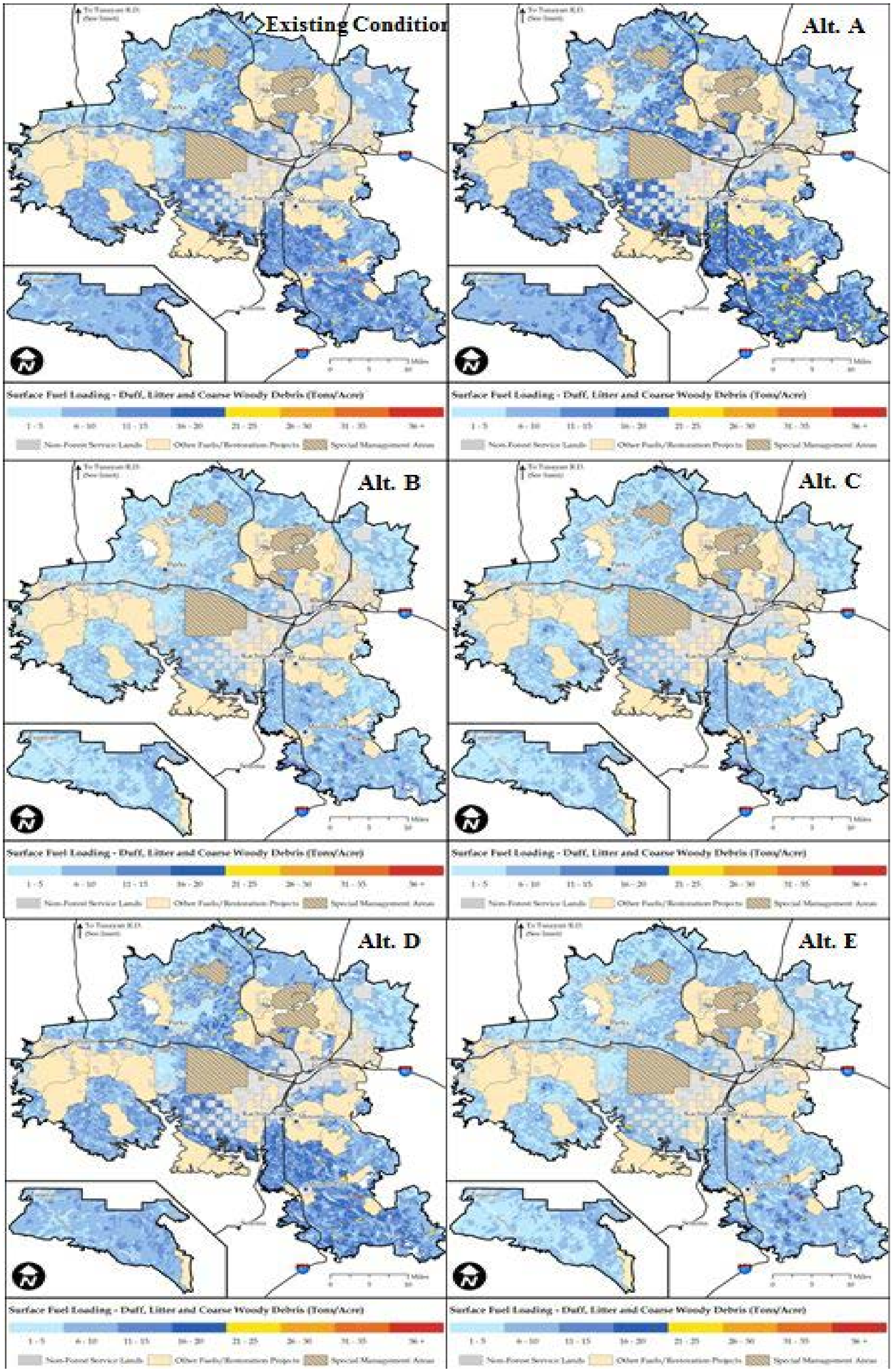

Figure 74. Surface fuel loading by stand averages by alternative.

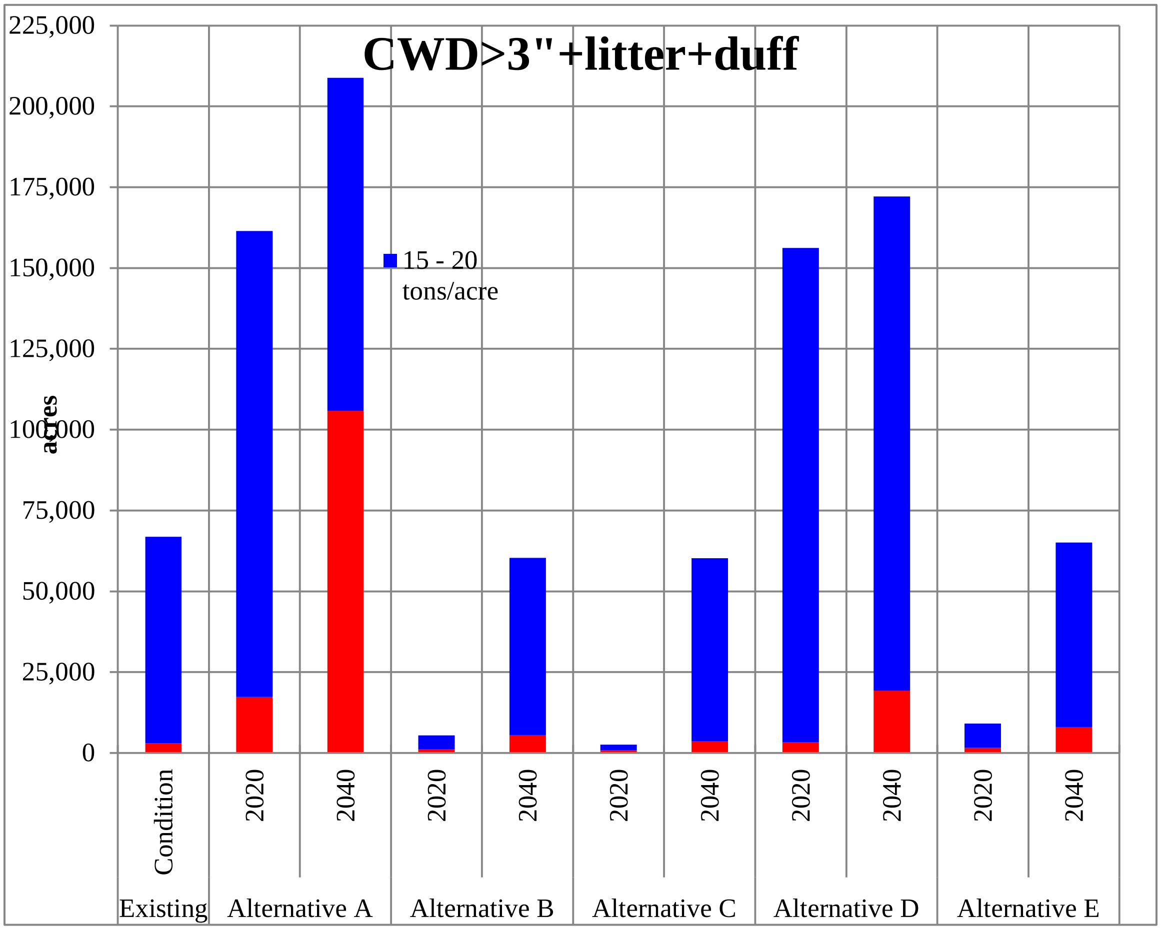

Figure 75. Acres with fuel loading 15-20 tons/acre and greater than 20 tons/acre by alternative.

Emissions: Air Quality and Ecological Effects

The amount of biomass consumed during a prescribed fire (and therefore the emissions produced) is more easily controlled than for wildfires burning on dry, hot, windy days. When comparing alternatives, all of the action alternatives propose prescribed fire at some level which could impact air quality in the surrounding communities but in a controllable manner. The post-treatment conditions from implementing these alternatives would reduce the amount of biomass available to burn during wildfire which would moderate fire behavior, fire effects, and reduce the emissions potential of wildfire occurring in those areas. Alternative A does not propose any prescribed burning, and would produce increasing amounts of biomass available to burn in the event of a wildfire. This would have direct and most likely uncontrollable impacts on recreation and surrounding communities from emissions, as well as longer lasting fire effects.

Examining the cumulative effects from smoke on air quality differs from the evaluation of cumulative effects for many other resources because of the transient nature of air quality impacts. It is a relatively simple exercise to estimate the total tons per acres of emissions, but there is no calculation that correlates total annual emissions to total concentrations of emissions. As discussed earlier, air quality impacts are measured as concentrations of emissions, whether it's in $\mu g/m^3$ for National Ambient Air Quality Standards (NAAQS), or in deciviews measuring visibility in Class I Areas. Cumulative effects are not the total emissions produced in a day or a year, but rather the concentration of all fire emissions in a given airshed at a given time. For NAAQS these concentrations have a varying time weighted period depending on the pollutant. For PM10 and PM2.5, they are measured as a 24 hour average, and as an annual arithmetic mean (Kleindienst 2012). The area of analysis discussed for air quality includes both forests, the Colorado River Airshed, the Little Colorado River Airshed, and the Verde River Airshed. The season for broadcast burning is about April through October, pile burning is most often done in the winter months, and wildfires generally occur from April through October. More acres are proposed to be burned in the implementation than are currently being burned annually on both forests, so there would be prescribed burning on more days each year. However, after the first entry burn, fuel loads would be significantly decreased, so potential tons/acre of emissions would be significantly lower. Additionally, because of the decrease in fuels, fire behavior potential would also be significantly lower (Table 134), so there would be more potential to burn on days with better smoke dispersal (higher winds and more lift).

The three action alternatives propose prescribed burning at different levels. There are too many variables that affect the concentration of smoke at specific locations for a given prescribed fire for a spatially explicit evaluation on the scale of this project a year (or more) in advance of implementing a burn. Burn Plans are tiered to the NEPA document for which they direct prescribed fire implementation, and include spatial specific modeling that specifies what effects are expected where, and to help determine what conditions would produce the desired results to minimize impacts from emissions. It is reasonable to assume there is a correlation between the amount of smoke produced in a fire, and the potential for that smoke to produce undesirable impacts.

Post-treatment, there would be the least emissions potential from alternatives B and C. E would be the next lowest, and would be closer to B and C than to D. D would have the highest potential emissions of all the action alternatives because of the lack of treatment of surface fuels, and the slight increase in surface fuels that comes from thinning.

FRCC/VCC

Modeled FRCC ratings for the ponderosa pine proposed for treatment are shown in (Table **135**). All action alternatives would move the ponderosa pine into FRCC2 post-treatment. Alternatives B, C, and E would remain in FRCC2 through 2050. Alternatives A and D either stay in (A), or revert to (D) FRCC3.

Table 135. Fire Regime Condition Class ratings for the ponderosa pine proposed for treatment.

	2010	2020	2050
Alt. A	3	3	3
Alt. B	3	2	2
Alt. C	3	2	2
Alt. D	3	2	3
Alt. E	3	2	2

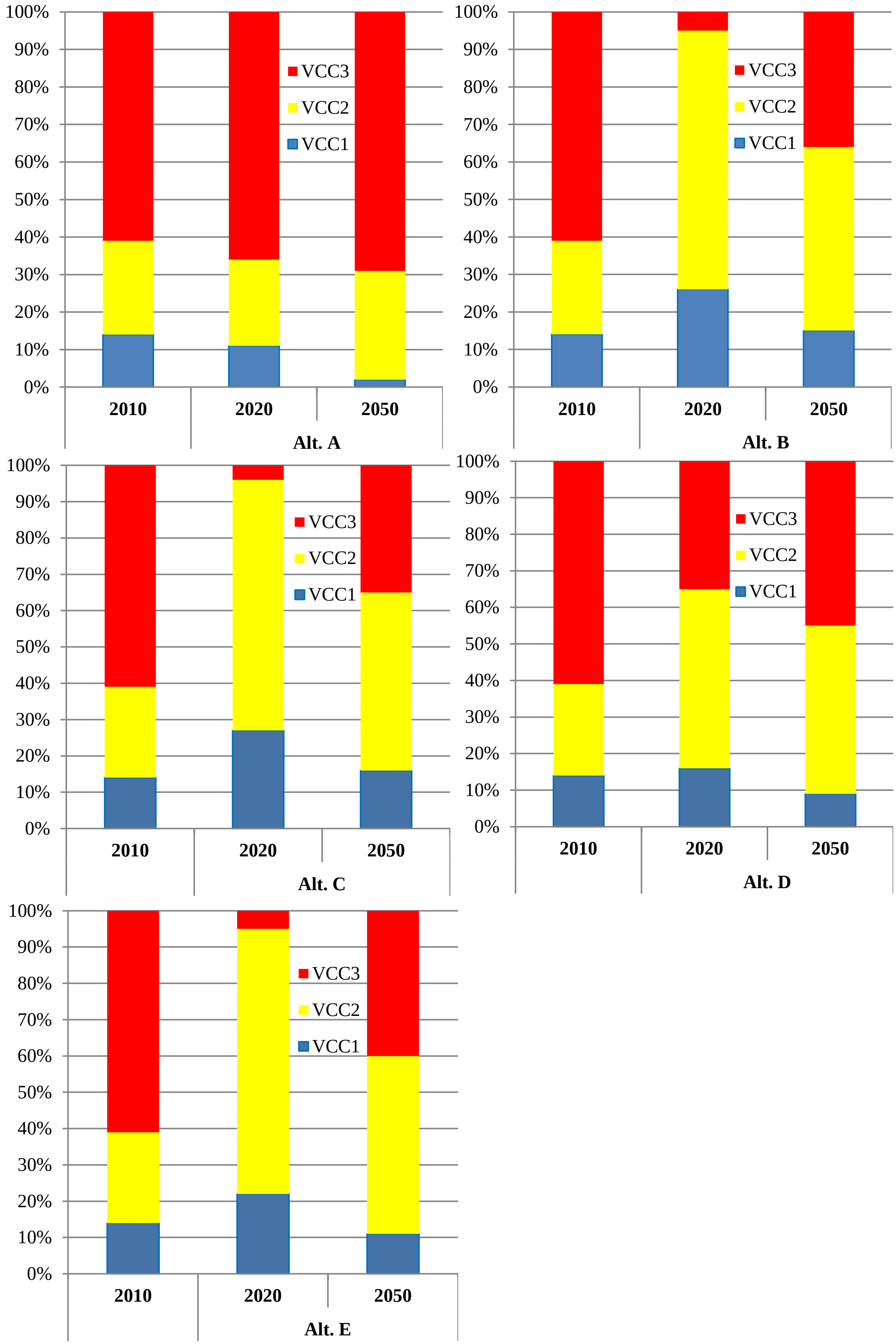

Figure 76. Vegetation Condition Class (VCC) modeled and used to determine FRCC

Acres of Vegetation Condition Class (VCC) are shown in Figure 76. Alternatives B, C, and E, are similar, moving the most acres out of VCC3, and maintaining the most acres in VCC1. Alternative D moves acres in the right direction, but not nearly as many as Alternatives B, C, and D. More acres in Alternative D slip back into VCC3 in Alternative D than in the other action alternatives. Alternative A shows a steadily declining VCC, as canopies close up and the risk to key ecosystem components increases.

Summary

Alternative A: As the no action alternative, this would maintain and regress the ecosystem toward less and less sustainable and unstable characteristics. Canopies would continue to close and provide more and more contiguous fuel across the landscape. Increasing canopy cover (CC) would increasingly shade out lower branches, causing increases in canopy base height (CBH), and decreases in canopy bulk density (CBD), setting up forests for conditional crown fire. Alternative A would maintain 34% of the area with potential for high severity fire effects from crown fire, while Alternatives B, C, D, and E reduce this potential to 6%, 5%, 7%, and 5% respectively. Potential for crownfire in ponderosa pine would be reduced as well (Table 136). As canopies close up, surface fuel loading would continue to increase so that, when wildfires do burn, more area is subject to high severity surface fire. These canopy fuel changes have detrimental effects on understory vegetation, increasingly suppressing the production of forbs, grasses and shrubs. Over time it could be expected that most ponderosa pine forests would have little to no understory with only minimal light penetrating the canopy. Grasslands and savannas would continue to shrink as woody encroachment continued unchecked. Aspen would continue to decline as conifer encroachment continued, and the lack of disturbance continued to result in decreasing regeneration. The combination of abundant and contiguous canopy fuels, the lack of understory vegetation, and an already high and increasing surface fuel load, would combine with high potential for high severity fire effects from crown fire or surface fires that produce sufficient heat to lethally scorch crowns and/or damage soils, roots, tree boles, and seedbanks, maintaining the area in a FRCC3 into the foreseeable future.

Alternatives B, C, D, and E: all begin to restore the treatment area by it away from FRCC3, and moving acres out of VCC3 (Figure 76). Alternatives B and C move the most acres the furthest towards restoration. In the case of modeled crown fire, the differences between B, C, D, and E are minimal on the scale of the project. However, there are a large number of small differences between them and they combine to indicate that B would move the most acres the furthest towards desired conditions. Under Alternative E there would likely be greater potential for crown fire than under Alternatives B or C because, without an amendment, the forest plan would require less interspace, and result in more contiguous and denser canopy fuels, along with decreased heterogeneity and diversity. C would be second, E would be third, and D would be forth. Canopy characteristics directly affect the amount of sun and precipitation that can reach the surface, so Alternatives B, C, D, and E would all result in an increase of fine surface fuels and species diversity in the form of surface and understory vegetation. Most of the species diversity in ponderosa pine forests is contained in understory vegetation (Moore et al. 1999), and increasing diversity increases resilience. Understory vegetation can be >10 times higher in restored openings than under even sparse ponderosa pine cover (Clary 1975), and is important in supporting fire spread similar to that under which southwestern forests evolved. Over time, all action alternatives decrease Canopy Cover and Canopy Bulk Density and increase Canopy Base Height, with the most change occurring in Alternative C, the second most change in Alternative B, the third most change in Alternative E, and the least in Alternative D[8]. In ponderosa pine systems, surface vegetation is necessary for maintaining fire regimes that are sustainable over time. More fine, herbaceous surface fuels could increase surface fire rates of spread, compared with fine surface fuel loading composed of litter and duff which are more compact and produce slower fires that can put more heat into the soil.

[8] These metrics were not re-evaluated to account for changes to treatment intensity on ~40,000 acres. Although expected change would be minimal and, at most, cbd for Alt. E could increase to that of Alt. D, and cbd for Alt. C could increase above Alt. B. Changes to canopy base height would be expected to be minimal because prescribed fire would still be implemented and would be expected to produce a more significant change in canopy base height than mechanical treatments.

Table 136. Summary of modeled outputs for all metrics for 2020. Shaded cells do not meet desired conditions or recommended levels.

Veg type	Metric	Desired Condition	Current Condition	Alt. A 2020	Alt. B 2020	Alt. C 2020	Alt. D 2020	Alt. E 2020
Ponderosa pine (***includes savanna***)	Crown fire (% of all ponderosa pine/ total acres)*	<10	38/ 191,209	38/ 192,919	5/ 26,149	5/ 26,217**** 6/27/959*****	6/ 32,367	6/ 28,142**** 6/29,884*****
	CBH (average % of ponderosa pine based on treatment intensity/ total acres)	>18'	16.5	16.7	25	25	23	24
	CBD (average % of ponderosa pine based on treatment intensity/ total acres)	<0.05 kg/m^3	0.059	0.59	0.032	0.032	0.035	0.034
	CC (average % of ponderosa pine based on treatment intensity/ total acres)***	n/a	41	43	26	26	30	27
	FRCC overall rating	2	3	3	2	2	2	2
	VCC (% of ponderosa pine / acres in	0 acres in FRCC3	61/ 309,782	66/ 335,174	5/ 25,392	4/ 20,314	35/ 177,744	5/ 25,392

	VCC3)							
	Surface fuel loading (average % of ponderosa pine based on treatment intensity/ total acres)** (Litter + Duff + CWD)	>20** tons/acre	<1/0	<1/0	<1/0	<1/0	<1/0	<1/0
		>15*** tons/acre	5/ 24,142	8/ 42,814	1/ 4,895	<1/ 0	8/ 42,814	1/ 4,895
Grasslands	Crown fire*	<3	9	9	8	<1	12	<1
All vegetation	Crown fire*	n/a	34	34	5	5****	7	5****
	Surface fuel loading (by stand, % all acres/ total acres) (Litter, Duff, & CWD)	<20** tons/acre	1/ 2,953	3/ 17,335	<1/ 1,048	<1/ 810	1/ 3,298	<1/ 1,579
		>15*** tons/acre	11/ 66,871	28/ 161,405	1/ 5,418	<1/ 2,569	14/ 77,294	2 /9,075

***Crown fire refers to active crown fire and passive crown fire combined**

****Twenty tons per acre is a *recommended* maximum average for surface fuel loading, but is not specifically discussed in forest plans.**

*****No desired condition, but it was modeled and may be useful for informing discussion**

******Includes 2,310 acres of crown fire in the control (no treatment) watersheds in the paired watershed research study. Does not include potential increases resulting from adjustments made to ~40,000 acres.**

*******Acres of potential crownfire in ponderosa pine if adjusted for changes in treatment intensity for ~40,000 acres of VSS4, VSS5, and VSS6**

Monitoring

Monitoring would be a critical component in the success of the 4FRI. Fulé and Laughlin (2007) stated: "Ecological restoration can be criticized because future climate conditions will not be like those of the past (Millar & Wolfenden 1999). However, the issue is not whether future climates will be unchanging, they will not, but rather whether native forest ecosystems can persist under future conditions. Climate change, whether through gradual changes or greater extremes which affect disturbance severity, may create novel thresholds beyond which a species or ecosystem type cannot survive (Malcolm et al. 2002). But unless or until such a point is reached, **the most relevant question for assessing restoration is sustainability** (Clewell 2000)."

When choosing what to monitor, there should be a balance of the measures used to 1) evaluate the post-treatment condition of the treatment area and the treated areas in regards to potential fire behavior and potential fire effects and; 2) those that can provide information about the sustainability of management actions based on current and expected fire effects. Questions to be answered by monitoring include:

- How many acres (or percent of the landscape or vegetation type) burned with fire behavior that produced the desired fire effects? If monitoring data show treated areas do not meet desired conditions, there would be a re-evaluation of treatments to determine what changes are needed. Evaluation could be based on such things as burn severity (fire effects on soil), mortality of desirable species (such as large and/or old ponderosa pine, and large Gambel oak), and the response of surface vegetation for several years following treatments and/or wildfire.
- Were there any exceedences? This would be automatic feedback from ADEQ monitors to track this. If there are exceedences, there would need to be a re-evaluation of treatments to determine what changes are needed.
- Were the logistics and operations implementable at the desired spatial and temporal scales? If, after 5 years of implementation, the necessary acres are not being treated with prescribed fire and/or the trend in average acres burned indicates they would not be, there would need to be a re-evaluation of limitations to determine what changes would be needed to meet objectives for prescribed fire.

Adaptive Management

All alternatives assume the use of adaptive management principles. Forest Service decisions are made as part of an on-going process, including planning, implementing projects, and monitoring and evaluation. All Forests' Land Management Plans identify monitoring programs. Monitoring the results of actions would provide a flow of information that may indicate the need to change a course of action or amend either the Land Management Plans, the 4FRI EIS, or both. Scientific findings and the needs of society may also indicate the need to adapt resource management to new information. Forest Supervisors annually evaluate monitoring information displayed in evaluation reports through a management review and determine if any changes are needed in management actions or the documents themselves. In general, annual evaluations of the monitoring information consider the following questions:

- What are the effects of resource management activities on the health and condition of the land in regards to potential fire behavior and effects?
- To what degree are resource management activities maintaining or making progress toward the desired conditions and objectives for the plan?
- What changes are needed to account for unanticipated changes in conditions?

Recommended adaptive management actions for transportation, springs and roads were reviewed. None of the recommended management actions would conflict with desired conditions and proposed actions for Fire Ecology/Fuels/Air Quality.

Changes to the Fire Ecology and Air Quality Report from the DEIS to the FEIS

After reviewing public comments on the DEIS, and incorporating changes that have occurred since the analysis for the DEIS was completed, the Forest Service has made a number of changes that have resulted in changes or additions to the Fire Ecology / Air Quality analysis. They are discussed below in no particular order.

1) A new alternative was developed in response to public comments to see an Alternative with no forest plan amendments. This was developed into Alternative E. Under the heading 'Alternatives Analyzed' a paragraph was added summarizing Alternative E, and an additional column was added to Table 1, comparing the proposed actions for each Alternative. A new section was added with a full analysis of Alternative E, which included the modeling of new treatments that would comply with existing forest plans in areas where treatments proposed in Alternatives B, C, and D required forest plan amendments. The discussion, figures, and tables under 'Summary of Alternatives' were all expanded to include Alternative E, and outputs for the FRCC evaluation for were updated in Appendix D.

2) Throughout this report, discussions on potential fire behavior and effects are discussed quantitatively in either acres, or in percent of an area (habitat type, Restoration Unit, Subunit, etc.). These numbers were adjusted for 11 maps, 132 tables, and 35 graphs, in order to account for changes in boundaries and acres for PACs, PFAs, areas of overlap between 4FRI and other projects, control watersheds for research, and wildfires. Data updated includes descriptions of each alternative, fire type, acres of fuel loading by stand and by treatment, canopy characteristics, Fire Regime Condition Class, annual acres to be burned, and fire return intervals. Table 137 shows the difference in the percent of area for each fire type in each major vegetation type for each alternative.

3) Quantitative data for Fire Regime Condition Class (FRCC) in grasslands was removed and replaced with a qualitative write-up. The original data set had 'stands' with a Final Cover Type as 'Grasslands', which also had VSS, Canopy Closure classification, and single story (SS) vs. multi-story (MS) metrics. Those data were used, along with my experience in grasslands and FRCC and my expectations for fire/fire effects to anticipate rough changes to grassland FRCC. In discussions with other team members, I found out that there had been very few Grassland stands with tree data, so stand data had to use a version of Most Similar Neighbor for those stands. After looking harder at the data, it seemed like too many assumptions were needed to complete a valid FRCC analysis for montane grasslands in the project area.

   FRCC software was more accurately interpreted at the treatment area scale, so it was limited to that and Vegetation Condition Class is included along with FRCC.

   Consultation with the weed coordinator for the Coconino National Forest resulted in better numbers for uncharacteristic vegetation (non-native dominated) acres for the ponderosa pine.

4) Public comments resulted in additional explanation of the parameters used for fire modeling (Table 2, page 26). Additional numbers were added to Table 2 to help clarify which parameters were used, why they were used, and how to interpret them.

Table 137 shows the difference in fire type between the DEIS and the FEIS.

All	2010	Alt. A	Alt. B	Alt. C	Alt. D
Surface fire	0%	-1%	0%	0%	1%
Passive crown fire	0%	-1%	0%	0%	0%
Active crown fire	0%	2%	0%	0%	0%
Ponderosa pine	**2010**	**Alt. A**	**Alt. B**	**Alt. C**	**Alt. D**
Surface fire	0%	-1%	0%	0%	0%
Passive crown fire	0%	-1%	0%	0%	0%
Active crown fire	0%	2%	0%	1%	0%
Aspen	**2010**	**Alt. A**	**Alt. B**	**Alt. C**	**Alt. D**
Surface fire	-1%	-3%	0%	1%	2%
Passive crown fire	0%	0%	1%	0%	-2%
Active crown fire	0%	3%	0%	-1%	-1%
Grassland	**2010**	**Alt. A**	**Alt. B**	**Alt. C**	**Alt. D**
Surface fire	0%	-1%	-2%	0%	5%
Passive crown fire	0%	0%	1%	0%	-3%
Active crown fire	0%	1%	0%	0%	1%
Oak Woodland	**2010**	**Alt. A**	**Alt. B**	**Alt. C**	**Alt. D**
Surface fire	-6%	1%	1%	0%	1%
Passive crown fire	5%	-1%	0%	0%	0%
Active crown fire	0%	0%	0%	0%	0%
Pinyon/Juniper	**2010**	**Alt. A**	**Alt. B**	**Alt. C**	**Alt. D**
Surface fire	0%	1%	0%	0%	0%
Passive crown fire	0%	-1%	0%	0%	0%
Active crown fire	0%	0%	0%	0%	0%

5) Many comments from the public referred to 'fuels treatments', which is a misnomer since, with the exception of 535 acres in RU6, 'fuels' is not the primary objective of any 4FRI treatments. The existing discussion was expanded slightly (paragraphs 2 and 3 of this report).

6) Four mitigations were added:

- FE16 was added to ensure Fire Managers and Range Managers coordinate grazing in advance of prescribed fire to ensure there is sufficient surface fuel to meet burn objectives.
- FE17 was added to address managing CWD.
- FE18 was added to minimize impacts to threatened and sensitive frog species and to avoid the spread of invasive aquatic species when using natural lakes, ponds, or tanks as dipsites for helicopters.

7) Projects and acres in Cumulative Effects were updated based on better information, updated status of projects, and new projects (in particular, the Flagstaff Watershed Protection Project and the Slide Fire).

8) In response to public comments, an additional analysis was completed, and added to Appendix D, to better explain what is meant by modeling weather percentiles, and to clarify why, for this type of a project, it was not considered to be as useful as the modeling that was done.

9) Appendix A was updated to reflect direction in the new Kaibab National Forest Land and Resource Management Plan (2014).

10) Since this report was complete, the Kaibab National Forest Land and Resource Management Plan has been completed. This removed the necessity of forest plan amendments for the Kaibab NF, so those portions of the report have been removed and a short section added to each Alternative to reflect compliance with the new forest plan. Additionally, new forest plan guidance has replaced the old forest plan guidance in Appendix A.

11) In response to public comments, treatment intensity for about 40,000 acres of VSS4, VSS5, and VSS6 stands in alternatives C and E would be decreased to the lowest intensity within the proposed treatment. In the fire behavior modeling for the 4FRI EIS, the process that was used for assigning post-treatment fuel models was based on a key developed from FVS outputs. These outputs represented averages from all stands proposed for a given treatment. Treatments generally included a range of desired outputs based on the percent of interspace to be attained. Changes being applied mean there would no longer be a range, and FVS outputs that used would represent the lower end of the original range proposed. For example, a number that represented the average of all stands for which a UEA 45 – 65 treatment was proposed (meaning, depending on site conditions, the post-treatment condition would fall into the range of 45 – 65% interspace), would now represent the average of those same stands treated at a UEA 45 (meaning the post-treatment condition would be 45% interspace).

    Short-term effects of this change would be to increase the canopy fuel loading which, in turn, would be expected to increase potential crownfire to some degree. In order to provide some quantification for changes to potential fire behavior, an abbreviated evaluation was completed as described in Appendix D. Results indicate that ~1,750 acres currently modeled as surface fire would shift to crownfire, and about 130 acres currently modeled as passive crownfire would have potential for active crown fire. About 775 acres would occur in patches greater than 10 acres of contiguous crownfire. About 475 acres would occur in patches greater than 50 contiguous acres of crownfire. Fire under closed canopies would be more likely to lethally scorch tree crowns as heat would be trapped below them.

    Long term effects would be a greater increase in potential for active crownfire in these stands than under the previously proposed treatment intensity. The need to 'thin from below' would mean the stands would be more even aged, denser, and with more closed canopies which would not take as long to close up as more open treatments. The potential for lethal scorch from fires (prescribed fires and wildfires) would increase as these stands matured and canopy closure increased.

    These effects would not push any alternative out of desired conditions for fire behavior at any scale of analysis.

    No additional analyses were done to evaluate changes to surface or canopy fuel loading, Fire Regime/Condition Class, or emissions. Changes to surface fuel loading would be minimal since most of those changes would be the result of prescribed fire, and those treatments are not affected. There would be some changes to canopy fuels, and a short qualitative description was added to the effects as described in Alternatives C and E.

The Slide Fire

The Slide Fire was reported in the afternoon on May 20th, 2014, and was declared contained on June 4, after burning 21,227 acres. Almost 8,000 acres burned in 4FRIs treatment area, all in RU3. The majority of the area burned was in SU3-5, with a little in SU3-4 (Figure 77).

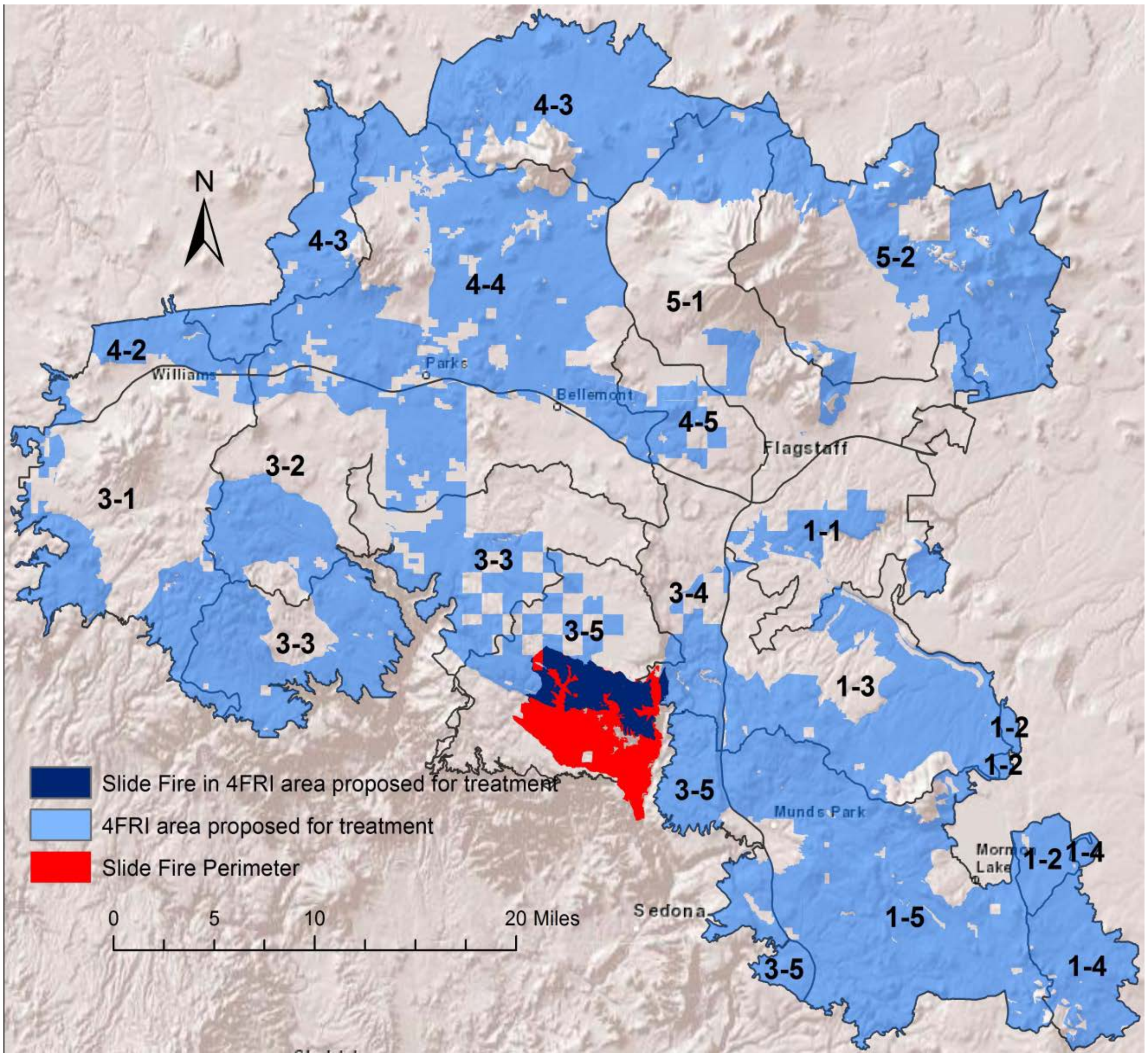

Figure 77. Southern EIS area showing the 7,884 acres where the Slide Fire burned.

Changes to the existing condition

The effects of the Slide Fire on most of the burned area were beneficial and included: decreased surface fuel loading which, in addition to having potential to produce undesirable fire effects was also suppressing surface vegetation; raised canopy base heights (decreasing the potential for crown fire initiation), decreased canopy bulk densities (decreasing the potential for active crown fire and allowing more light to the forest floor); recycled nutrients (providing a kick of nutrients to surface vegetation as the monsoons began); reinvigorated decadent shrubs (which would have been spending energy trying to keep old and dying stems alive); scarified seeds, etc.

Using post-fire data from the Burned Area Reflectance Classification to inform post-fire fuel models, fire behavior for the burned area was remodeled to better represent the new 'existing condition'. Under existing conditions (post-fire), there is potential for over 500 acres of crown fire in that part of the 4FRI treatment area that burned in the Slide Fire. That indicates a decrease in potential crownfire by about 4,000 acres in RU3. Acres with decreased crown fire potential include:

1. High severity effects, where greater than >75% of the dominant overstory vegetation was killed or topkilled (about 800 acres) (Figure **78**). In these areas, crown fire consumed the crowns of trees, and/or surface fire produced sufficient heat to lethally scorch the crowns of trees.

Figure 78. High severity fire effects from the Slide Fire in the area proposed for treatment under the 4FRI.

   a. acres on where there was **active crown fire** usually had 100% consumption of surface fuels, leaving bare, exposed soil. Surface fuel in these areas is unlikely to recover to much more than herbaceous and/or shrubs in the next few years. In particular, where there was Gambel oak or New Mexican locust (*Robinia neomexicana*), shrub height may be several feet in a few years, but would not carry a fire well. In some areas of high burn severity, there may be no vegetation for a few years.

   b. acres on which there was **surface fire** (sometimes interspersed with passive crown fire) that produced sufficient heat to lethally scorch tree crowns, the needles that fall may provide sufficient surface fuels to support surface fire, though it would be low intensity/low severity (short flame lengths), and of a short duration. These fires could ignite some snags or CWD, but the overall effects would be low severity because of a lack of fuel.

2. Acres for which low and/or mixed severity effects include decreased ladder fuels and/or decreased surface fuel loading (approximately 6,500 acres) (Figure 79). In these areas, the fuel consumed decreased the potential fire intensity, which translates into lower flame lengths. That makes it less likely surface fire would transition into crown fire. Where there was low to moderate crown scorch, the increase in canopy base height would further decrease the potential for surface fire to transition into crown fire, and the decrease in canopy bulk density would decrease the potential for active crown fire.

Figure 79. Low severity fire effects from the Slide Fire in the area proposed for treatment under the 4FRI.

About half of the acres with high severity fire effects are in MSO habitat, and did not move towards desired conditions. Dead trees in the areas with high severity are expected to fall in the next 5 – 10 years (Chambers and Mast 2005). Across much of the fire area, particularly the high severity areas, effects of the fire over the next 5 – 10 years will depend largely on environmental conditions, such as precipitation, temperature, and wind. There are about 1,100 acres of treatments being implemented to mitigate second order fire effects (flooding, erosion, debris flows) that include seeding and mulching. The effectiveness of these treatments depends largely on precipitation events immediately after the fire and weather conditions for the first year or two after the fire.

It is safe to assume that all of the area with very low to low severity effects (about 4,700 acres), and about half of the acres with mixed severity effects (~2,300 acres) moved towards desired conditions.

Over the next few years, it is expected that some trees that appear to be dead now may recover, and others will die from insects and additional stressors. The exact configuration of dead/live trees is unknown at this time, though changes to the current severity maps would most likely occur in the areas with mixed severity fire effects.

In SU 3-5, the Slide Fire burned about 7,300 acres, and crown fire potential decreased by a little over 4,000 acres (~70%). In SU 3-4, the Slide Fire burned about 450 acres, and crown fire potential was reduced by about 150 acres (~48%).

Environmental Consequences in the Slide Fire

Slide Fire: Alternative A

Under Alternative A, the 4FRI area burned in the Slide Fire would receive no treatments. In Restoration Unit 3 (Subunits 3-5 and 3-4), the slide fire effects decreased potential for crown fire, so, for the next ~10 years, wildfires burning though areas that had low to moderate severity effects would be expected to be mostly beneficial although, as described above, there is still potential in some areas for high severity fire effects. In areas with high severity effects, fire-killed trees will begin to fall in the next few years. Where fallen trees create 'jackpots' of coarse woody debris or where there is some continuity in CWD at the surface, there is potential for high severity effects soil and vegetation (including regeneration) in the event of a wildfire burning under undesirable conditions.

All action alternatives

All treatments in the burned area would be deferred for at least 5 years to allow some recovery of surface and forest vegetation prior to implementation. Following the 5 year deferral, the area would be re-evaluated by the appropriate resource specialists to determine if proposed treatments are still appropriate.

Slide Fire: Alternatives B, C, and E

Prescribed fire would be implemented as indicated by monitoring results after a 5 year deferral. The use of prescribed fire could mitigate the potential for high burn severities (fire effects to soil) resulting from a heavy dead/down component from trees killed in the Slide Fire falling. In areas with little to no change in canopy fuels, thinning would decrease the potential for crown fire and for high severity fire effects from surface fires.

Slide Fire: Alternative D

In areas where mechanical treatments were proposed, as stated above, after a deferral of at least 5 years, it may be determined that the proposed mechanical treatments are no longer appropriate. In those cases, there would be no treatment, or treatments would be adjusted to fit existing and desired conditions. Where there would be heavy dead/down fuel loads from fire-killed trees falling and increasing surface fuel loading, there would be increased potential for high burn severity from wildfire burning through the area under undesirable burning conditions.

Summary

Under Alternative A, there would be the greatest risk of undesirable fire effects and behavior. Under all action alternatives, the potential for crown fire is decreased significantly because the horizontal and vertical continuity of the canopy fuels is broken up. Under Alternatives B, C, and E, the availability of prescribed fire as a tool across most of the treatment area would increase treatment options for managers as the high severity areas of the Slide Fire recover, and surface fuel loading changes. Alternative D would also decrease potential crown fire, but would not mitigate the increasing potential for high burn severity as fire killed trees fall and add to surface fuel loading, unless there would be no mechanical treatments.

Appendix A: Forest Plan Direction and Consistency of management actions proposed under the 4FRI

Direction from both forest plans in regards to fire and air quality that relate to the 4FRI are included in Table 138 and Table 139, with brief descriptions of how they were addressed. Summaries, by Alternative, are given at the end of this appendix.

Coconino National Forest

Table 138. Coconino NF Forest Plan Direction and 4FRI Consistency.

Level	Program or geographic component		Standards, Guidelines, Desired Conditions, and Objectives	4FRI Evaluation
Forest Wide	Wilderness	p. 22	Protect the current status of air quality related values (AQRV's) in the Sycamore Canyon Wilderness Class I Airshed. Treat other wildernesses in the same manner as Class I Airsheds.	4FRI Is consistent with air quality guidelines, and would comply with all federal and state regulations addressing air quality, including Class I areas (Details in the DRAFT Fire Ecology report, pgs. 99 – 101; DEIS pgs. 167 – 168).
	Soil, Water, and Air Quality	p. 23	Consider air quality during prescribed fires especially Class I areas over wildernesses.	
	Management Direction	Protection p. 25	Use fire as a resource management tool where it can effectively accomplish resource management objectives.	Prescribed fire is proposed as a treatment at some level in all action alternatives as a tool for meeting desired conditions. Under Alternative D, this management direction would not be followed because, although prescribed fire "…can effectively accomplish resource management objectives on over 400,000 acres.
	Fire Management Planning and Analysis pp. 92 - 96	Protection p. 92	Continue fire management analysis and planning for activities such as presuppression, detection, suppression, prevention, and fuel treatment… Prepare fuel treatment plans for projects that generate slash. Coordinate fuel treatment plans with other resources with input provided by other resource specialists. Manage smoke from prescribed fires to meet legal standards and to provide for public safety.	The 4FRI is not proposing 'fuels treatments' on the Coconino NF, but there is an overlap in post-treatment objectives in ponderosa pine between 'restoration' and 'fuel' treatments (Fire Ecology report page 15. Most treatments proposed by the 4FRI would meet some objectives of 'fuel treatments'. Slash would be disposed of in keeping with forest plan direction (see Appendix E in the Fire Ecology report and Appendix C in the DEIS).

				The 4FRI analysis includes extensive input from specialists for all affected resources on both forests. Refer to response in row 1 of this table.
		Fuel Treatment pp. 95 - 96	1. Plan fuel treatments on an area basis. Fuel treatment objectives are met on the area as a whole and not necessarily on each acre. 2. Plan fuel treatments that have the least impact on the site, meet resource management needs, are cost effective, and meet fuel treatment objectives. 3. Snags and downed logs that are necessary to meet wildlife management objectives for the area are identified and fire lined to protect them. They are also monitored during burning to protect them. T&E and sensitive species are also protected by lining and monitoring. 4. Limit the treatment of natural fuels to areas where fuel buildups are a threat to life, property, adjacent to old-growth areas, or specifically identified high resource values. 5. Fuel treatment projects include pretreating fuels to meet specified air quality standards and mop-up to control residual smoke, whenever necessary. Prescriptions for the use of prescribed fire for any purpose include measures to minimize smoke production when projects will impact smoke sensitive areas. Monitor and document the effects on smoke sensitive areas of smoke from prescribed burning during the burning season. The purpose is to prevent smoke intrusions. Adjust the burning program as needed based upon the monitoring. The initial monitoring will be by aerial observation, photography from observation points, and ground observations. Monitoring may be daily or less frequent depending upon the amount of burning and atmospheric conditions. Evaluate potential for smoke intrusions on airports, highways, and roads.	Restoration treatments proposed by the 4FRI would serve as fuel treatments in many cases because of the overlap in effects of some fuel treatments and restoration treatments in ponderosa pine (Fire Ecology p. 15). With that assumption, Forest Plan direction for fuel treatments is addressed based on the overlap (where restoration treatments decrease undesirable fire behavior/ effects). 1. Treatments proposed would leave a mosaic of forest conditions that, across the landscape, are expected to moderate potential fire behavior and effects. 2. Proposed restoration treatments were prioritized based on forest plan direction and public input. 3. Coarse Woody Debris would be managed in accordance with forest plan direction (refer to Appendix E in the Fire Ecology report and Appendix C in the DEIS). 4. The 4FRI is proposing mechanical treatments and prescribed fire across the landscape, with the intensity of the treatment depending on prioritization of resource values. 5. Refer to response in row 1 of this table, as well as Appendix E in the Fire Ecology report and Appendix C in the DEIS. A monitoring plan is being written that would be included in the FEIS, and would include monitoring protocols

			Employ appropriate measures to provide for public safety by keeping smoke off of these types of facilities to the degree possible. Keep smoke warning signs posted on roads. If an intrusion occurs take cooperative action with appropriate law enforcement personnel to provide for public safety. Review and make recommendations to the State on air quality and visibility redesignation proposals in the first decade.	consistent with forest plan direction.
MA 1		p.97	Protect the current status of AQRV's in the Sycamore Canyon Wilderness Class I Airshed. Treat other wildernesses in the same manner as Class I Airsheds. Predict the impacts of air pollution generating activities with current and cost effective modeling techniques. Monitor specific air pollutant and meteorological parameters necessary for determining air quality in Class I areas. In the Class I Airsheds, maintain high quality visual conditions.	The 4FRI is not proposing any treatments in wilderness areas, so the only effects would be as described in Cumulative effects (p. 331 DEIS; p. 172 and 255 Fire Ecology). Potential effects from proposed actions to Wilderness would be from Air Quality impacts from prescribed fire (Fire Ecology Final Draft p. 268), which would not be expected to exceed allowed Federal and State limits.
MA 2		p. 113.	No direction applicable to the 4FRI.	
MA 3	Fire Management, Planning, and Analysis	Protection p.137	Prescribed fire using planned and unplanned ignitions is used to meet resource objectives.	There are more treatments proposed for this MA than any other under the 4FRI. Prescribed fire and mechanical thinning are proposed as treatments at some level in all action alternatives as a tool for meeting desired conditions.
MA 4	Fire Management, Planning, and Analysis	Protection p. 140	Standards and Guidelines for fire management planning and analysis are the same as for MA 3.	Prescribed fire and mechanical thinning are proposed as treatments at some level in all action alternatives as a tool for meeting desired conditions. Many treatments in this MA are for prescribed fire only because of the difficulty of thinning on steep slopes.
MA 5	Fire Management, Planning, and Analysis	Protection p. 144	Prescribed fire using planned and unplanned ignitions is used to meet resource objectives.	Prescribed fire and mechanical treatments are proposed as treatments in all areas of MA5 within the project area in Alternatives B, C, and E, and some in D. Treatments would improve aspen health and viability.
MA 6	Management Emphasis	p. 145	Use prescribed fire as a tool to help meet desired resource objectives	Prescribed fire and mechanical thinning are proposed for treatments at some level in all action alternatives as a tool for meeting desired conditions. Proposed treatments would be expected to expand the decision space for line
	Fire Management, Planning, and	Protection p. 147	Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface.	

	Analysis			officers and fire managers making decisions on the management of unplanned ignitions.
MA 7	Management Emphasis	p. 148	Use prescribed fire to help achieve resource objectives	Prescribed fire is proposed in MA7 and MA8 as 'operational burn only', meaning prescribed fire would be implemented only as a means to implement prescribed fire in adjacent areas of ponderosa, grasslands, or other areas for which there are treatment objectives. Treatments that did occur would be expected to expand the decision space for line officers and fire managers making decisions on the management of unplanned ignitions.
	Fire Management, Planning, and Analysis	Protection p. 155	Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface	
MA 8	Fire Management, Planning, and Analysis	Protection p. 157	Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface.	
MA 9	Fire Management, Planning, and Analysis	Protection p. 161	Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface.	Prescribed fire is proposed as a treatment at some level in all action alternatives as a tool for meeting desired conditions, and restoring grasslands within MA9.
MA 10	Fire Management Planning and Analysis	Protection p. 165	Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface.	Prescribed fire is proposed as a treatment at some level in all action alternatives as a tool for meeting desired conditions, and restoring grasslands within MA10.
MA 11		p. 166	No direction applicable to the 4FRI. References are for managing unplanned ignitions.	
MA 12		p. 177	No direction applicable to the 4FRI. References are for managing unplanned ignitions.	Prescribed fire and mechanical treatments are proposed in all action alternatives as a tool for meeting desired conditions consistent with the Coconino NF Forest Plan.
MA 13		Guideline p. 182	Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except there is no provision for unplanned ignitions in areas included in the urban interface.	Prescribed fire is proposed within MA13 as a treatment at some level in all action alternatives as a tool for meeting desired conditions.
MA 14	Management Emphasis	p. 184	No direction applicable to the 4FRI. References are for managing unplanned ignitions.	There are about 24 acres of treatment, including prescribed fire proposed within this MA, they are within an MSO PAC.
		Objectives p. 184	Use prescribed fire and mechanical methods to achieve fire management goals.	
MA 15	Fire Management, Planning, and Analysis	Protection p. 190	Prescribed fire using planned ignitions is used as a management tool where it is needed to accomplish resource objectives.	Prescribed fire is proposed as a treatment at some level in all action alternatives as a tool for meeting desired conditions.
MA	Fire	Protection	Prescribed fire using planned ignitions is used to accomplish fuel	There are no proposed 4FRI treatments within

16	Management, Planning, and Analysis	p. 192	treatment and other resource objectives.	MA16.
MA 17	Fire Management, Planning, and Analysis	Protection p. 196	Use prescribed fire with planned ignitions as a management tool provided its use is compatible with the management of the specific area.	There are no proposed 4FRI treatments within MA17.
	Management Emphasis	p. 196	Ecosystem processes such as fire and flood play a natural role	
MA 18	Management Emphasis	p. 197 - 198	Since these areas fall within the Urban/Rural Influence Zone, emphasize fuels reduction and other techniques to reduce the risk of catastrophic wildfire. In the Elden ESA implement tree thinning, prescribed fire or other activities that lessen risk of catastrophic wildfire and maintain shrubs, such as Arizona cliffrose, that provide winter food source for deer.	There are no proposed 4FRI treatments within MA18.
	Guideline	Prescribed Fire p. 199	Prescribed fires from planned ignitions are used to accomplish fuel treatment and other resource management objectives.	
MA 19	Management Emphasis	p. 201	Natural and created fuels are treated to manage large fire potential and to protect visual resource and wildlife habitat.	Prescribed fire and mechanical treatments are proposed at some level in all action alternatives as a tool for meeting desired conditions.
	Nonstructural Wildlife Habitat Improvement	p. 202	Use prescribed fire to improve wildlife forage.	There are no proposed 4FRI treatments within MA18.
	Fire Management, Planning, and Analysis	Protection p. 204 - 205	Use prescribed fire with planned and unplanned ignitions is used to meet resource objectives. Prescribed fire using planned ignitions is used as a management tool where such use is compatible with other resources. Fuel treatment projects in natural fuels are aimed at creating and maintaining a natural fuel condition that is maintained through the periodic use of prescribed fire.	
MA 20	Fuel Treatment	p. 207	Slash work may include piling, lop and scatter, pile burning, broadcast burning, chipping and hauling. Prescribed fire using planned ignitions is used as a management tool where such use is compatible with other resources.	Prescribed fire, including pile burning if/where necessary, is proposed as a treatment at some level in all action alternatives as a tool for meeting desired conditions.

The Entire Sedona/ Oak Creek Planning Area	Goals	p. 206	Fire should continue to play a natural ecological role within the constraints of human health and safety. The mosaic of vegetative patterns and conditions reduces the occurrence of catastrophic fires. Expand the use of prescribed fire along with other mechanical methods to achieve area goals. Fire management activities should: • protect resource values, such as property and riparian and scenic elements; • reduce natural and activity-generated fuels to lessen the risk of catastrophic fire; and • restore ecosystem functions. • Protect community values by reducing fire hazard and risk.	Very little of the Sedona/Oak Creek Planning (SOCP) area is within the 4FRI area proposed for treatment, but cumulative effects of 4FRI treatments would have positive effects on the SOCP. Prescribed fire is proposed as a treatment at some level in all action alternatives as a tool for meeting desired conditions. Refer to p. 331 in the DEIS and pg. 255 in the Draft Fire Ecology Specialist's report (Cumulative Effects).
FLEA	Bald Eagles	Guidelines p. 206-73	Prescribed fires to improve and protect roost areas may be used with effective protection of large trees and snags.	Refer to Appendix E in the Fire Ecology report and Appendix C in the DEIS).
	Forestry	Goals and Objectives	Fire should continue to play a natural ecological role within the constraints of human health and safety The risk of and potential for destructive crown wildfire is reduced, especially in the Urban/ Rural Influence Zone (U/RIZ) and the Wildland Urban Interface (1U) as depicted on the Fire Management Analysis Zones map.	Prescribed fires, along with mechanical treatments, would decrease the potential for 'destructive crown wildfire' by restoration treatments that increase resilience of treated areas. Treatments are expected to expand the decision space for line officers making decisions on how to manage unplanned ignitions.
		Guidelines	Reduce crown canopy and ladder fuels where needed to reduce risk of stand replacing crown fires.	See above.
	Watershed	Goals and Objectives	Natural vegetative and fuels composition area restored so as to reduce susceptibility to large-scale watershed disturbances, such as large catastrophic wildfire.	See above.
		Guidelines	Implement actions to restore a natural vegetative and fuels composition, and ensure that soil condition objectives are met on a landscape scale to reduce susceptibility of large-scale watershed disturbances, such as a large catastrophic fire or insect/disease outbreak.	DEIS p. 9 "The purpose of the project is to reestablish and restore forest structure and pattern, forest health, and vegetation composition and diversity…""
MA 31	Management Emphasis	p. 206-84	As stated in Management Area 10, of the Forest Plan, maintain and improve grasslands, including removing encroaching pinyon/juniper and re-introducing fire.	PJ in MAs31 and 32 that is being proposed for treatment is 'operational burn only'. Prescribed fire is proposed in grasslands in MA31 that would maintain and improve grassland condition.
MA 32	Management Emphasis	p. 206-88	As stated in Management Area 10, maintain and improve grasslands, including removing encroaching pinyon/juniper and re-introducing fire.	
MA	Management	p. 206-91	Most of this MA is within the Urban/Rural Influence Zone. Reduce the	Restoration treatments proposed by the 4FRI in

33	Emphasis		risk of catastrophic wildfire, especially within the Urban/Rural Influence Zone. Reintroduce fire's natural role as much as possible. This MA is a high priority for efforts to reduce the risk of catastrophic fire especially in the ponderosa pine lands.	MA33 would have the effect of decreasing the potential for undesirable fire behavior and effects.
MA 34	Management Emphasis	p. 206-95	As long as these lands remain in National Forest ownership, within the Urban/Rural Influence Zone (entire MA), reduce the risk of catastrophic wildfire…	Restoration treatments proposed by the 4FRI in MA34 would have the effect of decreasing the potential for undesirable fire behavior and effects.
MA 35	Management Emphasis	p. 206-98	The northwestern portion of this MA is within the Urban/Rural Influence Zone. Reduce the risk of catastrophic wildfire, especially within the Urban/Rural Influence Zone. In the entire MA, re-introduce fire's natural role as much as possible, and ponderosa pine lands progress towards desired forest structure, including northern goshawk and Mexican spotted owl habitats.	Prescribed fires, along with mechanical treatments proposed for MA35, would restore structure to forests, decreasing the potential for 'destructive crown wildfire.' Treatments would be expected to expand the decision space for line officers making decisions on how to manage unplanned ignitions. Northern goshawk and Mexican spotted owl habitat would be improved by the proposed treatments. Eagle roosts, osprey nests, snags, yellow pines, oaks and rare plant habitat would be at a lower risk of uncharacteristically severe fire effects if proposed treatments are implemented.
	Fire Management	p.206 - 101	Per the FLEA Area-wide direction, reduce potential for catastrophic wildfire within the Urban/Rural Influence Zone. Because of prevailing winds, lands south and west of the Urban/Rural Influence Zone should be evaluated for wildfire risks and appropriate measures taken to reduce potential for catastrophic fire. Take steps to minimize wildfire losses to key wildlife habitat components such as eagle roosts, osprey nests, snags, yellow pines, oaks and rare plant habitat.	
MA 36	Management Emphasis p.	206-103	A small portion of this MA is within the Urban/ Rural Influence Zone. Reduce the risk of catastrophic wildfire, especially within the Urban/Rural Influence Zone. Reintroduce fire's natural role as much as possible.	Restoration treatments proposed by the 4FRI in MA34 would have the effect of decreasing the potential for undesirable fire behavior and effects.
	Fire Management	p. 206-105	Per the FLEA Area-wide direction, reduce potential for catastrophic wildfire within the Urban/Rural Influence Zone. Because of prevailing winds and steep terrain, lands north and east of the Urban/Rural Influence Zone should be evaluated for wildfire risks and appropriate measures taken to reduce potential for catastrophic fire.	
MA 37	Management Emphasis	Walnut Canyon p.206-108	Reduce the risk of catastrophic wildfire, especially within the Urban/Rural Influence Zone. Reintroduce fire's natural role as much as possible. Reduce the risk of catastrophic fire especially in the Urban/Rural Influence Zone. There is concern for wildfire losses to the National Monument from fires starting southwest of the park. Balance the need to reduce wildfire risk in these areas with desired conditions for Primitive	Restoration treatments proposed within MA37 include both mechanical treatments and prescribed fire. These treatments would increase the resiliency of the treated areas to natural disturbances, and decrease the potential for uncharacteristic fire effects and behavior. Appendix C in the DEIS describes Design

			and Semi-primitive ROS settings and disturbance sensitive species habitat. Reference FLEA area-wide direction and other the Forest Plan management direction related to vegetation and fire management.	Features, Best Management Practices, and Mitigations that would be implemented.
MA 38	Management Emphasis	p. 206-113	More than half of this MA is within the Urban/ Rural Influence Zone. Within the Urban/ Rural Influence Zone, and along the Highway 89A corridor, reduce the risk of catastrophic wildfire… In the remainder of the MA, re-introduce fire's natural role as much as possible, progress towards desired conditions described (MSO and goshawk guidelines), restore meadows, and promote healthy pine/oak forests. The portions of this MA that lie southwest of developed lands are high priority for fire risk reduction efforts. This includes the Urban/Rural Influence Zone and the Wildland Urban Interface as depicted on the Fire Management Analysis Zones map.	Prescribed fires, along with mechanical treatments, would decrease the potential for 'destructive crown wildfire' by restoration treatments that increase resilience of treated areas. Treatments are expected to expand the decision space for line officers making decisions on how to manage unplanned ignitions.
	Fire Management p. 206-116		Per the FLEA Area-wide direction, reduce potential for catastrophic wildfire within the Urban/Rural Influence zone. Because of prevailing winds and steep terrain, lands south and west of the Urban/Rural Influence zone should be evaluated for wildfire risks and appropriate measures taken to reduce potential for catastrophic fire. Continue partnerships with city, county, and State fire departments to coordinate fire hazard reduction treatments, prevention, and suppression.	
Forest wide	Monitoring (table 14)		Ensure prescribed fire does not cause violations of State and Federal air quality standards in sensitive areas.	4FRI would comply with all federal and state regulations addressing air quality, including Class I areas (Details in the DRAFT Fire Ecology report, pgs. 99 – 101; DEIS pgs. 167 – 168).

Revised Kaibab National Forest Land Management Plan (2014) Forest-wide Direction

Chapter 1. Introduction (pg. 3)

Summary of the Analysis of the Management Situation

The Comprehensive Evaluation Report (CER/Analysis of the Management Situation (AMS)) and subsequent management reviews considered this information along with the Forest Service mission, Forest role and contributions, and anticipated demands. They identified four areas where there were priority needs for change in program direction. These are to:

- Modify forest structure and species composition to restore or maintain sustainability and restore historic fire regimes.

- Protect and regenerate aspen to ensure long-term healthy aspen populations.
- Protect and restore natural waters and wetlands to ensure healthy riparian communities.
- Restore grasslands by reducing tree encroachment and restoring fire.

The most apparent need for change is to reduce the risk of uncharacteristic fires and restore the structure, species composition, and function of forested ecosystems. This emerged as the highest need for change in the ecological sustainability report and as a very high need in the socio-economic sustainability analysis. The concordant socioeconomic and ecological benefits of restoring forest structure include providing quality wildlife habitat, improving scenic integrity, providing for commercial and personal use wood products, protecting cultural resources, protecting against undesired fire effects, improving public and firefighter safety, increasing understory diversity, and improving soil condition.

Restoring aspen also emerged as a high priority. Aspen is an important species because of its contribution to local ecological diversity and its high social and economic value associated with scenery and tourism. Aspen has declined in areas across the West due to the combined effects of ungulate browsing, insects, disease, severe weather events, and lack of fire disturbance.

Plan Concepts (pgs. 7-8)

Potential natural vegetation is the vegetation that would occur in the presence of natural disturbance processes such as frequent fire return intervals. In some areas, there is a difference between the existing vegetation type and the potential vegetation type, such as where historic grasslands are currently encroached by trees. The potential natural vegetation, not the existing vegetation, determines which desired conditions apply.

Natural variability references past conditions and processes that provide important context and guidance relevant to the environments and habitats in which native species evolved. Disturbance driven spatial and temporal variability is vital to ecological systems. Biologically appropriate disturbances provide for heterogeneous conditions and subsequent diversity. Conversely, "uncharacteristic disturbance" such as high-intensity fire in plant communities that historically had a frequent low intensity fire regime can have the effect of reducing diversity, increasing homogeneity, and resulting in states that may be permanently altered.

Ranges of values presented in desired conditions reflect either natural or desired variation in the composition and structure within a community or resource area. Desired conditions may or may not be the same as historic conditions and may have wide ranges due to spatial variability in soils, elevation, aspect, or social values. Where desired conditions specify a range of values, the full spectrum of values within that range is desirable, although the desirable distribution of values within that range may vary depending on the resource. It may also be desirable to manage for desired conditions at the upper or lower end of a range in a particular area, such as lower vegetation density in the wildland-urban interface (WUI) to achieve the desired fire behavior within proximity of private property and human occupancy. Higher densities may be desired in other areas to meet habitat requirements for specific species.

Table 139. Kaibab NF Plan direction and 4FRI consistency.

Kaibab Forest Plan	4FRI

Chapter 2. Forestwide Desired Conditions and Strategies (pgs. 11-18)	***Forest Resources***	***Major Vegetation Community Types*** The mapped boundaries of the vegetation communities are based on of the potential natural vegetation type	**Pinyon-juniper Communities (pgs. 11 – 15)** Much of the pinyon-juniper vegetation communities are currently denser than they were historically because of changes in wildfire occurrence. Greater tree density has increased competition for water and nutrients. This, in turn, has caused a reduction in understory plant cover and diversity, a loss of ground cover, and subsequent increases in soil erosion. **<u>Desired Conditions Common to All Pinyon-juniper Communities</u>** The composition, structure, and function of vegetative conditions are resilient to the frequency, extent, and severity of disturbances (e.g. insects, diseases, and fire) and climate variability. Management Approach for Pinyon-juniper Communities Following stand replacing fire in pinyon-juniper shrublands and pinyon-juniper woodlands, the return to woodland stand structure can take many decades.	With the exception of ~535 acres adjacent to the town of Tusayan in RU6, the only treatments that would be implemented in PJ are 'Operational Burns', in which PJ is burned only to facilitate prescribed fire in adjacent areas for which there are specific resource objectives. On the 535 acres, the objectives are specific to fuels reduction, and direction would relate to DCs in WUI.
			Ponderosa Pine Forests (pgs. 16 – 20) Lack of fire disturbance has led to increased tree density and fuel loads that heighten the risk of uncharacteristically intense wildfire and drought-related mortality. When fires occur under current (2014) conditions, they tend to kill a lot of trees, including the large and old trees. These trees take longer to replace, moving the Kaibab NF further from desired conditions, and increasing the time it would take to return to desired conditions. Fine-scale (10 acres or less) Desired Conditions for Ponderosa Pine Fires generally burn as surface fires, but single-tree torching and isolated group torching is not uncommon. **Mid-scale (100 to 1,000 acres) Desired Conditions for Ponderosa Pine** Fires burn primarily on the forest floor and typically do not spread between tree groups as crown fire. **Landscape-scale (over 10,000 acres) Desired Conditions for Ponderosa Pine** The landscape is a functioning ecosystem that contains all components, processes, and conditions associated with endemic levels of disturbances (e.g., fire, dwarf mistletoe, insects, diseases, lightning, drought, and wind). Forest vegetation conditions are resilient to the frequency, extent, and severity of disturbances and climate variability. Grasses and needle cast provide the fine flashy fuels needed to maintain the natural fire regime. Fire and other disturbances are sufficient to maintain desired overall tree density, structure, species composition, coarse woody debris loads, and nutrient cycling.	Desired conditions in the ponderosa pine relating to fire behavior/effects are for there to be less than 10% crown fire under modeled conditions at landscape scale, mid-scale (RU), and small scale (SU). This aligns well with the DCs in the KNF Forest Plan for ponderosa pine. (DEIS p. 24, Fire Ecology Report p. 28 4FRI restoration treatments are intended to restore the composition, pattern, and structure of ponderosa pine and the associated systems (grasslands, aspen, pine/oak), with the assumption that ecological function would be restored in the process. (DEIS p. 9). This includes the expected response of surface vegetation to more open canopies and low

		The risk of uncharacteristic high-severity fire and associated loss of key ecosystem components is low. Frequent, low-severity fires (Fire Regime I) occur across the entire landscape with a return interval of 0 to 35 years. **Objectives for Ponderosa Pine:** To make progress toward the desired conditions and reduce the potential for active crown fire in ponderosa pine communities at a rate that would maintain the desired conditions over time: Mechanically thin 11,000 to 19,000 acres annually. Treat an average of 13,000 to 55,000 acres annually, using a combination of prescribed fire and naturally ignited wildfires (acres of lightning caused wildfire counted toward this objective are only those that make progress towards or maintain desired conditions). Management Approach for Ponderosa Pine Projects in ponderosa pine are aimed at restoring forest structure and process (e.g. natural disturbances such as low-severity fire and dwarf mistletoe, watershed function, and nutrient cycling). Treatments typically strive to mimic the structure and patterns of reference conditions using historical evidences and soil characteristics. However, treatments may consider other circumstances, desired conditions, and objectives, such as species specific habitat needs. As a result, reconstructed reference conditions are general guides rather than rigid restoration prescriptions. In ponderosa pine, reintroducing fire as a disturbance agent is critical to restoration. Fire-only treatments may be appropriate for some areas with open canopies and low fuel loads, but mechanical fuel reduction is needed in many areas before fire can be safely reintroduced. Fire management needs to maintain an appropriate balance between smoke impacts and public concerns (health, visibility, etc.). Treatments to promote oak regeneration and establishment are fairly effective, because oak sprouts prolifically after release treatments. Oaks may be cut or burned to stimulate new growth, maintain growth in large-diameter trees, or to stimulate mast production.	severity surface fire. The associated change in fuel structure would support low-severity fire, and the frequency proposed for prescribed fire would all meet the DCs described for ponderosa pine in the KNF Forest Plan. Alternative D is an exception, with no prescribed fire proposed on 384,966 acres where there would be mechanical treatments. This would not meet DCs for ponderosa pine on the Kaibab National Forest. Acres of mechanical or prescribed fire treatment on any given area in the 4FRI would vary from year to year, but will certainly contribute towards the KNF objectives for ponderosa pine. Refer to answer above, specifically the 4FRI purpose and need on p. 9 of the DEIS. Aligns well with 4FRI, refer to pp. 39 – 50 in the Fire Ecology report, and pp. 96 – 25 in the DEIS.
		Aspen (pgs.27 – 29) **<u>Desired Conditions for Aspen (General)</u>** Aspen stands are characterized by disturbances that may include fire, mechanical treatments, insects, pathogens, and abiotic factors. Collectively, these agents of change promote healthy tree	Aspen are specifically target in the 4FRI for treatments that would promote healthy aspen clones, including mechanical treatments to remove encroaching conifers that are too

		regeneration, decadence, and nutrient cycling. These processes further contribute to high quality wildlife habitat and biodiversity. Fire intervals are similar to reference conditions and maintain aspen. **Desired Conditions for Aspen in Ponderosa Pine and Frequent Fire Mixed Conifer** In ponderosa pine and frequent fire mixed conifer vegetation types, the size, age, and spatial extent of aspen stands reflect reference conditions. **Guidelines for Aspen Management** Small patch clear-cuts (less than 5 acres in size), conifer removal, and wildland fire should be used to stimulate aspen sprouting in areas that have or previously had aspen.	big to be killed with prescribed fire, and prescribed fire. 4FRI proposed one prescribed fire over the life of the NEPA document, except for Alternative D which would implement either prescribed fire or mechanical treatments, never both.
		Guidelines for Vegetation Management in All Forested Communities The location and layout of vegetation management activities should effectively disconnect large expanses of continuous predicted active crown fire. Vegetation management prescriptions should provide for sufficient canopy breaks to limit crown fire spread between groups, allow for the redevelopment and maintenance of a robust understory, and mimic the spatial arrangement of the reference conditions.	4FRI treatments would result in a 'groupier' arrangement of ponderosa pine, with non-forested openings between them. The result would be expected to sometimes allow groups to torch (under extreme conditions), but then drop to the ground as surface fire between groups. (See Silvicultural Report; McCusker and Gonzalez 2214).
		Grassland Communities (pgs. 35 – 38) **Desired Conditions for Colorado Plateau/Great Basin Grasslands** Vegetation height and canopy cover are sufficient to carry fire under low wind conditions to support a 10 to 30 year fire return interval.	Alternatives C and E would provide both prescribed fire and mechanical treatments on almost 50,000 acres of grasslands. Alternative C would implement prescribed fire on almost 60,000 acres of grasslands, while Alternatives B and D would implement prescribed fire on a little over 11,000 acres.
	Air Quality (pgs. 54	The areas of particular concern for nuisance smoke from wildland fire on the Kaibab NF are the Sedona/Verde Valley, Flagstaff, Williams, Parks, Tusayan, Grand Canyon National Park, and Sycamore Canyon Wilderness.	4FRI will comply with all federal and state regulations addressing air quality. Details can be found in the DRAFT

		Temporary decreases in air quality from management activities on the Kaibab NF are primarily from prescribed fires. Wildfires originating on the Kaibab NF also produce emissions. Smoke and visibility impairment from wildland fire that closely mimics what would occur naturally is generally acceptable. Prescribed fires are implemented when ventilation conditions are favorable to reduce the concentration of emissions, and other emission-reduction techniques are used when feasible. They generally produce far fewer emissions than the uncharacteristic severe wildfires they are designed to deter because they burn primarily surface fuels, and not the forest canopy. Over time, as fire reentry occurs, the reduced fuel load results in lower emissions per acre. **Desired Conditions for Air Quality** • Air quality meets or surpasses State and Federal ambient air quality standards. • Management activities on the Kaibab NF do not adversely impact Class I airshed visibility as established in the Clean Air Act. **Guidelines for Air Quality** • Project design for prescribed fires and strategies for managing wildfires should incorporate as many emission reduction techniques as feasible, subject to economic, technical, safety criteria, and land management objectives. • Decision documents, which define the objectives and document line officer approval of the strategies chosen for wildfires, should identify smoke sensitive receptors, and identify appropriate objectives and courses of action to minimize and mitigate impacts to those receptors. **Management Approach for Air Quality** Public tolerance for nuisance smoke, rather than law, regulation, or policy, effectively sets the social limit to the number of acres that can be treated with wildland fire. Community public relations and education, coupled with preburn notification, greatly improve public acceptance of fire management activities. In order to maintain public support for prescribed burns and the use of wildfires to accomplish resource benefits, it is important that land managers be responsive to the public's tolerance thresholds to balance ecological benefits with social and economic values. The public will tolerate several days of nuisance smoke in a row, and up to several weeks total a year, but even the most supportive have tolerance limits. Public acceptance of smoke varies greatly from year-to-year. Acceptance of smoke from prescribed fires and wildfires is high following seasons with high profile, high-severity events, and during extremely dry years when the threat of large, high-severity incidents is elevated. Conversely, acceptance wanes during wetter years when the threat of uncharacteristic fires is low.	Final Fire Ecology report, pgs. 86 – 101 and Appendix E; DEIS pgs. 167 – 168 and Appendix C).

	Livestock Grazing	**<u>Guidelines for Livestock Grazing</u>** Post-fire grazing should not be authorized until Forest Service range staff confirm range readiness.	Refer to DRAFT Final Fire Ecology report Appendix E; DEIS Appendix C).
	Forestry and Forest Products (pgs. 70 – 72)	**<u>Management Approach for Forestry and Forest Products</u>** On lands classified as suitable for timber production, mechanical tree removal and prescribed fire are needed to effectively make progress toward the desired conditions and are intended to retain characteristics of desired conditions for at least 20 years.	Prescribed fire is proposed for 586,111 acres under Alternatives C and E, and for 583,333 acres under Alternative B. Alternative D would not align with this management approach because of the lack of prescribed fire on 384,966 acres.

		Most of the Kaibab NF's vegetation is adapted to recurring wildfires started by lightning from spring and summer thunderstorms. Frequent, low-intensity fire plays a vital role in maintaining ecosystem health of much of the pinyon-juniper, ponderosa pine, and frequent fire mixed conifer vegetation types. These three vegetation types cover over 80 percent of the Kaibab NF. Grasslands are also adapted to frequent fire. Other vegetation types, such as pinyon-juniper-sagebrush, mesic mixed conifer, and spruce-fir, are also fire dependent, but have a historic fire regime of less frequent, mixed-severity fires. Today, the Kaibab NF contains uncharacteristically dense forests with many more young trees than were present historically. Ponderosa pine, spruce, fir, juniper, and pinyon seedlings have invaded forest openings, grasslands, and savannahs. The forest and woodlands are deficient in grasses, forbs, and shrubs due to tree competition, and are at high risk for insect and disease outbreaks. With the denser more continuous canopy cover and accumulated live and dead woody material, the probability and occurrence of large, uncharacteristic, stand-replacing fires continues to increase. These fires burn with more intensity, have higher tree and seed mortality, degrade watersheds, change soil chemistry, structure, nutrient availability, kill seeds,, and threaten homes and communities. Entry with fire during appropriate weather and fuel moisture conditions is the most cost-effective way to reduce the likelihood of a high-severity fire. A single fire entry, with low to moderate fire behavior, reduces high-severity fire potential for 5 to 10 years in ponderosa pine and frequent fire mixed conifer and other vegetation communities in Fire Regime 1. With repeated fire entry within the historic fire frequency interval, the risk of a high-severity fire could be kept to a minimum indefinitely, except for a few days per year when fire danger indices are at their peak. To achieve a forest that is resilient to fire disturbance even during dry and windy conditions, forest structure needs to be more in line with desired conditions. In addition to treatment with fire, activities such as thinning and tree harvesting are needed to reduce tree density and canopy cover and promote the natural fire regime. Strategic placement and design more efficiently protects values at risk, given the limited resources and capacity to implement activities across the landscape. **Desired Conditions for Wildland Fire Management** • Wildland fire maintains and enhances resources and, as nearly as possible, is allowed to function in its natural ecological role. • Regular fire entry protects social, economic, and ecological values at risk from high-severity disturbance effects. • Wildland fires burn within the range of intensity and frequency of the historic fire regime of the vegetation community. Uncharacteristic high-severity fires rarely occur, and do not burn at the landscape scale. **Management Approach for Wildland Fire Management** Objectives for wildland fires may be developed based on fuel conditions, current and expected weather, current and expected fire behavior, topography, resource availability, and values at risk.	Prescribed fire is proposed for 586,111 acres under Alternatives C and E, and for 583,333 acres under Alternative B, including maintenance burning. Alternative D would not align with this management approach because of the lack of prescribed fire on 384,966 acres. Desired conditions under 4FRI in the ponderosa pine relating to fire behavior/effects are for there to be less than 10% crown fire under modeled conditions at landscape scale, mid-scale (RU), and small scale (SU). This aligns well with the DCs in the KNF Forest Plan for ponderosa pine. (DEIS p. 24, Fire Ecology Report p. 28 4FRI restoration treatments are intended to restore the composition, pattern, and structure of ponderosa pine and the associated systems (grasslands, aspen, pine/oak), with the assumption that ecological function will be restored in the process. (DEIS p. 9). This includes the expected response of surface vegetation to more open canopies and low severity surface fire. The associated change in fuel structure would support low-severity fire, and the frequency proposed for prescribed fire would all meet the DCs described for ponderosa pine in the KNF Forest Plan.

Chapter 3. Management Areas (pgs. 85 – 108)	***Existing Wilderness on the Kaibab NF (pgs. 94 – 96)***	**Desired Conditions for Wilderness Areas** Natural processes are maintained within wilderness. Fires function in their natural ecological role.	The 4FRI is not proposing any treatments in wilderness areas, so the only effects would be as described in Cumulative effects (p. 331 DEIS; p. 255 Fire Ecology). Potential effects from proposed actions to Wilderness would be from Air Quality impacts from prescribed fire (Fire Ecology Final Draft p. 268), which would not be expected to exceed allowed Federal and State limits.
	Wildland-urban Interface Areas (pgs. 96 – 98)	For the purposes of this plan, the WUI area is refined to a buffer around WUI values to focus more intensive treatments where they will have the most impact for fire protection, and includes the following lands: • Half-mile buffer around all private lands. • Half-mile buffer around administrative sites, fee use cabins, fire lookouts, developed campgrounds, day use picnic areas, and facilities managed under special use permits. • Half-mile buffer around at-risk communication sites. **Desired conditions for WUI Areas** • Wildland fires in the WUI do not result in the loss of life, property, or characteristic ecosystem function. • Wildland fires in the WUI are low intensity surface fires. Firefighters are able to safely and efficiently suppress wildfires in the WUI using direct attack. • The desired tree basal area in the WUI is on the lower end of the range given in the vegetation community desired conditions. • Openings with grass/forb/shrub vegetation occupy the mid to upper end of the percentage range in the desired conditions. Trees within groups may be more widely spaced with less interlocking of the crowns than desirable in adjacent forest lands. • Logs and snags, which often pose fire control problems, are present in the WUI, but at the lower end of the range given in the vegetation community desired conditions. • Higher fuel loading or tree densities may be desired in areas where it provides for important fine scale habitat structure, as long as it meets the overall intent of protecting WUI values at risk. • Ladder fuels are nearly absent. • Dead and down fuel load is between 1 and 5 tons per acre. This light fuel load is desirable even	The 4FRI is using this definition for treatments proposed on the KNF. 4FRI has only ~535 acres of treatment that is specifically Fuels Reduction, and for which decreasing potential fire behavior is a specific objective. Across the rest of the treatment area, fire behavior is expected to decrease as a result of restoration treatments. Treatments would move treated areas towards desired conditions of <10% crown fire (affecting control and fire effects) and average surface fuel loading generally less than

		in vegetation types with higher reference fuel loads, such as mesic mixed conifer, to provide improved fire protection to human developments deemed to have special significance. • When WUI intersects vegetation types with a mixed or high-severity fire regime, characteristic ecosystem function is modified to promote low intensity surface fires. • Openings between tree groups are of sufficient size to discourage isolated group torching from spreading as a crown fire to other groups. **Management Approach for WUI Areas** Firefighters need more open stands, with few ladder fuels and low fuel loadings, where wildfires drop to the surface before they reach the values at risk. Treatments in the WUI area are designed to provide a zone where firefighters can safely perform direct attack on wildfires. The more open stand conditions also serve to protect NFS lands from human-caused fires started on private lands because firefighters can more readily contain a wildfire before it burns into denser, more flammable vegetation in the Kaibab NF at large. While fire protection is the key objective in this area, other resource objectives are also met, and the integrity of the ecosystem is maintained. Treatments are guided by the same Forestwide desired conditions for resources, goods, and services as outside the zone, but lands within the WUI area are managed to achieve the more open end of the desired conditions for the vegetation community. A half-mile buffer around human developments is the starting point for determining where more open, intensive treatments occur. This distance is recommended in the HFRA (2003) and provides a distance conducive for passive crown fire to transition to surface fire. During project-specific planning, the area where more intensive treatments are needed may call for adjustment. Continuous steep slopes, continuous heavy fuels, or other fire hazards may indicate a need to expand more open treatments. On the other hand, sound reasons for retaining more dense stands may exist. For example, in the case of a habitat for a narrow endemic species, less intensive treatment, no treatment, or moving the buffer area to the outside or around the more densely stocked area may be necessary. All private lands, regardless of whether they contain human improvements or the type of improvements they contain, are treated as WUI. In doing so, making subjective value judgments on different structures is avoided. It also accounts for the potential that any given private inholding could be developed during the lifespan of the plan. Due to variable budgets, market capacity, and workforce capacity, achieving desirable structural	the recommended 20 tons/acre (control and effects). Treatments in WUI are not specifically “designed to provide a zone where firefighters can safely perform direct attack on wildfires.” However, there would be more open stand conditions following treatments which will improve conditions for initial engagement of wildfire.

		changes through planned mechanical treatments is sometimes delayed or occurs sporadically. Projects that include lands in the WUI should allow flexibility in the order of treatment implementation. This allows fire managers the option to burn before mechanical treatments, greatly reducing fire hazard in the WUI area in the interim until mechanical treatments take place. Including maintenance burning in project design is essential to securing the investment made with mechanical thinning and initial entry burns. Without maintenance burning, the fire protection value from treatments is largely lost within 40 to 50 years because of increased fuel loads and more densely stocked stands.	
Appendix A. Proposed and Possible Actions	***Fire and Fuels Management***	• Use prescribed fire and wildfire on 14,000 to 68,000 acres per year (in all vegetation types except desert communities) to reduce fuel loadings, restore forest structure, promote understory vegetation, improve nutrient cycling, etc. • Burn activity generated slash. • Thin and treat fuels in the wildland-urban interface and around other highly valued human improvements to prevent loss in the event of a wildfire, and thin to improve control lines for prescribed burns.	Refer to answers above.

Summaries of forest plan consistency by alternative

Consistency with revised Kaibab NF Land and Resource Management Plan

Alternatives B and C

Management actions proposed under Alternatives B and C would meet direction in the Revised Kaibab National Forest Land and Resource Management Plan. Under the new plan, there is direction to change program direction in four areas, two of which explicitly state restoring fire to the ecosystems. Additionally it states:

> "The most apparent need for change is to reduce the risk of uncharacteristic fires and restore the structure, species composition, and function of forested ecosystems. This emerged as the highest need for change in the ecological sustainability report and as a very high need in the socio-economic sustainability analysis." (Page 3 KNF 2014 LRMP)

Additionally, there is direction to restore aspen and 'natural waters, wetlands, and riparian areas. Actions proposed under this alternative would include aspen restoration in aspen where it occurs within the ponderosa pine, and spring and stream restoration is included.

Previous (USDA 1988) forest plan direction was for Coarse Woody Debris (CWD) to be within 5 – 7 tons per acre. The new forest plan allows for 3 – 10 tons per acre (revised KNF forest plan, pages 18 and 128). This analysis classifies CWD post-treatment conditions treatments by intensity without consideration of which forest a given acre is on. For example, if a table shows that 10% of the ponderosa pine treated at a 'high' intensity would average 3-5 or 7-10 tons per acre, those acres could be within desired conditions for the Kaibab NF, but not for the Coconino NF.

Additionally, the revised KNF forest plan specifies desired conditions for the Wildland Urban Interface (WUI) which fall on the more open end of desired conditions for ponderosa pine (KNF 2014 LRMP page 97), and allow for treatments to follow applicable forest plan guidance for CWD. Desired conditions for 'dead and down fuel load' are between 1 and 5 tons per acre. It does not specify any particular size, or type (woody, herbaceous, needle litter, etc.) of fuel comprising the fuel load. Additionally, page 98 of the revised KNF forest plan states, "…sound reasons for retaining more dense stands may exist", so there is flexibility built in for habitat needs in the WUI. The proposed actions in Alternatives B and C would move treated areas towards desired conditions as defined in the revised LRMP for the Kaibab NF.

Alternative D

Management actions proposed under Alternative D would not meet direction in the Revised Kaibab National Forest Land and Resource Management Plan for 384,966 acres on which there would be mechanical treatments. Under the new plan, there is also direction to change program direction in four areas, two of which explicitly state restoring fire to the ecosystems. Additionally it states:

> "The most apparent need for change is to reduce the risk of uncharacteristic fires and restore the structure, species composition, and function of forested ecosystems. This emerged as the highest need for change in the ecological sustainability report and as a very high need in the socio-economic sustainability analysis." (Page 3 KNF 2014 LRMP)

There is also specific direction to restore aspen and ‘natural waters, wetlands, and riparian areas. Actions proposed under this alternative would include aspen restoration in aspen where it occurs within the ponderosa pine, and spring and stream restoration is included.

Previous (USDA 1988) forest plan direction was for Coarse Woody Debris (CWD) to be within 5 – 7 tons per acre. The new forest plan allows for 3 – 10 tons per acre (revised KNF forest plan, pages 18 and 128). This analysis classifies CWD post-treatment conditions treatments by intensity without consideration of which forest a given acre is on. For example, if a table shows that 10% of the ponderosa pine treated at a ‘high’ intensity would average 3-5 or 7-10 tons per acre, those acres could be within desired conditions for the Kaibab NF, but not for the Coconino NF.

Additionally, the revised KNF forest plan specifies desired conditions for the Wildland Urban Interface (WUI) which fall on the more open end of desired conditions for ponderosa pine (KNF 2014 LRMP page 97), and allow for treatments to follow applicable forest plan guidance for CWD. Desired conditions for ‘dead and down fuel load’ are between 1 and 5 tons per acre. It does not specify any particular size, or type (woody, herbaceous, needle litter, etc.) of fuel comprising the fuel load. Additionally, page 98 of the revised KNF forest plan states, “…sound reasons for retaining more dense stands may exist”, so there is flexibility built in for habitat needs in the WUI. The proposed actions in Alternative D would move treated areas towards desired conditions as defined in the revised LRMP for the Kaibab NF.

The proposed actions in Alternative D would move 384,966 acres *towards* desired conditions as defined in the revised LRMP for the Kaibab NF. However, on 384,966 acres, Alternative D would not meet forest plan direction to reintroduce fire and restore historic fire regimes.

Alternative E

Management actions proposed under Alternative E would meet direction in the Revised Kaibab National Forest Land and Resource Management Plan. Under the new plan, there is direction to change program direction in four areas, two of which explicitly state restoring fire to the ecosystems. Additionally it states:

> “The most apparent need for change is to reduce the risk of uncharacteristic fires and restore the structure, species composition, and function of forested ecosystems. This emerged as the highest need for change in the ecological sustainability report and as a very high need in the socio-economic sustainability analysis.” (Page 3 KNF 2014 LRMP)

Additionally, there is direction to restore aspen and ‘natural waters, wetlands, and riparian areas. Actions proposed under this alternative would include aspen restoration in aspen where it occurs within the ponderosa pine, and spring and stream restoration is included.

The earlier forest plan direction was for Coarse Woody Debris (CWD) to be within 5 – 7 tons per acre. The new forest plan allows for 3 – 10 tons per acre (revised KNF forest plan, pages 18 and 128). This analysis classifies CWD post-treatment conditions treatments by intensity without consideration of which forest a given acre is on. For example, if a table shows that 10% of the ponderosa pine treated at a ‘high’ intensity would average 3-5 or 7-10 tons per acre, those acres could be within desired conditions for the Kaibab NF, but not for the Coconino NF.

Additionally, the revised KNF forest plan specifies desired conditions for the Wildland Urban Interface (WUI) which fall on the more open end of desired conditions for ponderosa pine

(KNF 2014 LRMP page 97), and allow for treatments to follow applicable forest plan guidance for CWD. Desired conditions for ‘dead and down fuel load’ are between 1 and 5 tons per acre. It does not specify any particular size, or type (woody, herbaceous, needle litter, etc.) of fuel comprising the fuel load. Additionally, page 98 of the revised KNF forest plan states, “…sound reasons for retaining more dense stands may exist”, so there is flexibility built in for habitat needs in the WUI. The proposed actions in Alternative E would move treated areas towards desired conditions as defined in the revised LRMP for the Kaibab NF.

Consistency with Coconino NF Land and Resource Management Plan

The Mission of the Coconino NF, as stated in the forest plan includes:

> “The mission of the Forest is to manage National Forest lands and resources using the best systems available to meet the needs and desires of present and future generations, while protecting and enhancing the environment and effectively and efficiently administering Forest programs…”

The actions proposed under the 4FRI represent what may be the most effective and efficient method of restoring FS lands to date. Management direction throughout the plan specifies the use of prescribed fire and/or thinning be used to meet resource objectives. The 4FRI proposes to use thinning and prescribed fire to restore the pattern, composition, and structure to grasslands, ponderosa pine and pine/oak, and aspen.

In ponderosa pine, the forest plan specifies “leave at least 2 snags per acre, 3 downed logs per acre, and 5 – 7 tons of woody debris per acre.” This analysis classifies CWD post-treatment conditions treatments by intensity without consideration of which forest a given acre is on. For example, if a table shows that 10% of the ponderosa pine treated at a ‘high’ intensity would average 3-5 or 7-10 tons per acre, those acres could be within desired conditions for the Kaibab NF, but not for the Coconino NF.

Alternatives B, and C

Management actions proposed under Alternatives B, and C would meet direction in the Coconino National Forest Land and Resource Management Plan. Under this forest plan, there is direction to use prescribed fire as a management tool across much of the forest. Alternative B proposed to use prescribed fire on 583,330 acres, and Alternative C proposed to use prescribed fire on 586,111 acres.

Virtually all areas considered ‘Urban Interface’ are prioritized under the current forest plan. It is phrased differently in different management areas, but the intent is clear in each: to decrease the potential for undesirable fire behavior and effects (though it may be phrased ‘catastrophic fire’, or ‘fire risk’, or ‘stand replacing’). Because of the overlap between restoration and fuels treatments outcomes in ponderosa pine, the treatments proposed by the 4FRI would comply with forest plan direction for ‘urban interface’ areas where restoration treatments are proposed.

Alternative D

Management actions proposed under Alternative D would meet direction in the Coconino National Forest Land and Resource Management Plan for some areas of the forest, but not for all. Under this forest plan, there is direction to use prescribed fire as a management tool across much of the forest. Alternative D proposes mechanical treatments without prescribed fire for 384,966 acres, and prescribed fire is proposed for 175,441 acres.

Virtually all areas considered ‘Urban Interface’ are prioritized under the current forest plan and, although it is phrased differently in different management area, the intent is clearly stated in each to decrease the potential for undesirable fire behavior and effects (though it may be phrased ‘catastrophic fire’, or ‘fire risk’, or ‘stand replacing’). Under Alternative D, surface fuel loading increases on most acres, affecting potential emissions, fire intensity, and fire severity.

Alternative E

Management actions proposed under Alternative E would meet direction in the Coconino National Forest Land and Resource Management Plan. Under this forest plan, there is direction to use prescribed fire as a management tool across much of the forest. Under Alternative E, there are 586,111 acres proposed for prescribed fire.

Virtually all areas considered ‘Urban Interface’ are prioritized under the current forest plan. It is phrased differently in different management areas, but the intent is clear in each: to decrease the potential for undesirable fire behavior and effects (though it may be phrased ‘catastrophic fire’, or ‘fire risk’, or ‘stand replacing’). Because of the overlap between restoration and fuels treatments outcomes in ponderosa pine, the treatments proposed by the 4FRI would comply with forest plan direction for ‘urban interface’ areas where restoration treatments are proposed.

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Appendix C: Glossary

Active crown fire: a fire in which a solid flame develops in the crowns of trees, but the surface and crown phases advance as a linked unit dependent on each other.

Adaptive Management: a type of planning and implementation that incorporates the results of prior actions, new scientific findings, and changing societal needs into constantly evolving conservation goals and practices. This management style requires monitoring of baseline ecological data as well as the results of ongoing activities and the solicitation of public needs. Under adaptive management, plans and activities are treated as working hypotheses rather than final solutions to complex problems. The process generally includes four phases: planning, implementation, monitoring, and evaluation. The level of success of this process is dependent upon the participation of critical stakeholders.

Biomass: multiple definitions include: organic matter produced by plants and other photosynthetic organisms; total dry weight of all living organisms that can be supported at each level of a food chain or web; dry weight of all organic matter in plants and animals in an ecosystem; plant materials and animal wastes that functions as fuel for fire.

Burn: an effect produced by heating. To undergo combustion, consuming fuel and giving off light, heat and gasses. Also, an area where fire has occurred in the past.

Canopy Base Height (CBH): The lowest height above the ground at which there is a sufficient amount of canopy fuel to propagate fire vertically into the canopy (Scott and Reinhardt 2001). Canopy base height is a value that describes ‘ladder fuels’, such as understory trees, the lower branches of mature trees, or shrubs and/or herbaceous vegetation sufficient to produce a fire of high enough intensity to initiate crown fire (Figure 107). The lower the canopy base height, the easier is for crown fire to initiate (Van Wagner 1977), because shorter flame lengths may be sufficient to ignite the canopy. Continuity of canopy base height across a forest or a stand is not necessary to initiate crown fire, technically, a single ladder fuel is sufficient.

Canopy Bulk Density (CBD): The mass of available canopy fuel per unit volume. It is a bulk property of a stand of trees, not individual trees (Scott and Reinhardt 2001). The greater (higher) the canopy bulk density is, the harder it is to see the sky though the canopy when you’re looking up through it. The higher the canopy bulk density, the more easily fire can move through the crowns of trees, and the more fuel there is to burn, influencing fire intensity as well, so that greater flame lengths and radiant heat are more likely to carry fire though the canopy.

Canopy Cover: as used in modeling fire, is the horizontal fraction of the ground that is covered directly overhead by tree canopy, the percent of vertically projected canopy cover in the stand (Scott and Reinhardt 2005).

Condition Class (reference **FRCC**): A measure of departure from reference conditions that can be used to determine how ‘at risk’ key ecosystem components are in the event of a disturbance event, such as fire.

Conditional crown fire: a crown fire that is dependent on ladder fuels in adjacent stands in order for fire to access the crowns. In an area with conditional crown fire, ladder fuels are insufficient in a stand for crown fire to initiate, but canopy fuels are sufficient to support crown fire if it moves in from an adjacent stand.

Controlled burn: synonymous with Prescribed Fire.

Crown fire: a fire that advances from top to top of trees or shrubs more or less independent of a surface fire. Crown fires are sometimes classed as independent, conditional, or dependent (active or passive) to distinguish the degree of independence from the surface fire. Crown fires are common in coniferous forests and chaparral shrublands.

Disturbance: any relatively discrete event or series of events—either natural or human-induced—that causes a change in the existing condition of an ecosystem, community, or population structure and alters the physical environment.

Disturbance Regime: a set of recurring conditions due to a variety of disturbances (e.g., fire, flooding, insect outbreak) and their interaction, which characterize an ecosystem within a historic, natural or human induced context, within a given climate. This set of recurring conditions includes a specific range for each of the attributes of these disturbances. These attributes include: frequency, rotation period, intensity, severity, seasonality, patch size and distribution, residual structure, causal agent, the relative influence of each causal agent and how they interact. The attributes researchers choose to represent a regime will vary depending on a researcher's area of interest (Skinner and Chang 1996). An accurate description of a disturbance regime must include the full range of disturbance events, including those that are rare.

Drought: periods of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, there may be a shortage of precipitation during the growing season resulting in crop damage (agricultural drought), or during the winter runoff and percolation season affecting water supplies (hydrological drought).

Duff: the fermentation and humus layer lying below the litter layer and above mineral soil; consisting of partially decomposed organic matter whose origins can still be visually determined, as well as the fully decomposed humus layer. This layer does not include the freshly cast material in the litter layer, nor in the post-burn environment, ash (Brown 2000). The top of the duff is where needles, leaves, fruits and other castoff vegetative material have noticeably begun to decompose. Individual particles usually are bound by fungal mycelia. The bottom of the duff is mineral soil. There is a gradient, not a clear division between litter and duff.

Ecological Process: events or combinations of events (including ecological disturbances and perturbations) that occur in natural environments within a range of conditions and cause a range of dynamic effects on the structure, composition, and functioning of ecosystems

Ecosystem: a biotic community and its surroundings, part inorganic (abiotic) and part organic (biotic).

Erosion: the wearing away of the land surface by rain or irrigation water, wind, ice, or other natural or anthropogenic agents that abrade, detach and remove geologic parent material or soil from one point on the earth's surface and deposit it elsewhere.

FRCC: see Fire Regime/Condition Class

Fire: rapid oxidation, usually with the evolution of heat and light; heat fuel, oxygen and interaction of the three. We generally recognize two basic kinds of fire: structure fires and wildland fires.

Fire Adapted Ecosystem: an associated group of plant and animals that have made long term genetic changes in response to the presence of fire in their environment.

Fire Ecology: the study of fire's interaction with ecosystems.

Fireline Intensity: rate of heat release in the flaming front. A quantitative measure of fire behavior that is a measure of the fire itself (not it's effects). Indicators include flame length, flame height, peak temperatures, energy output/time, scorch height (as in indicator of flame height).

Fire Regime: a set of recurring fire conditions that characterize an ecosystem, within a historic, natural or human induced context, within a given climate. This set of recurring conditions includes a specific range of attributes: Sugihara et al. (2006) uses the following attributes: seasonality, frequency (fire return interval), intensity, severity, size, spatial complexity, and fire type. An accurate description of a fire regime will include the full range of fire events, including those that are rare and connect to the larger disturbance regime which contains the fire regime as a subset.

Fire Return Interval: the number of years between two successive fires in a designated area (i.e., the interval between two successive fires); the size of the area must be clearly specified (McPherson and others 1990).

Fire Regime/Condition Class (**FRCC**): an ecological evaluation protocol that uses three classes for describing the relative degree of departure from historical disturbance regimes, particularly fire.

Fire Severity A qualitative evaluation of immediate post-fire effects produced by the heat pulse on the biotic an abiotic components of an ecosystem. Indicators include the amount of biomass consumed, changes in the amount of mineral soil exposed, soil color, topkilled surface vegetation.

Fire Type: flaming front patterns that are characteristic of a fire.

First Order Fire Effects: effects resulting directly from the fire, such as fuel consumption and smoke production.

Flame Length: the length of flames in the propagating fire front measured along the slant of the flame from the midpoint of its base to its tip.

Fuel Continuity: a qualitative description of the distribution of fuel, both horizontally and vertically. Continuous fuel supports fire spread better than discontinuous fuel. See Fuel.

Fuel L**o**ad: weight of fuel per unit area. See Fuel.

Fuel: living and dead vegetation that can be ignited.

Fuel Type: an identifiable association of fuel elements of distinctive species, form, size, arrangement, or other characteristics that will cause a predictable rate of spread, or resistance to control under specified weather conditions.

Ground fire: fire that burns in the organic material below the litter layer, mostly by smoldering combustion. Fires in duff, peat, dead moss and lichens, and partly decomposed wood are typically ground fires.

Habitat: place where an animal or plant normally lives, often characterized by a dominant plant form or physical characteristic. Often described for individual species, e.g., spotted owl habitat, it is usually used as a generalization of where an animal may live.

Hazard: A fuel complex, defined by volume, type, condition, arrangement, and location that determines the degree of ease of ignition and the resistance to control. The state of the fuel, exclusive of weather or the environs in which the fuel is found (NWCG 2003, Hardy 2005).

Historic Range of Variation (HRV): refers to ecosystem composition, structure, and process for a specified area and time period. Historic range of variation (HRV) is often used to determine our best estimate of "natural" conditions and functions, and thus is often our best estimate of the natural range of variation (NRV). Ecosystems change over time. It is assumed that native species have adapted over thousands of years to natural change and that change outside of NRV may affect composition and distribution of species and their persistence.

Invasive: any species which can establish, persist, and spread in an area, and be detrimental or destructive to native ecosystems, habitats, or species and difficult to control or eradicate.

Ladder Fuel: fuel, such as branches, shrubs or an understory layer of trees, which allow a fire to spread from the ground to the canopy.

Landscape Pattern: the term for the contents and internal order of a diverse area of land. These include the number, frequency, size, and juxtaposition of landscape elements, such as corridors and patches, which are important to determine or interpret ecological processes.

Land Resource Management Plan (**LRMP**)**:** a document prepared with public participation and approved by an agency administrator that provides general guidance and direction for land and resource management activities for an administrative area. The L/RMP identifies the need for fire's role in a particular area and for a specific benefit. The objectives in the L/RMP provide the basis for the development of fire management objectives and the fire management program in the designated area.

Litter: the top layer of the forest, shrubland or grassland floor above the duff layer, including freshly fallen leaves, needles, bark, flakes, fruits (e.g., acorns, cones), cone scales, dead matted grass, and a variety of accumulated dead organic matter which is unaltered, or only slightly decomposed. This layer typically does not include twigs and larger stems. One rough measure to distinguish litter from duff is that you can pick up a piece of litter and tell what it was (a leaf or leaf part, a needle, etc.). Duff is generally not identifiable. There is a gradient, not a clear division between litter and duff.

Monitoring: a systematic process of collecting and storing data related to natural systems at specific locations and times. Determining a system's status at various points in time yields information on trends, which is crucial in detecting changes in systems.

Mosaic: the spatial arrangement of habitat where there is stand heterogeneity - measured at many spatial scales from the patch, the stand, and the vegetative community.

National Environmental Policy Act (NEPA): the environmental law passed by the U. S. Congress in 1969 that requires the preparation of specific environmental documentation for major undertakings using federal funds. Public involvement is an integral component of this process.

Native: a species which is an indigenous (originating where it is found) member of a biotic community. The term implies that humans were not involved in the dispersal or colonization of the species.

Objective: a defensible target or specific component of a goal, whose achievement represents measurable progress toward a goal. Thus an objective needs to be a clear, measurable and attainable refinement of a goal, which you intend to achieve within a stated time-period. Objectives need to be concise statements of what we want to achieve, how much we want to achieve, when and where we want to achieve them, and who is responsible for the work. Objectives provide the basis for determining strategies, monitoring accomplishments, and evaluating success. Goals usually have more than one objective.

PAC: Protected activity center for the Mexican Spotted Owl (habitat type)

PFA: Post-fledgling Family Areas for Goshawks (habitat type)

Passive crown fire: a fire in the crowns of the trees in which trees or groups of trees torch, ignited by the passing front of the fire. The torching trees reinforce the spread rate, but these fires are not basically different from surface fires.

Percentile weather: For a given weather parameter (such as temperature, wind speed, relative humidity, precipitation, etc.,) the percent of days in a year that fall below it. For example, if the 90th percentile temperature for a given location is 90°F, it means that for 90% of days in a year, the temperature is lower than 90°F.

Pile burning: Activity fuels, once piled by machine or by hand, are burned in place.

Planned Ignition: the intentional initiation of a wildland fire by hand-held, mechanical or aerial device where the distance and timing between ignition lines or points and the sequence of igniting them is determined by environmental conditions (weather, fuel, topography), firing technique, and other factors which influence fire behavior and fire effects (see prescribed fire).

Prescribed Fire: is a wildland fire originating from a planned ignition to meet specific objectives identified in a written, approved, prescribed fire plan for which NEPA requirements (where applicable) have been met prior to ignition (see planned ignition).

Protection: the actions taken to limit the adverse environmental, social, political, and economical effects of fire.

Reference Condition: a range of conditions (found in the present or the past) against which the effects of past and future actions can be compared. These states can provide an explicit, historically-based context for comparing different management effects. Examples include periods before fire suppression or the arrival of an invasive species, or a similar but "healthier" modern ecosystem. Ideally these environmental conditions are based on functioning ecosystems where natural ecosystem structure, composition, and function are operating with limited human intervention (very minor human-caused ecological effects).

Residence Time: time required for the flaming front of a fire to pass a stationary point at the surface of the fuel. The length of time the flaming front occupies one point; relates to downward heating and fire effects below the surface.

Resilience: the ability of an ecosystem to maintain the desired condition of diversity, integrity, and ecological processes following disturbance. The ability of a system to absorb or recover from disturbance and change, while maintaining its functions and services.

Response to wildland fire - the mobilization of the necessary services and responders to a fire based on ecological, social, and legal consequences, the circumstances under which a fire occurs, and the likely consequences on firefighter and public safety and welfare, natural and cultural resources, and values to be protected.

Risk: In the context of technical risk assessments, the term "risk" considers not only the probability of an event, but also includes values and expected losses. Within wildland fire, 'risk' refers only to the probability of ignition (both man- and lightning-caused) (Hardy 2005).

Seasonality: the timing of a fire during the year or the period/ of the year during which fires are likely to start and spread—seasonal component of a fire regime.

Second Order Fire Effects: the secondary effects of fire such as tree regeneration, plant succession, and changes in site productivity. Although second order fire effects are dependent, in part, on first order fire effects, they also involve interaction with many other non-fire variables, e.g. weather.

Seed Bank: the community of viable seeds present in the soil.

Seral Stage: a transitory or developmental stage of a biotic community in an ecological succession (does not include structural seral stage).

Severity: the quality or state of distress inflicted by a force. The degree of environmental change caused by a disturbance, e.g. Fire.

Soil Heating: an increase in soil temperature as a result of heat transfer from the combustion of surface fuel and smoldering combustion of organic soil horizons. Because of the variability of fuel consumption, soil heating is typically variable across landscapes. In many cases, the highest soil temperatures are associated with high fuel consumption and/or complete duff consumption. Under these circumstances, the duration and intensity of burning are affected.

Soil Texture: description of soil composition based on of sand, silt, and clay.

Stakeholder: any individual, group, or institution that has a vested interest (financial, cultural, value-based, or other) in the conservation, management and use of a resource and/or might be affected by management activities and have something to gain or lose if conditions change or stay the same. Stakeholders are all those who need to be considered in achieving project goals and whose participation and support are crucial to its success. Stakeholders can be internal (work for the management unit) or external.

Succession: the sequential change in vegetation and the animals and plants associated with it, either in response to an environmental change or induced by the intrinsic properties of the organisms themselves.

Suppression: all the work of extinguishing a fire or confining fire spread.

Surface Fire: a fire that burns over the forest floor, consuming litter, killing aboveground parts of herbaceous plants and shrubs, and typically scorching the bases and crowns of trees. See Backing Fire, Crown Fire, Fire, Flanking Fire, Ground Fire, Head Fire and Understory Fire.

Surface Fuel: fuels lying on or near the surface of the ground, consisting of leaf and needle litter, dead branch material, downed logs, bark, tree cones, and low stature living plants. See Duff, Fuel, Large Woody Debris and Litter.

Sustainability: the condition of maintaining ecological integrity and basic human needs over human generations.

Temporal: a characteristic that refers to the time at which a given data set was acquired; relating to measured time.

Threatened Species: any species of plant or animal likely to become endangered—within the foreseeable future—throughout all or a significant portion of its range. See Endangered Species.

Top Kill: for individual plants, when some portion of the aboveground portion of an individual is killed, by any cause.

Topography: the physical features of a geographic area, such as those represented on a map, taken collectively—especially, the relief and contours of the land.

Torching: see Passive crown fire.

Type Conversion: changing one vegetative type to another. Generally thought of as a rapid conversion from one type to a completely different type but can also occur subtly over time. This is different than successional trajectory where vegetation follows expected changes in type over time. An example is converting an area that would naturally contain mixed conifer hardwood forest to a pure conifer forest by removing hardwoods and planting only conifers. Another example could be suppressing frequent fires allowing conifers to shade out hardwoods converting mixed conifer hardwood forests to conifer forests.

Unplanned Ignition: the initiation of a wildland fire by lightning, volcanoes, unauthorized and accidental human-caused fires (see wildfire).

VCC: Vegetative Condition Class – quantifies the amount that current vegetation has departed from a simulated historical vegetation reference condition. Three classes describe condition; VCC1 indicates a low departure, VCC2 indicates moderate departure, and VCC3 indicates high departure.

VSS class: Classification of trees by size using DBH and Height as the primary criteria (see Silvicultural report for details (details in the Silviculture report).

Weather: the specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate is the average of weather over time and space. A simple way of remembering the difference is that climate is what you expect (e. g. Cold winters) and ‘weather' is what you get (e.g. a blizzard).

Wildfire: unplanned ignition of a wildland fire (such as a fire caused by lightning, volcanoes, unauthorized and accidental human-caused fires) and escaped prescribed fires. (See unplanned ignition and escaped prescribed fire).

Wildland Fire: a general term describing any non-structure fire that occurs in the wildland. Wildland Urban Interface (WUI) – The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetation fuels.

Woody Debris: the dead and downed material on the forest floor consisting of fallen tree trunks and branches.

Appendix D: Models and processes used in fire modeling

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.

Forest Vegetative Simulator/Fire Fuels Extension (FVS/FFE) Model

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 and Fuels Extension

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 effects for 2020 and 2050.

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

In the context of this analysis, Farsite was only used to edit the .lcp files used in FlamMap.

FireFamilyPlus (FF+)

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 Schultz 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.

Fire Regime Condition Class (FRCC)

A Fire Return Interval (FRI) of 8 years was used as the reference FRI. A reference severity of 10 was used, meaning that, most of the time, fires would produce up to 10% high severity. The numbers used to indicate severity were based on modeled acres of crown fire, but are a little higher to account for acres that could produce high severity surface fire. These conditions were compared with modeled conditions from 2020 and 2050 for each alternative. Seral stages were cross-walked to VSS classes bases on:

VSS1 – Class A: post-replacement; Grass-oak-shrub; stands post-replacement from crown fire or reburn

VSS2 – Class B: mid-development closed, >30% canopy cover of sapling and pole pine

VSS 3C - Class C: mid-open, <30% canopy cover of sapling and pole pine; oak or grass understory

VSS 4A/B - Class D: late-open; <30% ponderosa pine dominated canopy; oak or grass understory

VSS 5/6A/B - Class E: late-closed; >30% canopy cover ponderosa pine

VSS 5/6C - Class U: Uncharacteristic vegetation. In this case, it represented a minimal number of acres that would be dominated by non-native surface vegetation to the degree that it would be difficult, if possible, for native vegetation to be restored on its own. Numbers came from consultation with the COF NF weeds program manager.

Current severity in ponderosa pine was estimated at 40%, assuming the 37% that was modeled as crown fire would all be high severity, and there would be additional acres that would burn with high severity from high intensity surface fire that would lethally scorch canopies without crowning.

Figure 80 applies to all alternatives for all years. It shows the classifications that were used to represent the biophysical land units for the Fire Regime/Condition Class (FRCC) analysis.

Fire Regime Condition Class
Landscape Report - Code Summary

Stratum Biophysical Land Unit(BpS)

PPIN5 Ponderosa Pine (Colorado Plateau)

Lifeforms

CF Coniferous upland forest -- Pine, spruce, hemlock

Landform

NMF Nonglaciated Mountain

Average Slope

MOD Moderate (11-30 degrees)

Reference Composition Source

D coarse-scale default values from lit. review/modeling workshops

Current Composition Source

R walk through and visual estimate

Insolation Class

Upper Layer Majority Lifeform

HERB Herbaceous (graminoids, forbs and ferns

CONT Coniferous Trees

Species

PIPO Pinus ponderosa (ponderosa pine)

QUGA Quercus gambelii (Gambel oak)

MUMO Muhlenbergia montana (mountain muhly)

FEAR2 Festuca arizonica (Arizona fescue)

Size

SEED Seedling - Trees that are less than 4.5 feet (1.37 meters) tall.

POLE Pole - Trees that are greater than 5 in (13 cm) DBH and less than ...

LARG Large - Trees that are greater than 21 in (53 cm) DBH and less th ...

Figure 80 shows a summary of stratum biophysical code used for all alternatives, all years.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata Landscape Code: 4FRIpin Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	72	100	72
Sum		100	72

Landscape Departure: 72

Landscape FRCC: 3 (67-100%)

Legend
- Vegetation Departure
- Regime Departure
- Stratum Departure
- Landscape Departure
- No Departure *

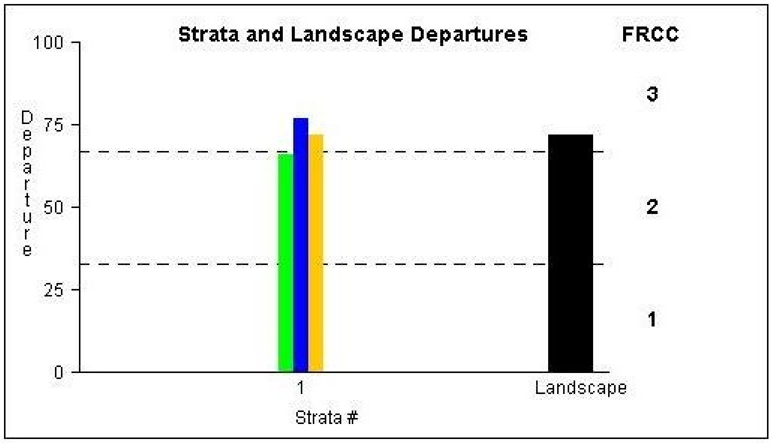

Figure 81. FRCC summary for Existing Condition.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata Landscape Code: 4FRIpin Characterization Date: 02/06/2014

Stratum Num: 1 Biophysical Setting: PPIN5 Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100 BpS Lifeform: CF Landform: NMF Avg Slope Class: MOD Insol Class:

Stratum Area: 507839 Acres Species: Low Elevation: High Elevation:

Reference Frequency: 8 Current Frequency: 40 Latitude: 34.75 Longitude: 111.375 Datum: WGS84

Reference Severity: 10 Current Severity: 38 Reference Composition Source: D Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	1	5078	1	-80	TRACE	1	0	-20313
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	58	294546	5	91	ABUNDANT	3	91	269154
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	25	126959	15	40	OVER REP	2	40	50783
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	5	25391	5	-92	TRACE	1	0	-304703
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	8	40627	8	-20	SIMILAR	1	0	-10156
U	CONT						0	3	15235	0	100	ABUNDANT	3	100	15235
						Total	100	100		34					

Stratum Vegetation Departure: 66 Stratum Fire Frequency Departure: 80 Stratum Regime Departure: 77

Stratum Vegetation Condition Class: 2 Stratum Fire Severity Departure: 74 Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed Stratum Departure: 72 Stratum Fire Regime Condition Class: 3

Figure 82. Stratum Data for Existing Condition.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata Landscape Code: 4FRIpin Characterization Date: 02/06/2014

Stratum Num: 1 Biophysical Setting: PPIN5 Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100 BpS Lifeform: CF Landform: NMF Avg Slope Class: MOD Insol Class:

Stratum Area: 507839 Acres Species: Low Elevation: High Elevation:

Reference Frequency: 8 Current Frequency: 80 Latitude: 34.75 Longitude: 111.375 Datum: WGS84

Reference Severity: 10 Current Severity: 45 Reference Composition Source: M Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	0	0	0	-100	TRACE	1	0	-25391
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	61	309781	5	92	ABUNDANT	3	92	284389
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	23	116802	15	35	OVER REP	2	35	40627
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	1	5078	1	-98	TRACE	1	0	-325016
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	10	50783	10	0	SIMILAR	1	0	0
U	CONT						0	5	25391	0	100	ABUNDANT	3	100	25391
						Total	100	100		31					

Stratum Vegetation Departure: 69 Stratum Fire Frequency Departure: 90 Stratum Regime Departure: 84

Stratum Vegetation Condition Class: 3 Stratum Fire Severity Departure: 78 Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed Stratum Departure: 77 Stratum Fire Regime Condition Class: 3

Figure 83. Stratum data for Alternative A, 2020.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata Landscape Code: 4FRIpin Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	77	100	77
Sum		100	77

Landscape Departure: 77
Landscape FRCC: 3 (67-100%)

Legend	
Vegetation Departure	green
Regime Departure	blue
Stratum Departure	yellow
Landscape Departure	black
No Departure	*

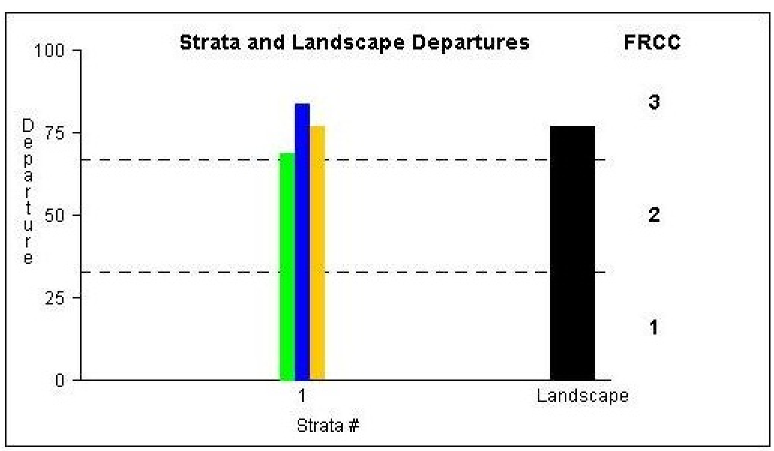

Figure 84. FRCC summary for Alternative A, 2020.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata | Landscape Code: 4FRIpin | Characterization Date: 02/06/2014

Stratum Num: 1 | Biophysical Setting: PPIN5 | Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100 | BpS Lifeform: CF | Landform: NMF | Avg Slope Class: MOD | Insol Class:

Stratum Area: 507839 Acres | Species: | Low Elevation: | High Elevation:

Reference Frequency: 8 | Current Frequency: 160 | Latitude: 34.75 | Longitude: 111.375 | Datum: WGS84

Reference Severity: 10 | Current Severity: 60 | Reference Composition Source: M | Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Upper Layer Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	0	0	0	-100	TRACE	1	0	-25391
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	60	304703	5	92	ABUNDANT	3	92	279311
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	1	5078	1	-93	TRACE	1	0	-71097
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	0	0	0	-100	TRACE	1	0	-330095
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	32	162508	10	69	OVER REP	2	69	111724
U	CONT						0	7	35548	0	100	ABUNDANT	3	100	35548
						Total	100	100		16					

Stratum Vegetation Departure: 84 | Stratum Fire Frequency Departure: 95 | Stratum Regime Departure: 89

Stratum Vegetation Condition Class: 3 | Stratum Fire Severity Departure: 83 | Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed | Stratum Departure: 87 | Stratum Fire Regime Condition Class: 3

Figure 85. Stratum data for Alternative A, 2050.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata | Landscape Code: 4FRIpin | Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	87	100	87
Sum		100	87

Landscape Departure: 87

Landscape FRCC: 3 (67-100%)

Legend
- Vegetation Departure
- Regime Departure
- Stratum Departure
- Landscape Departure
- No Departure *

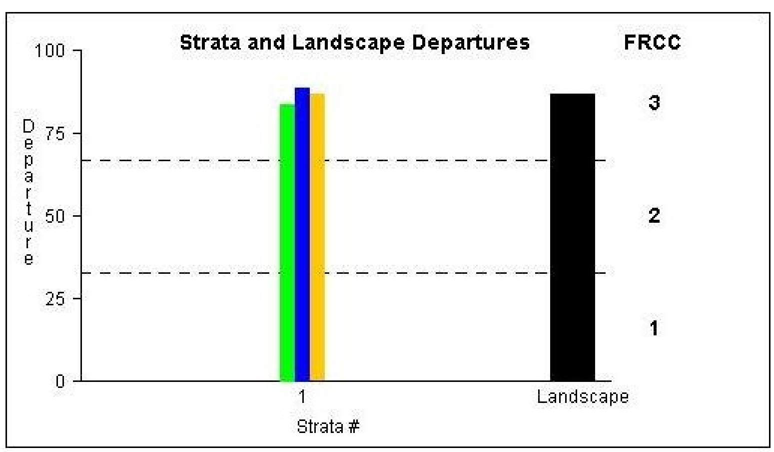

Figure 86. FRCC Summary for Alternative A, 2050.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata   Landscape Code: 4FRIpin   Characterization Date: 02/06/2014

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100   BpS Lifeform: CF   Landform: NMF   Avg Slope Class: MOD   Insol Class:

Stratum Area: 507839 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 8   Current Frequency: 10   Latitude: 34.75   Longitude: 111.375   Datum: WGS84

Reference Severity: 10   Current Severity: 6   Reference Composition Source: M   Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	7	35548	5	29	OVER REP	2	29	10156
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	25	126959	5	80	OVER REP	2	80	101567
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	27	137116	15	44	OVER REP	2	44	60940
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	26	132038	26	-60	UNDER REP	1	0	-198057
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	11	55862	10	9	OVER REP	2	9	5078
U	CONT						0	4	20313	0	100	ABUNDANT	3	100	20313
						Total	100	100		61					

Stratum Vegetation Departure: 39   Stratum Fire Frequency Departure: 20   Stratum Regime Departure: 30

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 40   Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 35   Stratum Fire Regime Condition Class: 2

Figure 87. Stratum data for Alternative B, 2020.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata   Landscape Code: 4FRIpin   Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	35	100	35
Sum		100	35

Landscape Departure: 35

Landscape FRCC: 2 (34-66%)

Legend
- Vegetation Departure
- Regime Departure
- Stratum Departure
- Landscape Departure
- No Departure *

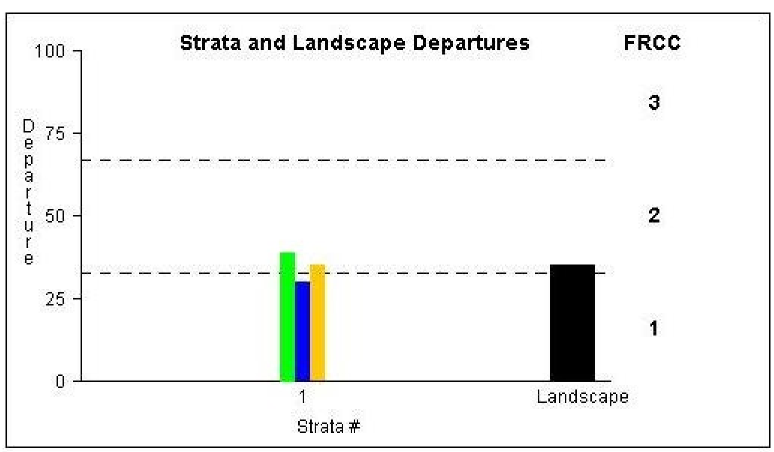

Figure 88. FRCC summary for Alternative B, 2020.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata | Landscape Code: 4FRIpin | Characterization Date: 02/06/2014

Stratum Num: 1 Biophysical Setting: PPIN5 | Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100 | BpS Lifeform: CF | Landform: NMF | Avg Slope Class: MOD | Insol Class:

Stratum Area: 507839 Acres | Species: | Low Elevation: | High Elevation:

Reference Frequency: 8 Current Frequency: 20 | Latitude: 34.75 | Longitude: 111.375 | Datum: WGS84

Reference Severity: 10 Current Severity: 22 | Reference Composition Source: M | Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Upper Layer Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	1	5078	1	-80	TRACE	1	0	-20313
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	31	157430	5	84	ABUNDANT	3	84	132038
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	9	45705	9	-40	UNDER REP	1	0	-30470
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	5	25391	5	-92	TRACE	1	0	-304703
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	49	248841	10	80	OVER REP	2	80	198057
U	CONT						0	5	25391	0	100	ABUNDANT	3	100	25391
						Total	100	100		30					

Stratum Vegetation Departure: 70 | Stratum Fire Frequency Departure: 60 | Stratum Regime Departure: 57

Stratum Vegetation Condition Class: 3 | Stratum Fire Severity Departure: 55 | Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed | Stratum Departure: 64 | Stratum Fire Regime Condition Class: 2

Figure 89. Stratum data for Alternative B, 2050.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata | Landscape Code: 4FRIpin | Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	64	100	64
Sum		100	64

Landscape Departure: 64
Landscape FRCC: 2 (34-66%)

Legend	
Vegetation Departure	green
Regime Departure	blue
Stratum Departure	yellow
Landscape Departure	black
No Departure	*

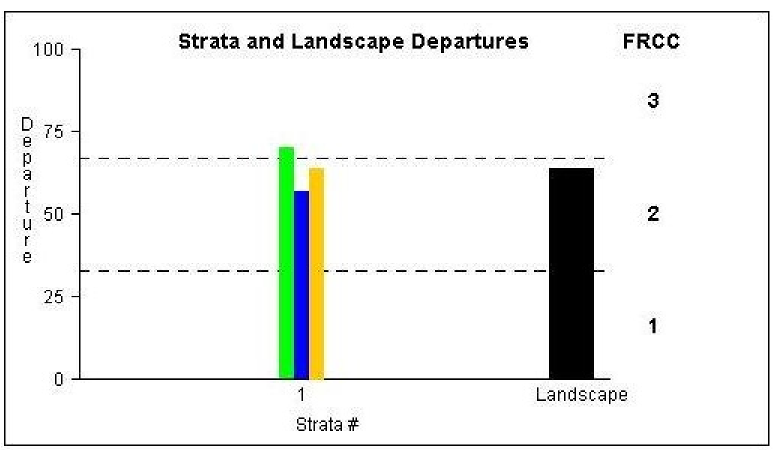

Figure 90. FRCC summary for Alternative B, 2050.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata   Landscape Code: 4FRIpin   Characterization Date: 02/06/2014

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100   BpS Lifeform: CF   Landform: NMF   Avg Slope Class: MOD   Insol Class:

Stratum Area: 507839 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 8   Current Frequency: 10   Latitude: 34.75   Longitude: 111.375   Datum: WGS84

Reference Severity: 10   Current Severity: 6   Reference Composition Source: M   Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Upper Layer Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	7	35548	5	29	OVER REP	2	29	10156
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	25	126959	5	80	OVER REP	2	80	101567
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	26	132038	15	42	OVER REP	2	42	55862
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	27	137116	27	-58	UNDER REP	1	0	-192978
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	11	55862	10	9	OVER REP	2	9	5078
U	CONT						0	4	20313	0	100	ABUNDANT	3	100	20313
						Total	100	100		62					

Stratum Vegetation Departure: 38   Stratum Fire Frequency Departure: 20   Stratum Regime Departure: 30

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 40   Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 34   Stratum Fire Regime Condition Class: 2

Figure 91. Stratum data for Alternative C, 2020.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata   Landscape Code: 4FRIpin   Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	34	100	34
Sum		100	34

Landscape Departure: 34
Landscape FRCC: 2 (34-66%)

Legend	
Vegetation Departure	green
Regime Departure	blue
Stratum Departure	yellow
Landscape Departure	black
No Departure	*

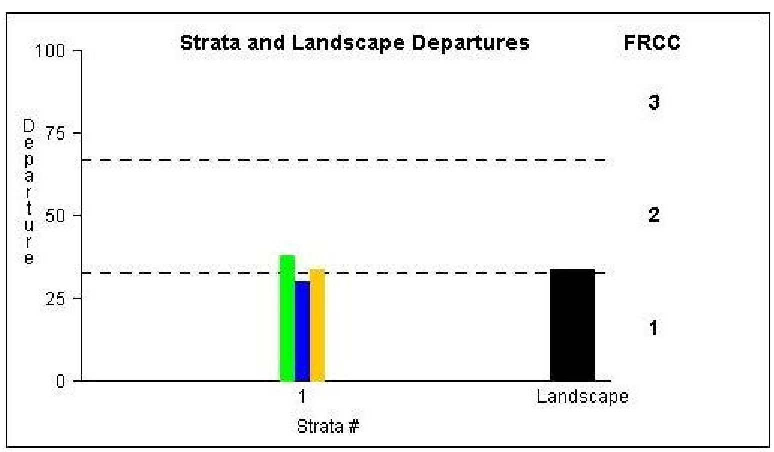

Figure 92. FRCC summary for Alternative C, 2020.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata   Landscape Code: 4FRIpin   Characterization Date: 02/06/2014

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100   BpS Lifeform: CF   Landform: NMF   Avg Slope Class: MOD   Insol Class:

Stratum Area: 507839 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 8   Current Frequency: 20   Latitude: 34.75   Longitude: 111.375   Datum: WGS84

Reference Severity: 10   Current Severity: 15   Reference Composition Source: M   Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	1	5078	1	-80	TRACE	1	0	-20313
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	31	157430	5	84	ABUNDANT	3	84	132038
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	9	45705	9	-40	UNDER REP	1	0	-30470
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	6	30470	6	-91	TRACE	1	0	-299625
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	49	248841	10	80	OVER REP	2	80	198057
U	CONT						0	4	20313	0	100	ABUNDANT	3	100	20313
						Total	100	100		31					

Stratum Vegetation Departure: 69   Stratum Fire Frequency Departure: 60   Stratum Regime Departure: 46

Stratum Vegetation Condition Class: 3   Stratum Fire Severity Departure: 33   Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 58   Stratum Fire Regime Condition Class: 2

Figure 93. Stratum data for Alternative C, 2050.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata   Landscape Code: 4FRIpin   Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	58	100	58
Sum		100	58

Landscape Departure: 58

Landscape FRCC: 2 (34-66%)

Legend	
Vegetation Departure	green
Regime Departure	blue
Stratum Departure	yellow
Landscape Departure	black
No Departure	*

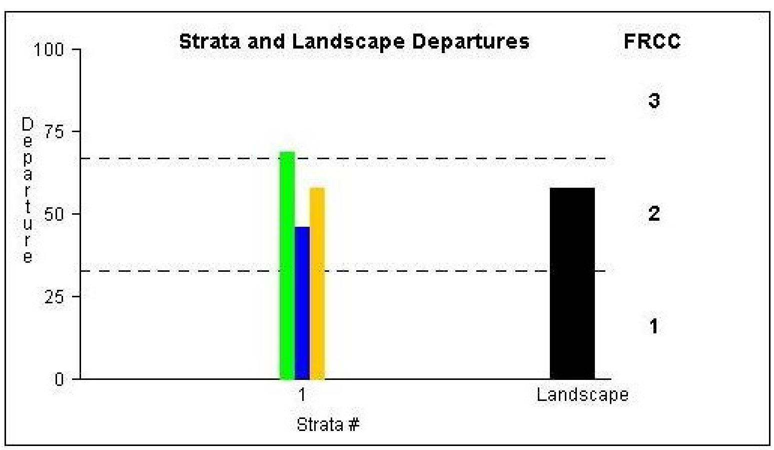

Figure 94. FRCC summary for Alternative C, 2050.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata   Landscape Code: 4FRIpin   Characterization Date: 02/06/2014

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100   BpS Lifeform: CF   Landform: NMF   Avg Slope Class: MOD   Insol Class:

Stratum Area: 507839 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 8   Current Frequency: 34   Latitude: 34.75   Longitude: 111.375   Datum: WGS84

Reference Severity: 10   Current Severity: 8   Reference Composition Source: M   Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	8	40627	5	38	OVER REP	2	38	15235
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	34	172665	5	85	ABUNDANT	3	85	147273
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	25	126959	15	40	OVER REP	2	40	50783
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	16	81254	16	-75	TRACE	1	0	-248841
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	13	66019	10	23	OVER REP	2	23	15235
U	CONT						0	4	20313	0	100	ABUNDANT	3	100	20313
						Total	100	100		51					

Stratum Vegetation Departure: 49   Stratum Fire Frequency Departure: 77   Stratum Regime Departure: 48

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 20   Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 49   Stratum Fire Regime Condition Class: 2

Figure 95. Stratum data for Alternative D, 2020.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata   Landscape Code: 4FRIpin   Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	49	100	49
Sum		100	49

Landscape Departure: 49

Landscape FRCC: 2 (34-66%)

Legend
- Vegetation Departure
- Regime Departure
- Stratum Departure
- Landscape Departure
- No Departure *

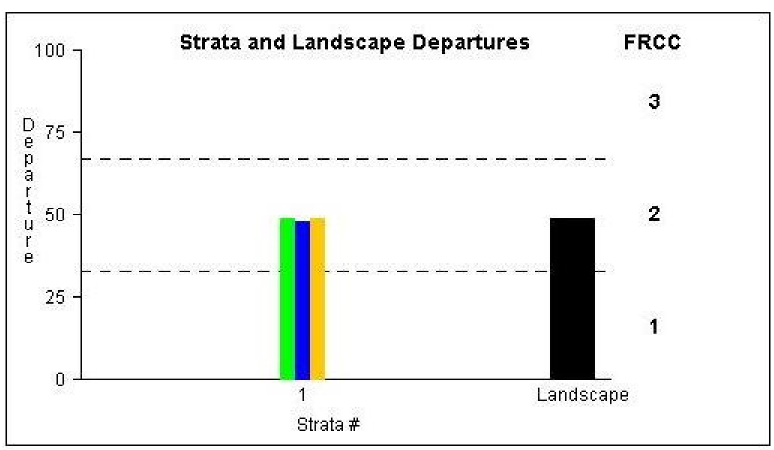

Figure 96. FRCC summary for Alternative D, 2020.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata   Landscape Code: 4FRIpin   Characterization Date: 02/06/2014

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100   BpS Lifeform: CF   Landform: NMF   Avg Slope Class: MOD   Insol Class:

Stratum Area: 507839 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 8   Current Frequency: 67   Latitude: 34.75   Longitude: 111.375   Datum: WGS84

Reference Severity: 10   Current Severity: 24   Reference Composition Source: M   Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	0	0	0	-100	TRACE	1	0	-25391
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	38	192978	5	87	ABUNDANT	3	87	167586
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	7	35548	7	-53	UNDER REP	1	0	-40627
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	2	10156	2	-97	TRACE	1	0	-319938
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	46	233605	10	78	OVER REP	2	78	182822
U	CONT						0	7	35548	0	100	ABUNDANT	3	100	35548
						Total	100	100		24					

Stratum Vegetation Departure: 76   Stratum Fire Frequency Departure: 88   Stratum Regime Departure: 73

Stratum Vegetation Condition Class: 3   Stratum Fire Severity Departure: 58   Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 75   Stratum Fire Regime Condition Class: 3

Figure 97. Stratum data for Alternative D, 2050.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata   Landscape Code: 4FRIpin   Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	75	100	75
Sum		100	75

Landscape Departure: 75
Landscape FRCC: 3 (67-100%)

Legend	
Vegetation Departure	green
Regime Departure	blue
Stratum Departure	yellow
Landscape Departure	black
No Departure	*

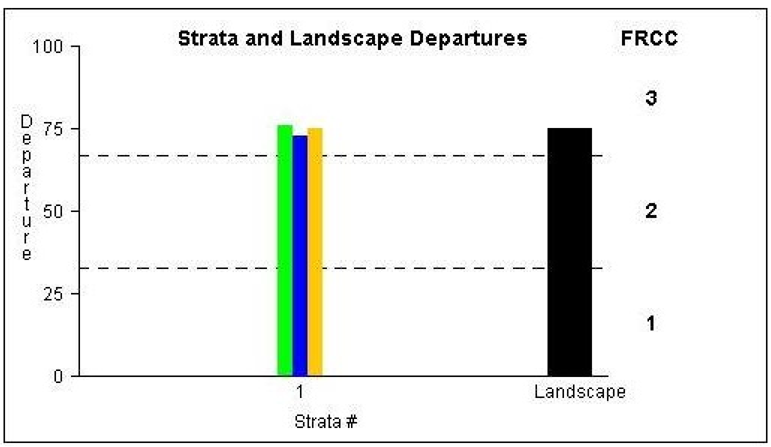

Figure 98. FRCC summary for Alternative D, 2050.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata Landscape Code: 4FRIpin Characterization Date: 02/06/2014

Stratum Num: 1 Biophysical Setting: PPIN5 Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100 BpS Lifeform: CF Landform: NMF Avg Slope Class: MOD Insol Class:

Stratum Area: 507839 Acres Species: Low Elevation: High Elevation:

Reference Frequency: 8 Current Frequency: 10 Latitude: 34.75 Longitude: 111.375 Datum: WGS84

Reference Severity: 10 Current Severity: 6 Reference Composition Source: M Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	8	40627	5	38	OVER REP	2	38	15235
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	25	126959	5	80	OVER REP	2	80	101567
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	29	147273	15	48	OVER REP	2	48	71097
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	22	111724	22	-66	UNDER REP	1	0	-218370
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	11	55862	10	9	OVER REP	2	9	5078
U	CONT						0	5	25391	0	100	ABUNDANT	3	100	25391
						Total	100	100		57					

Stratum Vegetation Departure: 43 Stratum Fire Frequency Departure: 20 Stratum Regime Departure: 30

Stratum Vegetation Condition Class: 2 Stratum Fire Severity Departure: 40 Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed Stratum Departure: 37 Stratum Fire Regime Condition Class: 2

Figure 99. Stratum data for Alternative E, 2020.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata Landscape Code: 4FRIpin Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	37	100	37
Sum		100	37

Landscape Departure: 37

Landscape FRCC: 2 (34-66%)

Legend
- Vegetation Departure (green)
- Regime Departure (blue)
- Stratum Departure (yellow)
- Landscape Departure (black)
- No Departure *

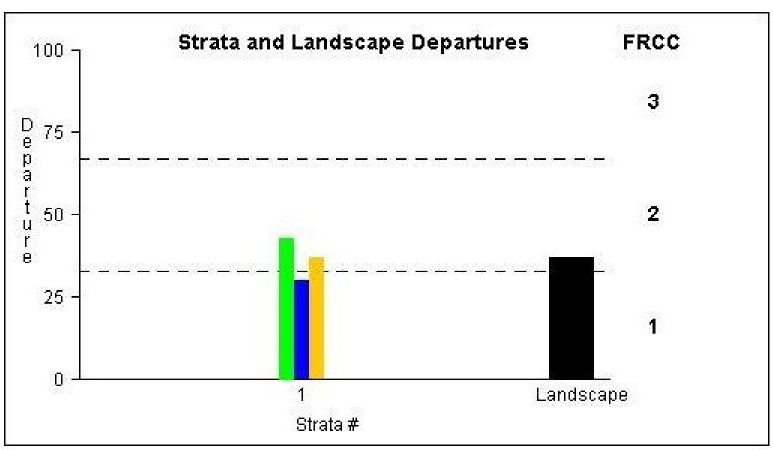

Figure 100. FRCC summary for Alternative E, 2020.

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: Lata | Landscape Code: 4FRIpin | Characterization Date: 02/06/2014

Stratum Num: 1 | Biophysical Setting: PPIN5 | Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 100 | BpS Lifeform: CF | Landform: NMF | Avg Slope Class: MOD | Insol Class:

Stratum Area: 507839 Acres | Species: | Low Elevation: | High Elevation:

Reference Frequency: 8 | Current Frequency: 20 | Latitude: 34.75 | Longitude: 111.375 | Datum: WGS84

Reference Severity: 10 | Current Severity: 20 | Reference Composition Source: M | Current Composition Source: R

Comments:

Uncharacteristic S Class Codes	Uncharacteristic S Class Descriptions
UFUS	Uncharacteristic: Fuel/Sucn/Lack Fire Effects
UFEF	Uncharacteristic: Post-Fire Effects

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species				Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB	SEED	PIPO	QUGA	MUMO	FEAR2	5	0	0	0	-100	TRACE	1	0	-25391
B	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	5	35	177743	5	86	ABUNDANT	3	86	152351
C	CONT	POLE	PIPO	QUGA	FEAR2	MUMO	15	8	40627	8	-47	UNDER REP	1	0	-35548
D	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	65	3	15235	3	-95	TRACE	1	0	-314860
E	CONT	LARG	PIPO	QUGA	FEAR2	MUMO	10	49	248841	10	80	OVER REP	2	80	198057
U	CONT						0	5	25391	0	100	ABUNDANT	3	100	25391
						Total	100	100		26					

Stratum Vegetation Departure: 74 | Stratum Fire Frequency Departure: 60 | Stratum Regime Departure: 55

Stratum Vegetation Condition Class: 3 | Stratum Fire Severity Departure: 50 | Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed | Stratum Departure: 65 | Stratum Fire Regime Condition Class: 2

Figure 101. Stratum data for Alternative E, 2050.

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: Lata | Landscape Code: 4FRIpin | Char Date: 02/06/2014

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	65	100	65
Sum		100	65

Landscape Departure: 65

Landscape FRCC: 2 (34-66%)

Legend
- Vegetation Departure
- Regime Departure
- Stratum Departure
- Landscape Departure
- No Departure *

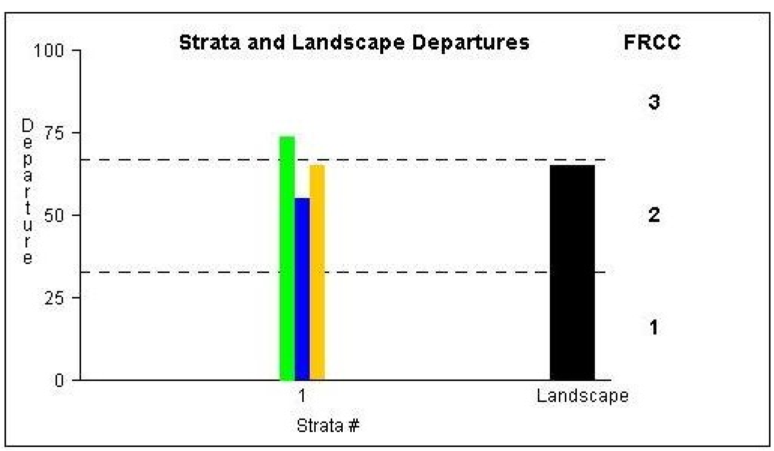

Figure 102. FRCC summary for Alternative E, 2050.

Mortality and consumption modeling

Initial FVS runs were adjusted to improve the accurately of modeled post-treatment mortality. Several people conferred on how to produce accurate mortality including:

- Linda Wadleigh (Fire Ecologist, Regional Office)
- Tessa Nicolet (Fire Ecologist, Regional Office)
- Stephanie Rebain (Forest Management Service Center - FVS Group)
- Patti Ringle (Silviculturist, Flagstaff Ranger District, Coconino NF)
- Mary Lata (Fire Ecologist, 4FRI Core Team)
- Neil McCusker (Silviculturist, 4FRI Core Team)
- Mike Battaglia (Research Forester, Rocky Mountain Research Station, Ft. Collins, CO)

Input from persons listed above was considered and the decision was made to use the method most commonly used. For this method, FVS inputs define how much of a 'burn unit' actually burns (between 0% and 100%). For the initial burn in 2015, the area that burned was set at 70%, and for the 2019 burn it was set at 50%. Based on conclusions from the group listed above mortality was fixed in 2015 and the FFE default was used for 2019. This better represented actual conditions for groups/clumps because outputs were stand averages, and having FVS only 'burn' a portion of the stand would show less impact to the stand – as if only clumps or groups had burned. However, in the first run at assigning fuel models based on FVS outputs, it became obvious that modeled post-treatment surface fuels were out of alignment with structural characteristics. An actual burn would have consumed more of the surface fuels and small trees because it would have burned more of the area. To more accurately represent post-treatment conditions for surface fuels, shrubs, and trees <5" diameter, we assumed that 80% of the area burned in 2015 and 75% burned in 2019. This also provided more accurate numbers for those species that respond to fire/cutting by sprouting.

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

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)

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

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.

Crowning and Torching Indices

This modeling was done with FVS-FFE (Forest Vegetation Simulator – Fire & Fuels Extension). Prescribed fire parameters for burns were the same as for the alternatives under Environmental Consequences. For the post-treatment maintenance burns (2029, 2039, and 2049), modeled parameters were the same as for the 2019 burn.

Regeneration is an important component in long-term fire modeling because of the potential for regeneration to mature into ladder fuels. Regeneration rates were set at 50 for the 2016 burn and at 100 for the 2029 burn. This was based on the premise that the bare mineral soil that is exposed following a fire is a beneficial seed-bed for ponderosa pine and would promote regeneration.

Fire Priority Ranking

Areas showing active or passive crown fire and high or extreme levels of surface fire intensity in timber fuel models were given points according to the matrix below (Table 140). Those areas of high probability of crown fire or high intensity surface fire occurring on slopes greater than 40 were given one additional point. Additionally, those areas identified on soils with high erosion hazard were given one additional point. Total points possible are 7.

Table 140. Fire prioritization process with hazards (fire behavior) and risks

Fire Priority Modeling Components		Points awarded	Description
Crown fire Hazard	Active	3	Highest priority. High mortality, high severity likely.
	Passive	2	High severity effects are localized.
High intensity surface fire	>4000 (extreme)	2	High intensity, high severity, 100% mortality is likely in ponderosa pine and negative surface effects are likely.
	1000 – 4000 (high)	1	Indicates flame lengths of <11 ft, good potential for high severity effects, but not always stand replacing. Control limited to indirect attack.
Slope >40		1	When combined with high severity fire, there is high potential for negative impacts to onsite resources (seed bank, soil, etc.) as well as potential downslope effects (debris flows, etc.).

High Risk of Erosion	1	When combined with high severity fire, these soils are at a high risk of erosion by wind or water

Table 141 shows how the spatial component of the scoring was laid out. Soils with erosion characteristics are not shown. Scoring is shown below, with the highest priority as a '7', indicating extremely negative consequences should a high intensity crown fire burn on a slope greater than 40 on highly erodible soils.

Table 141. Scoring used for prioritizing risks and hazards attributed to potential fire effects

Priority (1 to 7)	Risks and Hazards
1	high intensity
2	passive cf OR extreme intensity OR high intensity + >40 slope OR high intensity + erosion risk
3	active cf OR passive cf + >40 slope OR passive cf + high intensity OR passive cf + erosion risk
4	passive cf + extreme intensity OR passive cf + high intensity + >40 slope OR passive cf + high intensity + erosion risk OR active cf + >40 slope OR active cf + erosion risk
5	active cf +extreme intensity OR active cf + high intensity + >40 slope OR passive cf + extreme intensity + >40 slope OR active cf + high intensity + erosion risk OR passive cf + extreme intensity + erosion risk OR active cf + >40 slope + erosion risk
6	active crown fire + extreme intensity + >40 slope OR active crown fire + extreme intensity + high erosion risk
7	active crown fire + extreme intensity + >40 slope + erosion risk

According to this process, scores of two or greater indicate high probability of severe effects/behavior. It does not preclude severe fire effects that could occur if a fire of high intensity did not crown, but scorched a sufficient amount of crown to cause mortality. An average score was calculated for every mechanical treatment stand. Stands with an average score of two or greater and stands with ≥50 acres of high probability of severe effects/behavior (scores between 2 and 7) were identified as high fire priority stands. Table 142 show the fire priority ranking by Restoration Unit.

Table 142. Fire priority ranking by Restoration Unit and acres

Restoration Unit	Fire Priority Ranking

	1	2	3	4	5	6	7	Total	Acres
1	9	12	14	7	87	13	0	37	57,681
3	23	19	13	11	90	9	1	31	46,843
4	47	25	22	8	90	9	1	28	47,187
5	34	41	29	9	89	8	3	22	17,398
6	29	104	67	15	96	4	0	8	3,430
All	26	22	18	9	89	10	1	29	172,539

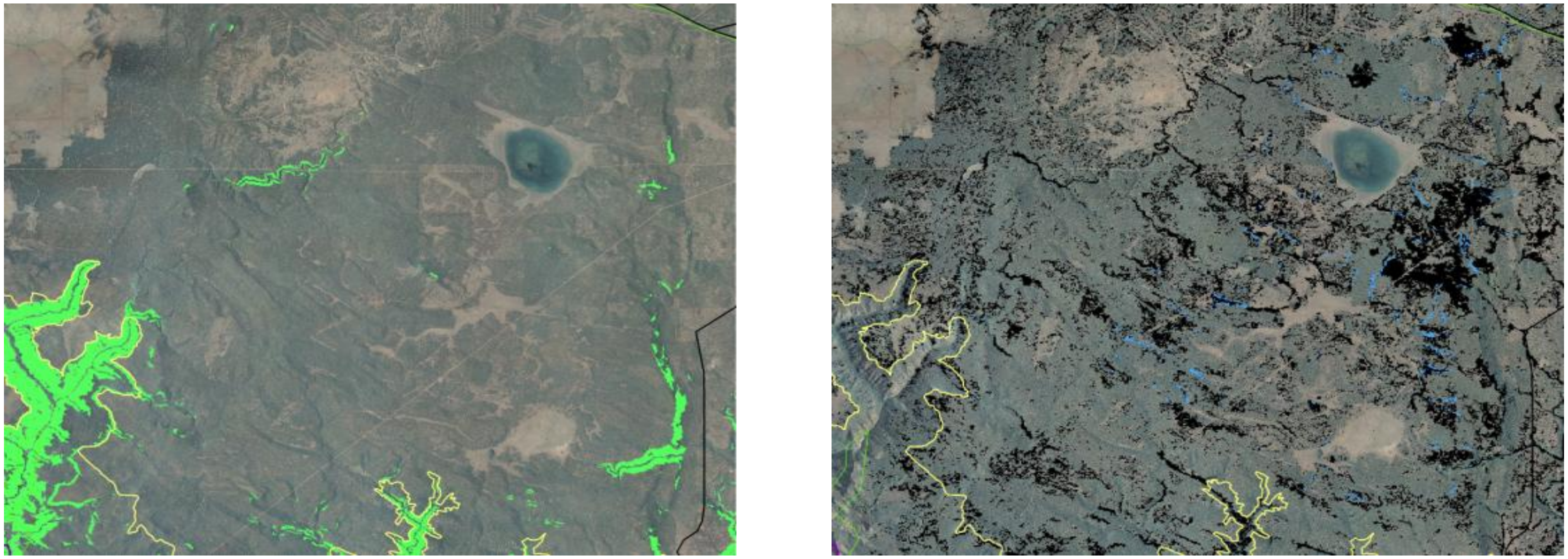

Figure 103.Left: slopes greater than 40 % are shown in green. Right: Fireline intensities: black (high) and blue (very high)

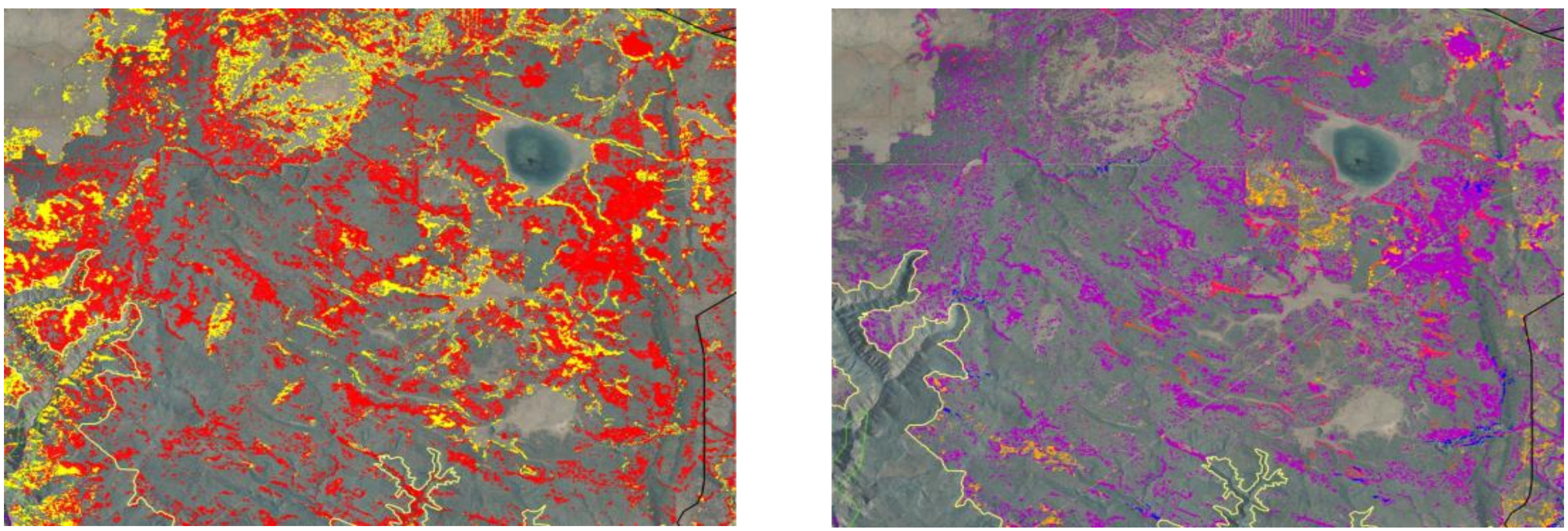

Figure 104. Left: active crown fire = red; passive crown fire = yellow. Right: Blue = highest priority; purple = second highest; yellow = lowest

Ignition Density

One additional analysis that was conducted to determine where the greatest concerns were regarding fire was an analysis of where ignitions have occurred. All fires were included, whether they were just a snag, or thousands of acres. They were considered by lightning ignitions, human ignitions, and the two combined. The intent is to provide a spatial picture of where fires were more likely to start (Figure 105). Human ignitions were most frequent near roads, towns, and recreation areas. Lightning ignitions were most numerous near high points and cinder cones. These data represent only those fires that fire personnel responded to, and are likely to omit many fires that were never reported.

When ignition density was evaluated with the priority rating, it was determined that the majority of areas with high ignition potential were already rated as very high priority by the fire priority rating.

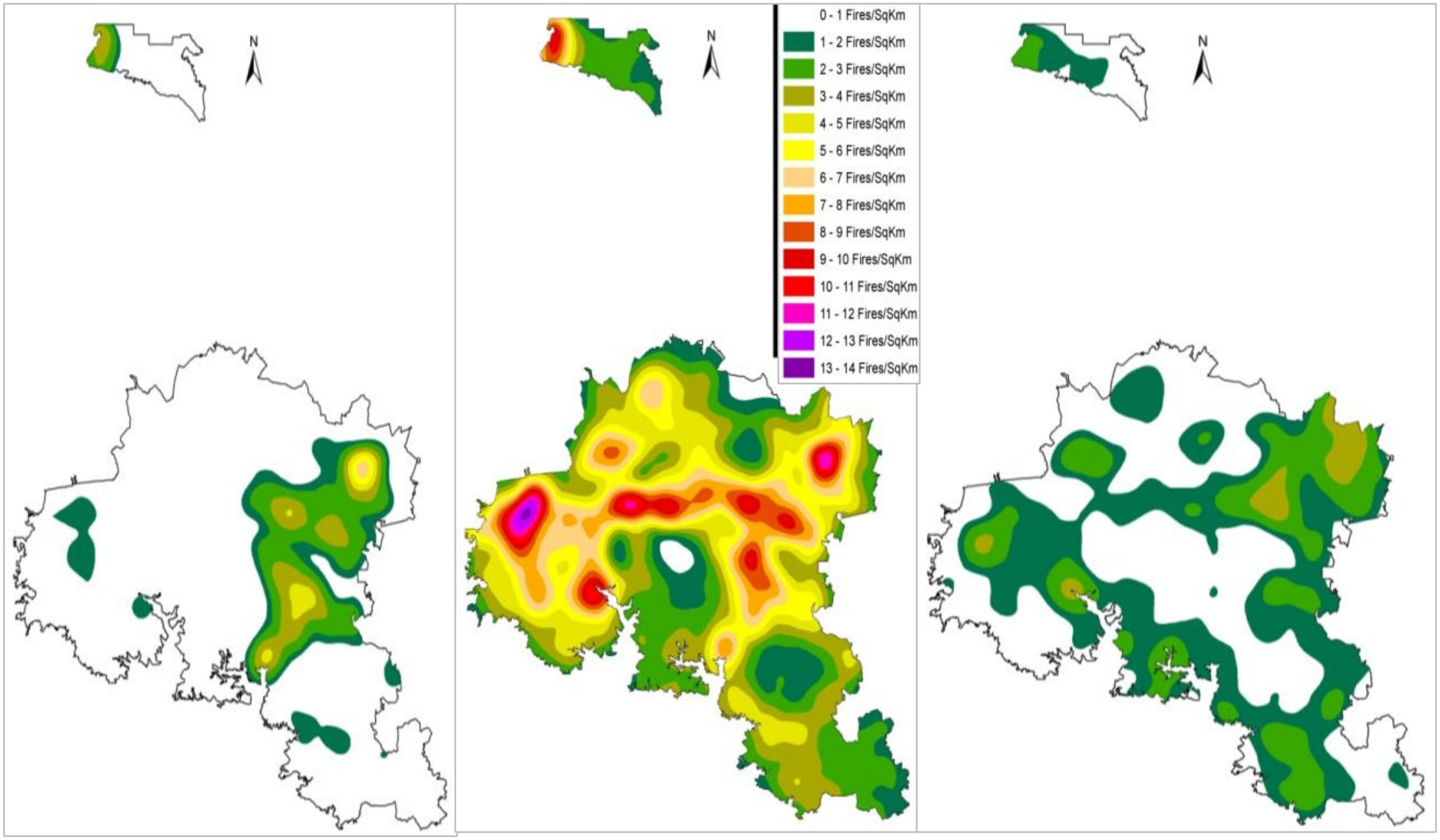

Figure 105. Ignition densities. Left = lightning; Right = human; center = all.

Modeling Assumptions

Fire Behavior, surface fuels, and canopy fuels modeling

Conditions modeled for prescribed burning in PACs represented a 'cooler' burn, with higher fuel moisture to represent the lower severity fire that would be implemented in these areas, because there is generally higher fuel loading and, in order to obtain the desired effects from a prescribed fire, more moderate conditions would be required to keep the fire severity at desired levels.

Outputs were modeled with 2010 data representing existing conditions because that was the most up-to-date data when the analysis began. Data for existing condition were modified with a change detection process developed by ForestERA (ForestERA 2010) to more accurately represent existing conditions since the base data had not been updated in 2009 and 2010.

This analysis uses running averages of acres treated by planned and unplanned fire for each Alternative as a fixed number per year in order to make broad comparisons between alternatives. In reality, there are wide fluctuations in the number of acres treated each year which depend on weather, resource availability, public tolerance, funding, and logistics.

All mechanical treatments were modeled to have occurred in 2012

Prescribed burns were modeled in 2015 and 2019 except for aspen for which only the 2015 burn was modeled.

Thinning parameters were modeled to assume 15% of stems cut are left on site, and 10% of the branchwood from those stems are also left onsite. This is what would be expected wherever there would be mechanical treatments, except where it would need to be modified to meet desired conditions.

Savanna is included in the numbers for ponderosa pine, despite the fire type generally being overwhelmingly surface fire in a healthy savanna. The 'All Pine' designation in the analysis includes the 45,469 acres of savanna restoration for Alternatives B, C, and D, so it should be assumed that over 35,000 acres of the surface fire indicated for the ponderosa pine in each Action alternative is in the 45,469 acres of savanna.

FRCC: The assumption is that 'large trees' = old trees for this analysis, thus, it likely over-predicts VCC1 acres.

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."

While there are weather indices, such as Energy Release Component (ERC), or Burning Index (BI), which are sometimes modeled by percentiles, and there are specific weather variables for each of these percentiles. Using the 97th percentile ERC or BI, and the weather parameters associated with them is not the same as modeling the 97th weather percentiles. We used FireFamilyPlus to analyze 12 years of data (2001 – 2012) from the Flagstaff Automated Weather Station (RAWS). Using data from 1968 through 2012, we determined 97th percentile weather for two periods of time during the fire season. The first period was from April 15th though July 15th, in order to roughly correspond with the most extreme fire season (Partial). The other period was from April 15th though September 15th, to include monsoon and some post-monsoon (Full). There are numerous variables that could be included. We used Maximum Temperatures (MxT); Minimum Relative Humidity (MinRH), Wind Speed (WS), and fuel moisture for 1 and 10 hour dead fuels because these parameters are the most important to fire spread and intensity. Of the 1,836 days between April 15th and September 15th (2001 – 2012) there were no days on which all weather factors reached the 97th percentile for either the Partial or Full periods.

Wind is the single most important fire weather factor for wildfire spread in the project area. The 97th percentile wind occurred on 16 days for the full period (0.9% of the days), and 11 days of the partial (0.6% of the days). 97th percentile wind was 22 mph for the full period, and 23 for the partial. 97th percentile winds co-occurred with up to two other variables on 7 days (0.4% of days) for the Full period, and for none of the Partial period. Concern has been expressed that using 20 mph wind is not representative. For the Full period, 20 mph was the 95th percentile, and for the Partial it was ~91%ile. We have added columns to Table 2 in the Fire Ecology report for the percentiles on the day of the Schultz Fire, as well as 97th percentile weathers as described above. In the project area, wind is the single most important weather factor. 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.

Decreased treatment intensity on about 40,000 acres and about 3,300 acres

RATIONALE:

In the fire behavior modeling for the 4FRI EIS, the process that was used for assigning post-treatment fuel models was based on a key developed from FVS outputs. These outputs represented averages from all stands proposed for a given treatment. Treatments generally included a range of acceptable outputs based on the percent of interspace to be attained. Changes being applied to ~40,000 acres of VSS4, VSS5, and VSS6 stands mean there would no longer be a range, and FVS outputs that would be used would represent the lower end of the original range proposed. For example, a number that represented the average of all stands for which a UEA 45 – 65 treatment was proposed (meaning, depending on site conditions, the post-treatment condition would fall into the range of 45 – 65% interspace), would now represent the average of those same stands treated at a UEA 45 (meaning the post-treatment condition would be 45% interspace).

The effect of this change would be to increase the canopy fuel loading which, in turn, would be expected to increase potential crownfire to some degree. In order to provide some quantification for changes to potential fire behavior, an abbreviated evaluation was completed as described below.

MODELING PROCESS:

There are several canopy characteristics that are key variables for modeling fire behavior. The Methodology section of this report states:

"*Canopy Base Height (CBH) is a critical factor in crown fire initiation, and can be used as an indicator of the potential for crown fire initiation (Agee and Skinner 2005, Stratton 2009, Scott 2003, Scott and Reinhardt 2002).*

Canopy Cover (CC)…is an important component for modeling and evaluating potential fire behavior and/or effects, affecting the potential for active crown fire."

In order to estimate the potential change, threshold values were determine for canopy cover (cc) and canopy base height (cbh). Those values represent levels that occur in the majority of pixels showing crown fire (Table 1). Within the ~40,000 acres, the following thresholds apply for active crownfire (acf) and passive crownfire (pcf):

Table 143. Threshold values for active and passive crownfire

cbh threshold			Cc threshold	
acf	6 feet	77% of all acf modeled occurred with a cbh value of 6 feet 97% of all acf modeled had a cbh value of 6 feet or less	27%	76% of all acf modeled occurred with a cc value of 27%. 96% of all acf modeled had a cc value of 27% or more
pcf	6 feet	43% of all pcf modeled occurred with a cbh value of 6 feet 91% of all pcf modeled had a cbh value of 6 feet or less		76% of all pcf modeled occurred with a cc value of 27%. 23% of all pcf modeled had a cc value of 85% or more

Standard deviation for 2020 (all Alts) for cc is 12 (percent); for cbh is 6 (feet).

Pixels which were within ½ of the standard deviation of the threshold values for cc and cbh for which fire potential had been modeled as surface fire were considered to have potential for crownfire.

1) Using a shapefile of the ~40,000, clipped:
   a. cf for Alt C
   b. CC for Alt C
2) Combine cf, cc, and fm for Alt. C
3) Export into excel and crunch.
4) Determine significant thresholds for active crown fire (acf) and passive crown fire (pcf)

RESULTS:

There is reasonable potential for additional crown fire on ~1,742 acres, and potential for 132 acres of existing passive crownfire potential to shift to active crownfire.

There are ~1,742 acres that have a cbh below AND a cc above ½ of the standard deviation of thresholds for pixels that showed as surface fire in Alternative C in the original FlamMap runs. The assumption is that these acres would have good potential to support active or passive crownfire.

There are an additional ~130 acres of passive crownfire that would have potential to become active crown fire.

Approximately 800 acres would occur as greater than 10 contiguous acres of crownfire.

Approximately 480 acres would occur as greater than 50 contiguous acres of crown fire.

Appendix E: Design features and mitigation

Table 135. Design features and mitigation measures for all action alternatives

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE1	Burn unit size, as well as strategic placement, would be a consideration in designing units and implementation prioritization (Finney et al. 2003).		X	Arrangements of large treatment areas are more effective at reducing fire behavior than arrangements of smaller ones. Larger burn blocks, when possible, would also be mitigation for emissions by increasing the potential number of acres that could be burned in a burn window. Larger burn units would produce more smoke when prescribed fires are implemented, but for a shorter duration.
FE2	Prescribed fire (pile, broadcast, and jackpot burning) would occur in accordance with Arizona Department of Environmental Quality (ADEQ) requirements.	X		Regulatory requirement.
FE3	Emission Reduction Techniques (see FE8) would be utilized when possible to minimize impacts to sensitive receptors of burn unit(s). Project design for prescribed fire and strategies for managing wildfires should incorporate as many emission reduction techniques as feasible, subject to economic, technical, and safety criteria, and land management objectives. Decision documents (which define the objectives and document line officer approval of the strategies chosen for wildfires) should identify smoke-sensitive receptors, and include objectives and courses of action to minimize and		X	ERTs are recommended by the ADEQ as techniques that can be effective for minimizing impacts to sensitive receptors.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
	mitigate impacts to those receptors as feasible.			
FE4	As needed, the burning of hand piles or machine piles would occur when conditions are favorable and risk of fire spread is low. Piles would be located far enough away from residual trees and shrub patches to minimize canopy scorch or damage to ponderosa pine or large oak (>6"dbh) where it is not desirable. Individual piles or groups of piles may have fireline cut around them if necessary to meet objectives.		X	Prevent undesirable impacts.
FE5	Firelines would be used to facilitate broadcast burns or pile burning operations as needed: (1) Firelines may consist of natural barriers, roads and trails, or may be constructed as needed. Line construction may consist of removing woody and/or herbaceous vegetation, removing surface fuels, pruning, or cutting breaks in fuels by hand, ATV (drag lines), or a dozer as needed, (2) Fireline width would be determined as adjacent fuels and expected fire behavior dictate, assuming compliance with the requirements of cultural, wildlife, and other resource areas, (3) Constructed firelines would be rehabilitated, which may include pulling removed material back into the lines, hand constructing water diversion channels and/or water bars, laying shrubs or woody debris in the lines following burning, or other methods appropriate to the site, and (4) Fireline construction would be coordinated with wildlife.		X	Facilitate broadcast burns or pile burning operations.
FE6	Mechanical treatments following broadcast burns would occur after surface vegetation has recovered sufficiently to minimize impacts from the mechanical treatments (generally 1 to 3 years). Prescribed fire treatments following mechanical treatments would occur after there has been adequate surface vegetation recovery that fuel loads are sufficient to meet the objectives of a prescribed burn.		X	Minimize impacts from mechanical treatments on vegetation and soil.
FE7	Prescribed fires may be conducted before or after mechanical treatments. The sequencing of prescribed fires and mechanical treatments would be decided on a site-specific basis, depending on the site, burn windows, available resources, thinning schedules, etc.		X	Increase the flexibility for implementing both prescribed fire and mechanical treatments.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE8	The following ADEQ emissions reduction techniques (ERTs) would be used when practicable to minimize impacts to sensitive receptors: pre-burn fuel removal, mechanical processing, increased burning frequency, aerial/ mass ignition, high moisture in large fuels, rapid mop-up, air curtain incinerators, burn before green-up, backing fire, maintain fireline intensity, underburn before litterfall, isolating fuels, concentrating fuels, mosaic/jackpot burning, moist litter and duff, burn before large activity fuels cure, and utilize piles.		X	Reduce emissions from prescribed fire.
FE9	Mitigation and design features for smoke impacts include: (1) Reducing the emissions produced for a given area treated, (2) Redistributing/diluting the emissions through meteorological scheduling and by coordinating with other burners in the airshed. Dilution involves controlling the rate of emissions or scheduling for dispersion to assure tolerable concentrations of smoke in designated areas, and (3) Avoidance uses meteorological conditions when scheduling burning in order to avoid incursions of wildland fire smoke into smoke sensitive areas. Also see FE8 for ERTs.			See FE9.
FE10	When prescribed burns are conducted in areas with, or near known populations of invasive weeds, follow-up monitoring would be conducted. Also see Botany B4.		X	Detect new weed infestations before they spread.
FE 11	See Rangeland Management: R1, R4, and R5.		X	Prevent damage or loss of infrastructure.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE12	When practicable, damage or mortality to old trees, and large trees would be mitigated or avoided by implementing prescription parameters, ignition techniques, raking, wetting, thinning, compressing slash, or otherwise mitigating fire impacts to the degree necessary to meet burn objectives and minimize fireline intensity and heat per unit area in the vicinity of old trees. Trees identified as being of particular concern (e.g. trees with known nests or roots for herons, eagles, osprey, or other raptors, occupied nest cores, or critical areas in PACs) would be managed in accordance with wildlife design features (see wildlife). Prepare old trees 1 year or more before a burn if possible.		X	There is a deficit of old trees across the project area. Implementing mitigation measures when possible is a critical component of restoration on a landscape scale. Large trees that are not old are not as susceptible to damage from fire. Mitigation measures that can be implemented a year or more before a burn, such as thinning or raking, may improve the health of the tree, improving its response to fire.
FE13	Mitigation measures and design features for wildlife species including Mexican spotted owl, golden eagle, bald eagle, pronghorn, northern goshawk, bats, northern leopard frog, turkey, deer, and other wildlife can be found in the wildlife section.			
FE14	Aspen, Gambel oak, pine-sage: fire effects would be managed primarily by implementing prescriptions, and ignition techniques to meet objectives in pine/sage systems. In Gambel oak, avoid lighting near the bases of large oak boles.		X	To serve as a detriment to ungulates would be inclined to browse on young aspen.
FE15	Concerned/interested public will be given as much warning as possible in advance of prescribed burns via notices, press releases, email lists, public announcements, phone lists, or other notification methods as appropriate.		X	To provide advanced notice for publics concerned about potential impacts from emissions resulting from prescribed fires.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE16	Range and fire managers will coordinate grazing schedules and prescribed fires on allotments within burn units to ensure there is sufficient surface fuel to allow burn objectives to be met. If grazing cannot cease long enough for sufficient fuel to build up to meet objectives, planned prescribed fires will be postponed until there can be sufficient fuel to meet objectives.		X	To improve the ability of prescribed fire managers to meet objectives when implementing prescribed fires.
FE17	CWD will be managed to achieve forest plan direction, though it may take more than one entry when the current conditions are deficit (i.e. are below forest plan guidelines). KNF: 1 – 5 tons/acre in WUI unless there are conflicts with other resource needs. (Refer to KNF revised forest plan page 98). Other areas in ponderosa pine on the KNF 3 – 10 tons/acre. COF: 5 – 7 tons/acre in ponderosa pine.	X		To provide levels of CWD to address the need for habitat (cover), soils (organic material and limited areas of high burn severity), and fire (limited areas of high burn severity and a high resistance to control).
FE18	Do not use tanks for water sources that are known to have populations of northern and Chiricahua leopard frogs as water sources for prescribed fire activities. Activities in and around natural or constructed waters will use decontamination procedures to prevent the spread of chytrid fungus and other invasive aquatic species, unless an evaluation by a forest biologist determines it unnecessary.	X	X	Avoid or minimize impacts to threatened and sensitive frog species, and avoid or minimze spreading the chytrid fungus or other invasive aquatic species.

Daily Burn Accomplishment Form **Contact Number:**

Updated 10/18/05 **Contact Name:**

Please submit accomplishment forms the day following ignition. Submit only one accomplishment for per burn for each ignition date.

BURN NAME:	
BURN NUMBER:	
IGNITION DATE: (MM/DD/YY)	
ACREAGE TREATED: Area for which management objective(s) were	
ACREAGE BURNED: Area blackened for broadcast burns only, not to	
ACREAGE ERT(s) USED: Area in which emission reduction techniques	
BURN LOCATION: (TT/RR/SS or SS-SS)	
BURN DURATION: (Hours)	
IGNITION DURATION: (Minutes) Non-piled Activity fuels only	
DEAD FUEL MOISTURE: (%) 10 hour	
DEAD FUEL MOISTURE: (%) 1000 hour	
DUFF FUEL MOISTURE: (%) (OPTIONAL) Natural fuels only	
FUEL MOISTURE METHOD: 1) NFDRS 2) Measured 3) Both	
DAYS SINCE LAST RAINFALL: Non-piled activity fuels only.	
SNOW-OFF DATE: (MM/YY) Non-piled activity fuels only.	
PRIMARY EMISSION REDUCTION TECHNIQUE: (Select the primary	

1. Pre-Burn Fuel Removal 2. Mechanical Processing 3. Ungulates 4. Burn More Frequently
5. Aerial / Mass Ignition 6. Rapid Mop-Up 7. Windrow Burning 8. Air Curtain Incinerators
9. Burn Before Green Up 10. Backing Fire 11. Maintain fire line intensity 12. Isolating Fuels

DIURNAL PLUME CHARACTERISTICS:

REMARKS:

FUEL INFORMATION (BROADCAST BURNING)

PRIMARY FUEL TYPE: 1)Ponderosa 2)Ponderosa /Grass 3)Juniper 4)Mixed Conifer 5)Grass			
PRIMARY NFDRS FUEL MODEL:		**FIRE REGIME**	
HARVEST DATE: (If Applicable)		**PRIMARY DUFF TYPE:** 1) Black (Litter	

SOUND AND ROTTEN **(Woody Fuels Only –** Do		***ROTTEN*** **(Woody fuels only**	
0.0 – 0.25 IN FUELS:		**>3.0 IN FUELS:** (T/A)	
0.26 – 1.0 IN FUELS:		***OTHER (Do not include these fuels in***	
1.01 – 3.0 IN FUELS:		**STUMP 20+ IN FUELS:**	
SOUND **(Wood fuels only –** Do not include piles		**SHRUB /BRUSH**	
3.01 – 9.0 IN FUELS:		**GRASS /HERB FUELS:**	
9.01 – 20 IN FUELS:		**AVERAGE LITTER**	
>20.0 IN FUELS: (T/A)		**AVERAGE DUFF**	

FUELS

NUMBER OF PILES PER ACRE: Provide the average number of piles per	

TONS OF PILES PER ACRE: Provide the average fuel loading per acre	
SOIL IN PILES: (%)	
PRIMARY SPECIES: (>50%) 1) Ponderosa Pine, 2) Douglas Fir, 3)	
PRIMARY SPECIES: (%)	
SECONDARY SPECIES: (<50%) 1) Ponderosa Pine, 2) Douglas Fir, 3)	
SECONDARY SPECIES: (%)	
QUALITY: 1) Clean, 2) Dirty, 3) Real Dirty	
DIMENSIONS: (FT) Provide the average width and height of round piles, as	**W H**
PACKING RATIO: 1) Ponderosa Pine <10 IN, 2) Short needle conifer,	

Limitations to prescribed fire

Prescribed fire, is a critical component of restoration in ponderosa pine and its associated vegetation types (grasslands, oak, PJ, aspen). In order to implement fire as a restoration tool and a maintenance tool on the landscape level, it would be necessary to plan prescribed burns on a larger scale to the degree possible. Limits relating to emissions were discussed in Emissions: Air Quality and Ecological Effects on page 92. Restrictions across the proposed treatment areas and adjacent areas would dictate how burn units can be organized and delineated. Across the proposed treatment area, there are specific spatial and temporal restrictions that differ by species (specifics are listed in Appendix E and in the Wildlife Specialists' Report). These limitations, when combined with others such as National Ambient Air Quality Standards, resource availability, social constraints, climate, highway safety, and thinning contract obligations, would make it a challenge for fire managers to implement the proposed acres of prescribed fire needed to meet the purpose and need and restore the spatial and temporal patterns of the fire regimes within the treatment areas.

Restrictions for prescribed include the following:

- Firefighter safety is of paramount concern. Using hand lines or drag lines in areas with high fuel loading, would further narrow burn windows in order to do it when it is safe.
- No burning: Under Alternatives B and D there are PACs and core areas where no prescribed fire is allowed. A PAC is 600 acres, and a core area is at least 100. This means that the restricted area must be blocked out of burn units. PAC boundaries do not often follow roads, rocky ridges, or other areas that would make natural fire breaks. That means that much more than the 600 acre PAC could not be burned. The blocked out area could remove over 1,000 acres from a prescribed fire unit, depending on the setting of the PAC/core area.
- Spatial restrictions: Desired conditions within the PAC and/or Core Areas differ from the surrounding area. That requires that, as above, the area be blocked in some manner in order to produce the appropriate fire behavior within the PAC or core area. Fire behavior and effects required in these areas are usually much reduced from that in the surrounding area so that, within a burn unit blocked to include a PAC or core area, the NON-PAC and core areas would not receive the fire and behavior most beneficial to them.
- Additional spatial and timing restrictions apply for other species. Both temporal and spatial restrictions differ from species to species, with some overlap in time and space.
- Restrictions also apply outside of some designated habitat, as well as within that

addresses potential smoke impacts. These are generally buffers within which fire may not be allowed in order to reduce potential smoke impacts within the designated habitat.

- There are self-imposed social limits that are fairly standard, such as not burning on homecoming weekends, not burning on the 1st day of deer hunting, etc.
- Legal limits are set by the Arizona Department of Environmental Quality to ensure compliance with the Clean Air Act.
- Burn windows must meet prescriptions.
- Social limits are imposed, generally based on emissions.
- Logistical limits are set by the capacity of firefighting resources available.

Appendix F: Smoke and emission modeling details

The most common stand conditions across the 4FRI area are VSS3 and VSS4. Forest Vegetation Model outputs from three simulations were used as inputs to model potential emissions. The First Order Fire Effects Model (FOFEM) was used to model emissions because, though it doesn't produce concentrations at sensitive receptors, the temporal and spatial scales of modeling for this stage of 4FRI suggest that trying to predict where smoke would end up and at what concentrations is premature. That modeling would be done as burn plans are written for the implementation stage of 4FRI. The objective of this modeling is to compare and contrast expected emissions outputs for different treatment options.

The three simulations included:

1. BurnGHawk_4AB: (a burn only treatment in VSS4AB stands)
2. FA_UEA_4ABSS 45 - 55: (Foraging area, uneven age management in VSS4AB single story stands)
3. FA_UEA_4ABMS 45 - 55: (Foraging area, uneven age management in VSS4AB multi story stands)

To represent burn only treatments, outputs from #1 were used. To represent mechanical and fire treatments combined, outputs from #2 and #3 were averaged, including weighting for the difference in acres (Table 143).

In order to compare apples to apples, BurnGHawk_4AB existing conditions were used for all modeling change between years were determined for #'s 2 and 3 and averaged (weighted as before). These changes were then applied to the applicable treatment. This allowed the comparison of different treatments on the same stand, rather than using different stands and comparing numbers that started at different points.

Stands were modeled in FVS based on their proposed treatments, so these stands were not equivalent to begin with. The burn only stand started out with 24% lower fuel loading.

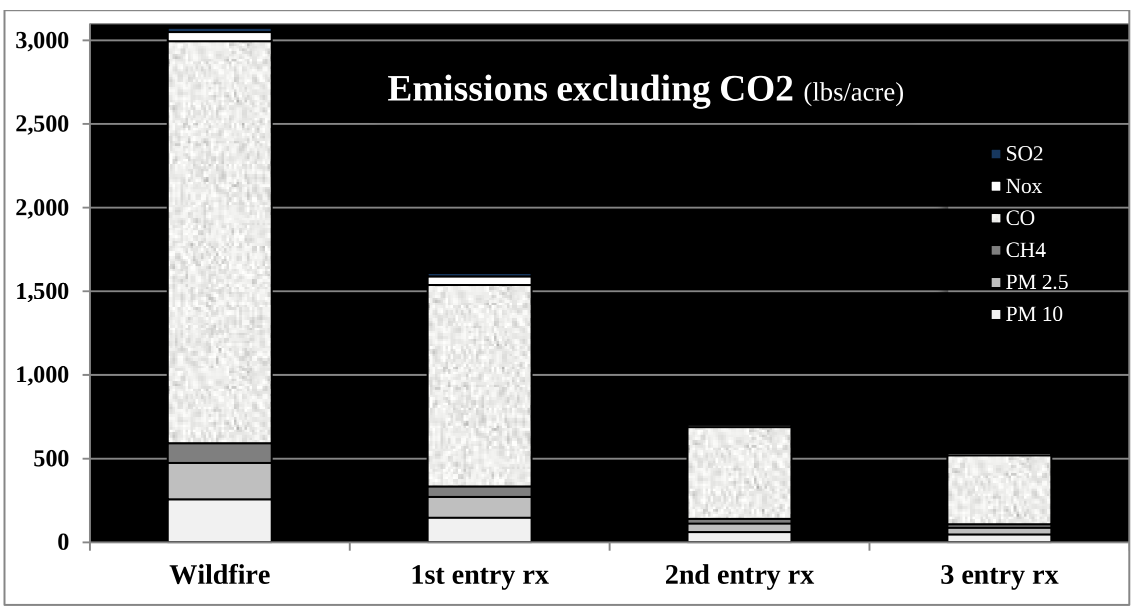

Figure 106. Modeled emissions from a typical stand with no treatment prior to burning

Table 144. Inputs used for emissions modeling.

	Prescribed Fire-Only						Mechanical Treatment Before Prescribed Fire					
Fuels tons/acre	Existing Condition Wildfire	1st burn	2nd burn	3rd burn	4th burn	Wildfire After Treatments	Mechanical only Wild Fire	1st burn	2nd burn	3rd burn	4th burn	Wildfire After Treatments
Litter	2.55	2.55	1.13	1.23	1.18	1.23	2.67	2.67	2.85	3.05	3.80	3.05
1 hour	0.23	0.23	0.09	0.08	0.09	0. 08	0.23	0.23	0.20	0.18	0.18	0.18
10 hour	1.23	1.23	0.55	0.60	0.74	0. 60	1.35	1.35	1.41	1.48	1.36	1.48
100 hour	1.53	1.53	0 92	0.96	1.11	0. 96	1.66	1.66	1.74	1.83	1.70	1.83
1000+ hour	3.36	3.36	1.79	1.92	2.19	1.92	3.58	3.58	3.06	2.62	2.83	2.62
Duff	3.30	3.30	3.32	2.84	2.44	2.84	2.66	2.66	2.28	1.96	2.26	1.96
Herb	0.22	0.22	0.22	0.22	0.23	0.22	0.23	0.23	0.23	0.23	0.23	0.23
Shrub	0.26	0.26	0.26	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26
Foliage	12.21	12.21	10.96	10.71	10.69	10.71	11.86	11. 86	11.60	11.35	11.46	11.35
Branch	21.74	21.74	20.05	20.09	20.50	20.09	21.26	21.26	20.85	20.45	20.29	20.45
Total fuels	33.95	33.95	31.01	30.80	31.19	30.80	45.76	33.13	33.13	32.45	31.79	31.79
Moist 10 hour	3	6	6	6	6	3	3	6	6	6	6	3
Moist 1000+	12	20	20	20	20	12	12	20	20	20	20	12
Moist Duff	20	60	60	60	60	20	20	60	60	60	60	20
Log Rotten	20	20	15	10	8	15	20	20	15	10	8	10
Duff Depth	0.40	0.40	0.40	0.34	0.30	0.40	0.40	0.20	0.27	0.24	0.3	0.40
Log Loading Distribution	Center											
Crown Burn	60	19	6	10	5	30	60	6	6	13	5.00	30
Season	Summer											
Conditions	Very Dry	Dry				Very Dry	Dry					Very Dry

Appendix G: General concepts used for this analysis

Fire Effects

Fire Effects refers to the responses of an ecosystem to a fire, and are dependent upon a myriad of variables including but not limited to: soil temperature and moisture before, during, and after a fire; fire behavior; long and short term weather before and following the fire; season of burn; time since last burn; and so on. Fire effects may be beneficial, detrimental, or both. They are classified as either 'First Order Fire Effects' or 'Second Order Fire Effects', with the primary difference being the temporal immediacy to the fire. Both kinds may be long or short term. Generally, first order effects, with the exception of smoke effects, are on site. Second order fire effects may be on or off site, such as sediment deposition downslope from a high severity burn. Second order effects are generally more complex than first order effects because the longer time period allows far more variables to play a role. This makes them more difficult to predict and, therefore, more difficult to address in advance. Table 144 lists some first and second order fire effects, but is intended only to give examples so only a few are shown in each order.

Table 145. Examples of First and Second Order Fire Effects

First Order Fire Effects (direct effects)	Second Order Fire Effects (indirect effects)
• Amount of fuel consumed • Amount of bare, mineral soil exposed • Scorch and char height • Decreased surface albedo • Oxidation of some minerals in the soil • Creation of hydrophobic soil • Immediate mortality	• Erosion • Sediment deposition • Longer term mortality (ex: large and/or old trees and shrubs may take years to die, though the catalyst was a fire). • Increased surface vegetation • Increased shrub vigor

Canopy Characteristics

The structure of the canopy affects wind speed at the ground. A more open canopy (less closure, higher CBH) allows faster wind at the surface which can increase fire intensity and rate of spread. Surface fire intensity is directly related to crown fire initiation (Omi and Martinson 2002). Figure 3 shows an area of the Schultz Fire a few months after the burn. Yellow arrows show what the crown base height was before the fire. Blue arrows show what the crown base height will be after the 'red' needles fall. Flames must be at least half as tall as the crown base height to initiate crown fire.

- Affects heat dissipation. Closed canopies trap heat beneath the canopy, increasing the potential for scorch and mortality. Open canopies allow heat to dissipate upwards with little damage to tree crowns. Other canopy measures may combine with CC to augment or minimize the effects.

- Regulates insolation by shading (or not) the surface. The amount of sunlight at the surface directly affects fuel moisture and temperature at the surface, as well as the potential for surface fuels to grow.

- Contiguous canopy cover can support active crown fire. The more open the canopy is, the less chance of active crown fire.

Figure 107. Canopy base heights before and after the Schultz Fire (2010)

In order for a crown fire to initiate, a surface fire must be intense enough to ignite branches that can propagate fire to the upper levels of the canopy. Flame lengths must be about ½ the canopy base height to initiate crown fire, though additional variables also come into play, such as needle moisture and wind speed (Van Wagner 1973). In order for a passive crown fire to become an active crown fire, canopy fuels must be contiguous enough and wind speed high enough for the fire to spread from one tree crown to another. Low and moderate intensity fires can effectively raise canopy base height to levels that make crown fire initiation less likely, as well as decreasing canopy bulk density, decreasing the potential for active crown fire (Figure 107).

Appendix H: Response to Comments on DEIS

Below are a selection of public comments and the responses to them. These comments are the majority of those concerning fire and/or air quality that cited oposing science.

Artley CARA #8 Attach **#11** opposing view #	**TOPIC: COHEN Fuels Reduction projects**	**Comment/Issue and link to publication**	**Response – What does DEIS and report say? What does FEIS/ROD say?**	**Analysis – Conclusion** Changes to the FEIS and report? Why? If not, why?
8-11/1		"Research results indicate that the home and its immediate surroundings within 100-200 feet (30-60 meters) principally determines the home ignition potential during severe wildland-urban fires. Research has also established that fire is an intrinsic ecological process of nearly all North American ecosystems. Together, this understanding forms the basis for a compelling argument for a different approach to addressing the wildland-urban fire problem." (Pg. 1 – abstract) Source: Wildland-Urban Fire—A different approach http://www.nps.gov/fire/download/pub_pub_wildlandurbanfire.pdf	See 'Chapter 1 – Purpose and Need for Action' in the DEIS, pages 1 – 45, as well the following pages for details on the alternatives: 62 – 104. Table 31 (pages 96 – 104), is a detailed summary of each alternative. There are about 535 acres of proposed WUI (fuels) treatments, all in RU6. In the DEIS, these treatments are described in Table 17 on (page 72), Table 24 (page 84), and Table 27 (page 91). Additionally, there is a brief discussion on page 275 under 'Wildfire and Forestray Related Economic Enviroment' description of the cost influence of suppression efforts in the WUI on overall suppression costs. This includes Table 85	This information isn't relavent to the 4FRI. However, the first time 'Wildland-urban interface (WUI) is mentioned in the DEIS (page 21), there is no explanation of what it is. This paper focuses on the 'home ignition

			(page 276). There is a single mention on page 279 in regards to the expected increase in suppression costs as WUI areas continue to expand on both forests.	zone', and is primarily a publication intended for homeowners on how to decrease the chances that their home might ignite.
8-11/47		"Thinning to reduce crown fire potential requires careful evaluation of the tradeoffs in treatment effects on potential surface fire behavior and crown fire behavior (Scott and Reinhardt, 2001). Thinning will often result in increased potential surface fire behavior, for several reasons. First, thinning reduces the moderating effects of the canopy on windspeed, so surface windspeed will increase (Graham et al., 2004). It also results in increased solar radiation on the forest floor, causing drier surface fuels. It may also cause an increase in flammable grassy and shrub fuels over time, due to the reduced tree competition." (Pg.2000)	See response to 8-11/1	See response to 8-11/38
8-11/48		"Some viable fuel treatments may actually result in an increased rate of spread under many conditions (Lertzman et al., 1998; Agee et al., 2000). For example, thinning to reduce crown fire potential can result in surface litter becoming drier and more exposed to wind. It can also result in increased growth of grasses and understory shrubs which can foster a rapidly moving surface fire." (Pg.2000)	See response to 8-11/1	See response to 8-11/38
8-11/49		"Treating fuels may not improve ecosystem health. Ecosystem restoration treatment and fuel treatment are not synonymous. Some ecosystem restoration treatments reduce fuel hazard, but not all fuel treatments restore ecosystems. Ecosystem restoration treatments are often designed to recreate presettlement fire regimes, stand structures and species compositions while fuel treatment objectives are primarily to reduce fuels to lessen fire behavior or severity—this is known as ''hazard reduction.'' Achieving fuel hazard reduction goals in the absence of ecosystem restoration is insufficient (Dombeck et al., 2004; Kauffman, 2004)." (Pg.2000)	See response to 8-11/1	See response to 8-11/38
8-11/50		"Conversely, some fuel treatments can reduce fuels but create stands that are quite dissimilar from their historical analogs. Examples include mastication treatments that break, chip, or grind canopy and surface woody material into a compressed fuelbed and	See response to 8-11/1	See response to 8-11/38

		thinning treatments that remove the fire adapted species and leave shade-tolerant, late successional species." (Pg.2000) **Source:** Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States Published in *Forest Ecology and Management* 256, 2008 http://www.firewise.org/Information/Research-and-Guidance/WUI-Home-Ignition-Research/~/media/Firewise/Files/Pdfs/Research/CohenFuelTreatment.pdf		

Artley CARA #8 Attach #3 opposing view #	TOPIC: Opposition to fuels reduction projects	Summary of Comment/Issue and link to publication	Response – What does DEIS and report say? What does FEIS/ROD say?	Analysis – Conclusion Is anything changing in FEIS and report? If so, why? If not, why?
8-3/1		"large, severe wildfires are more weather-dependent than fuel-dependent," Agee, James K. Ph.D. "**The Severe Weather Wildfire-Too Hot to Handle?** *Northwest Science*, Vol. 71, No. 1, 1997 http://www2.for.nau.edu/courses/pzf/FireEcolMgt/Agee_97.pdf (link goes to NAU home page)	No response is deemed necessary since the quoted statement so clearly was taken out of context, and the paper implied the opposite (of the quoted statement) in regards to the project.	No changes or additions are needed for the DEIS. I have added this as a citation in my report in the discussion on the difference between severity and intensity because James Agee is a well know, highly credible, well published, well respected fire ecologist. The phrase Mr. Artly chose to quote gives the opposite impression intended by the paper. Here is the quote in context with the part Mr. Artly quoted in bolded italics: "Recent statementsi n the scientiflc literature and popular press suggest that recent large, severe wildfires in westem North America are largely due to extreme weather. The long-accepted view of fire behavior as a function of fuels, weather, and topography has changed for some from an equilateral fire triangle, where each factor can be significant, to a distorted isosceles triangle with the wide base being the weather contribution to fire behavior. This "weather hypothesis" that all ***large, severe wildfires are more weather-dependent than fuel-dependent*** is found in statements such as the following: Forest fire behavior is determined primarily by weather variation among years rather than fuel variation associated wilt

				stand age. (Bessie and Johnson 1995) Fire behavior should be directly related to regional patterns of weather that influence fuel moisture contents and wind speed, rather than ecosystem propeties that affect fuel loads and structure. (Bessie and Johnson 1995) There is increasing evidence that climatic conditions such as severe drought, not fuels, ultimately control fire size and intensity…The point is that climatic conditions are the most important factor in nearly all large fires. (Cascadia Times, May, 1996) ...thinning has done little to slow the spread or intensity of flames in most big western fires.... In most big fires "there is no relationship between the condition of the stand before the fire, and whether it burns or not"...(Portland Oregonian, January 12, 1997) While the two latter statements may not flow directly to from the Bessie and Johnson paper, people discussing this topic with me have cited this paper as evidence for the "weather hypothesis." Bessie and Johnson do an excellent job in establishing weather as a primary factor affecting wildfire size in subalpine forests near the boreal forest ecotone in Alberta, and the title of their paper clearly states that it focuses on subalpine forests. As none of the tree dominants are fire resistant (all are thin-barked), these fires are also high-severity fires. However, the implied generality of some statements in the paper have encouraged others, including those quoted I the popular press, to conclude that the results of this study are applicable everywhere. Evidence from studies in other areas suggests that these statements should not be generalized to all forest types."
8-3/4		"Fire intensity was correlated to annual area burned; large area burned years had higher	Information on the science that was	No changes or additions are needed. As stated in the title of the paper, the focus of the research discussed in this paper was on

		fire intensity predictions than smaller area burned years. The reason for this difference was attributed directly to the weather variable frequency distribution, which was shifted towards more extreme values in years in which large areas burned. During extreme weather conditions, the relative importance of fuels diminishes since all stands achieve the threshold required to permit crown fire development. This is important since most of the area burned in subalpine forests has historically occurred during very extreme weather (i.e., drought coupled to high winds). The fire behavior relationships predicted in the models support the concept that forest fire behavior is determined primarily by weather variation among years rather than fuel variation associated with stand age." Bessie, W. C. Ph.D. and E. A. Johnson Ph.D. "The Relative Importance of Fuels and Weather on Fire Behavior in Subalpine Forests" *Ecology*, Vol. 76, No. 3 (Apr., 1995) pp. 747-762. Published by: Ecological Society of America http://www.jstor.org/pss/1939341	used for the fire analysis is presented in the Fire Ecology/Air Quality specialists' report. Little additional response is needed because the paper isn't relevant to the project area.	Subalpine Forests. Agee (1997) (cited by Mr. Artley in 8-3/1) stated: "…Bessie and Johnson do an excellent job in establishing weather as a primary factor affecting wildfire size in subalpine forests near the boreal forest ecotone in Alberta, and the title of their paper clearly states that it focuses on subalpine forests. As none of the tree dominants are fire resistant (all are thin-barked), these fires are also high-severity fires. However, the implied generality of some statements in the paper have encouraged others, including those quoted I the popular press, to conclude that the results of this study are applicable everywhere. Evidence from studies in other areas suggests that these statements should not be generalized to all forest types."
8-3/16	Gray Lit PNW GTR-355 fire behavior in forests in OR & WA	"In general, rate of spread and flame length were positively correlated with the proportion of area logged (hereafter, area logged) for the sample watersheds. Correlation coefficients of area logged with rate of spread were > 0.57 for five of the six river basins (table 5). Rate of spread for the Pend Oreille and Wenatchee River basins was strongly associated (r-0.89) with area logged. Correlation of area logged with flame length were > 0.42 for four of six river basins (table 5). The Deschutes and Methow River basins showed the strongest relations. All harvest techniques were	This is an article on forested landscapes in Oregon and Washington. The fire analysis is based on knowledge of the project area, the best available science and information that	No changes or additions are needed. This GTR analyzed the results of logging operations in Oregon in 1995, and the effects on fire behavior and smoke production. The objectives of the thinning proposed by the 4FRI would have very different post-treatment conditions than logging in or earlier than 1995. The methods described for analyzing fire behavior and smoke production could be applied to the 4FRI, however, more recent research and methods were available and were used in the DEIS.

		associated with increasing rate of spread and flame length, but strength of the associations differed greatly among river basins and harvesting methods." (pg.9) "As a by-product of clearcutting, thinning, and other tree-removal activities, activity fuels create both short- and long-term fire hazards to ecosystems. The potential rate of spread and intensity of fires associated with recently cut logging residues is high, especially the first year or two as the material decays. High fire-behavior hazards associated with the residues can extend, however, for many years depending on the tree. Even though these hazards diminish, their influence on fire behavior can linger for up to 30 years in the dry forest ecosystems of eastern Washington and Oregon." Huff, Mark H. Ph.D.; Ottmar, Roger D.; Alvarado, Ernesto Ph.D. Vihnanek, Robert E.; Lehmkuhl, John F.; Hessburg, Paul F. Ph.D. Everett, Richard L. Ph.D. 1995. "Historical and current forest landscapes in eastern Oregon and Washington. Part II: Linking vegetation characteristics to potential fire behavior and related smoke production" Gen. Tech. Rep. PNW-GTR-355. USDA Forest Service, Pacific Northwest Research Station. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/4706/PB96155213.pdf;jsessionid=C8DDB611DB29D3716BBF313AADBA2E70?sequence=1	apply to those ecosystems, and experience with similar projects in similar vegetation. Methods used for analyzing fire behavior can be found under 'Methodology' on pages 16 - 22 of the Fire Ecology / Air Quality report. Additional information is in Appendix D on pages 283 – 321. Methods used for analyzing emissions can be found under 'Methodology' on page 25 of the Fire Ecology / Air Quality Report. Additional information is in Appendix F on pgs 329 – 330.	
8-3/31		"We inferred climate drivers of 20th-century years with regionally synchronous forest fires in the U.S. northern Rockies. We derived annual fire extent from an existing fire atlas	Invalid link, but was able to find it using Google	No changes or additions are needed. There is no additional information or concern brought forward. This paper is not relevant to the 4FRI because it discusses an analysis done in Idaho and Montana, and area where large scale climate shifts

		that includes 5038 fire polygons recorded from 12070086 ha, or 71% of the forested land in Idaho and Montana west of the Continental Divide. The 11 regional-fire years, those exceeding the 90th percentile in annual fire extent from 1900 to 2003 (>102314 ha or ~1% of the fire atlas recording area), were concentrated early and late in the century (six from 1900 to 1934 and five from 1988 to 2003). During both periods, regional-fire years were ones when warm springs were followed by warm, dry summers and also when the Pacific Decadal Oscillation (PDO) was positive. Spring snowpack was likely reduced during warm springs and when PDO was positive, resulting in longer fire seasons. Regional-fire years did not vary with El Nino-Southern Oscillation (ENSO) or with climate in antecedent years. The long mid-20th century period lacking regional-fire years (1935-1987) had generally cool springs, generally negative PDO, and a lack of extremely dry summers; also, this was a period of active fire suppression. The climate drivers of regionally synchronous fire that we inferred are congruent with those of previous centuries in this region, suggesting a strong influence of spring and summer climate on fire activity throughout the 20th century despite major land-use change and fire suppression efforts. The relatively cool, moist climate during the mid-century gap in regional-fire years likely contributed to the success of fire suppression during that period. In every regional-fire year, fires burned across a range of vegetation types. Given our results and the projections for warmer springs and continued warm, dry summers, forests of	Scholar. In order for comments to result in improved analysis and decisions, they need to be within the scope of the project, relevant to the project and have a direct relationship to the proposed actions. We could not find meaningful recommendations or comments for the Responsible Official to consider.	and patterns are very different from the southwest.

		the U.S. northern Rockies are likely to experience synchronous, large fires in the future." Morgan, Penelope Ph.D., Emily K. Heyerdahl Ph.D., and Carly E. Gibson 2008 "**Multi-season climate synchronized forest fires throughout the 20th century, Northern Rockies**", *Ecology*, 89, 3: 717-728. http://www.firelab.org/index.php?option=com_jombib&task=showbib&id=343		
8-3/40		"We question the validity of thinning as a means both to reduce the threat of wildfire and to restore historic forest structure in the absence of site-specific data collection on past and present landscape conditions." Platt, Rutherford V. Ph.D., Thomas T. Veblen Ph.D., and Rosemary L. Sherriff **"Are Wildfire Mitigation and Restoration of Historic Forest Structure Compatible? A Spatial Modeling Assessment"** Published Online: by the by Association of American Geographers. Sep. 8, 2006 http://www.ingentaconnect.com/content/routledg/anna/2006/00000096/00000003/art00001	See response to 8-3/28	See response to 8-3/28
8-3/43		"No evidence suggests that spruce–fir or lodgepole pine forests have experienced substantial shifts in stand structure over recent decades as a result of fire suppression. Overall, variation in climate rather than in fuels appears to exert the largest influence on the size, timing, and severity of fires in subalpine forests (Romme and Despain 1989, Bessie and Johnson 1995, Nash and Johnson 1996, Rollins et al. 2002). We conclude that	Link is broken, but came up on a google search. In order for comments to result in improved analysis and decisions, they	No changes or additions are needed. This paper is not relevant to the 4FRI. The quote Mr. Artley chose to use clearly indicates that the discussion is about spruce/fir or lodgepole pine forests and does not apply to the 4FRI. An additional sentence in the abstract further underlines this: "The idea that decades of fire suppression have promoted unnatural fuel accumulation and subsequent unprecedentedly large, severe wildfires across

		large, infrequent stand replacing fires are "business as usual" in this forest type, not an artifact of fire suppression." (Pg. 666) "Variation in daily area burned was highly correlated with the moisture content of 100-hour (2.5- to 7.6- cm diameter) and 1000-hour dead fuels (Turner et al. 1994). Once fuels reached critical moisture levels later in the season, the spatial pattern of the large, severe standreplacing fires was controlled by weather (wind direction and velocity), not by fuels, stand age, or firefighting activities (Minshall et al. 1989,Wakimoto 1989, Turner et al. 1994)." (Pg. 666) Schoennagel, Tania Ph.D., Thomas T. Veblen Ph.D., and William H. Rommie Ph.D. "**The Interaction of Fire, Fuels, and Climate across Rocky Mountain Forests**" *Bioscience*, July 2004 / Vol. 54 No. 7 http://www.montana.edu/phiguera/GEOG430/PurdyFireFieldTrip/Schoennagel_et_al_2004_Bioscience.pdf	need to be within the scope of the project, relevant to the project and have a direct relationship to the proposed actions. We could not find meaningful recommendations or comments for the Responsible Official to consider.	western forests has been developed primarily from studies of dry ponderosa pine forests."
8-3/48		"Why is the natural fire regime in most Rocky Mountain ponderosa pine–Douglas fir forests variable in severity? Extended droughts and high winds can lead to exceptional fire spread across a broad spectrum of fuel loads and forest structures. For example, almost 25,000 ha of ponderosa pine– Douglas fir forest burned on a single day (9 June 2002), driven by strong winds (Finney et al., 2003). Yet, brief episodes when the winds declined and fuel moisture	This a 273 page Enviromental Assessment from the Wallowa-Whitman NF. In order for comments to result in improved analysis and decisions, they	No changes or additions are needed. There are no new concerns or information brought forward. Additional comments in the portion of the Finney paper included: "Fuels across the landscape were generally continuous, with no recent wildfires or fuel management activities occurring downwind of the ignition location for perhaps 10 miles. Surface fuels generally consisted of ponderosa pine duff and needle litter, short grass, and occasional patches of brush. Low crowns of the

		rose, led to low-severity fire in the same landscape (Finney et al., 2003), suggesting that extreme weather, not fuels, was the chief cause of high-severity fire under those conditions. Even during summer, ponderosa pine–Douglas fir landscapes in the Rocky Mountains are subject to rapid increases in wind speed and changes in direction from jet streams or cold fronts (Baker, 2003).” (pg. 5) USDA Forest Service BALD ANGEL VEGETATION MANAGEMENT PROJECT ENVIRONMENTAL ASSESSMENT. La Grande Ranger District, Wallowa-Whitman National Forest December 2006 https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/6608/Wallowa_Whitman_Bald_Angel_Vegetation_Management_EA.pdf?sequence=1	need to be within the scope of the project, relevant to the project and have a direct relationship to the proposed actions. We could not find meaningful recommendations or comments for the Responsible Official to consider.	predominating conifer species (ponderosa pine, Douglas-fir, and blue spruce) facilitated transition from surface to crown fire.” Even in the most extreme fire weather conditions and topography, there can be no high severity crown fire if there is no way for the fire to get into the crowns.

Artley CARA #8 Attach **#8/** opposing views # 1-34	**TOPIC: Benefit from Fire**	**Comment/Issue and link to publication**	**Response – What does DEIS and report say? What does FEIS/ROD say?**	**Analysis – Conclusion** Is anything changing in FEIS and report? If so, why? If not, why?
8-8/21		“Trees that survive the fire for even a short period of time are critical as seed sources and as habitat that will sustain many elements of biodiversity both above and below ground. The dead wood, including large snags and logs, is second only to live trees in overall ecological importance.”	Information may be found in the Fire Ecology / Air Quality Report. Both are available on the 4FRI website at: http://www.fs.usda.gov/main/4fri/hom	

		Noss, Reed F. Ph.D., Jerry F. Franklin Ph.D., William Baker, Ph.D., Tania Schoennagel, Ph.D., and Peter B. Moyle, Ph.D. "**Ecological Science Relevant to Management Policies for Fire-prone Forests of the Western United States**" Society for Conservation Biology, February 24, 2006 http://www.nifc.gov/fuels/downloads/planning/EcologicalScience.pdf	e See the response to #8-8/1 for more information on how the 4FRI is managing for snags.	
8-8/26		"Species that breed exclusively in the first 30 years after fire may be difficult to maintain in the ecosystem without fire. Fire exclusion and post-fire salvage of dead trees after fire may reduce populations of these species over large geographic areas." Smith, Jane Kapler, ed. "**Wildland Fire in Ecosystems: Effects of Fire on Fauna"** USDA Forest Service Rocky Mountain Research Station. *General Technical Report RMRS-GTR-42*-volume 1. January 2000. http://nps.gov/fire/download/fir_eco_wildlandfireJan2000.pdf	For information about what the 4FRI DEIS says about the role of fire, please see response #8-8/3. Additional information may be found in the Fire Ecology / Air Quality Report. Both are available on the 4FRI website at: http://www.fs.usda.gov/main/4fri/home	No changes or additions are needed. No new concerns or information are brought forward. Salvage logging is out of the scope of this project.

Pg	Name	Comment/Issue	Response – What do the DEIS and report say? Is there an additional analysis that covered this? What did it say? (Rim Lakes, for example)	Analysis – Conclusion is anything changing in FEIS and report? If so, why? If not, why
1, 2	Cara 148 & 149 Chad Hanson:	Further, the DEIS (p. 158, Table 58) states that the Proposed Action and Preferred Alternative would result in only 1-2% active crown fire (high-severity fire), and only	The bulk of the science relating to fire regimes in southwestern ponderosa pine does not agree with Williams and Baker (2012, 2013). Fulé et al. (in press), refute the conclusions of Williams and Baker, and describe in detail how the preponderance of scientific evidence indicates that conservation of dry forest ecosystems in the West and their ecological, social, and economic values is not consistent with a contemporary	No changes or additions to the Fire Ecology/Air Quality Specialists'

	John Muir Institute	3% passive crown fire (mixed-severity fire). Williams and Baker (2012) found that the historic forests had 15% high severity fire effects and 23% mixed-severity fire effects (Williams and Baker 2012, Table 2, indicating that the action alternatives would not restore historic fire regimes but, rather, would take forests outside of the natural, historic range of variability, compromising ecological resilience. This information, though well known to the Forest Service, is simply not addressed in the DEIS, in violation of NEPA"...	disturbance regime of large, high severity fires, especially under changing climate. Fulé et al. in press) has 18 co-authors, the majority of whom are well published in peer-reviewed journals. It seems unlikely that a paper published in 2012 would be 'well known to the Forest Service', since the majority of research does not align well with the findings of Williams and Baker (2012).	report or the DEIS. The opposing science that is brought up here is sufficiently offset by existing and new science supporting the proposed actions.
3	"	b) The FRCC model assumes that the areas that have missed the highest number of fire intervals (FRCC3) will burn unnaturally severely (much more than FRCC2, e.g.), with predominately high-severity fire effects. However, the DEIS fails to divulge the fact that every single scientific study that has empirically tested the FRCC model has found it to be invalid, and all studies have concluded that the areas with the highest FRCC ratings burn predominately at low/moderate-severity, and do not burn more severely than areas with lower FRCC ratings (Odion et al. 2004, Odion and	b) It is inaccurate to say that "The FRCC model assumes that the areas that have missed the highest number of fire intervals (FRCC3) will burn unnaturally severely (much more than FRCC2, e.g.), with predominately high-severity fire effects." FRCC considers the departure from whatever the natural/historic fire regime is. For example, in ecosystems such as lodgepole pine or boreal forests, the natural fire regime is for high severity fire. It those cases, high severity fire would be considered FRCC1. Without a list of studies, we are not sure which studies are included in 'every single scientific study'. For a given biophysical setting, an FRCC assessment combines fire regime departure (frequency and severity) with vegetation departure between the reference (historical) and current periods. Simply put, FRCC = similarity to reference conditions (in regards to fire regime and vegetation). A low rating (FRCC1) means that key ecosystem components are intact. A high rating (FRCC3) implies that key ecosystem components are at risk. FRCC is not a measure of fire risk. The classes are based on changes (from reference conditions) in age, structure, species composition, and stand density and are used to quantify the condition of the land resulting from fire exclusion and other influences (timber harvesting, grazing, fragmentation, insects, disease, and the introduction and establishment of non-native plant species).	No changes or additions to the Fire Ecology/Air Quality Specialists' report or the DEIS. Not much specific information given that relates to the 4FRI.

		Hanson 2006, Odion and Hanson 2008, Odion et al. 2010, Miller et al. 2012, van Wagtendonk et al. 2012).	In response to the steady increase of large and high severity wildfires the FS and Interior developed the National Fire Plan and used the 2000 FRCC definition and maps. The Healthy Forest Initiative used the 2000 FRCC definition and maps and a 2002 finer-scale estimate of FRCC of 190 million acres on federal lands of FRCC3. The Healthy Forest Restoration Act used similar information and incorporated direction for use of the Interagency FRCC guidebook for assessment, inventory, monitoring, and reporting. In addition FRCC has been adopted as a federal agency Performance Measure. (Schmidt et al. 2002, Hardy et al, 2000). Understanding, maintaining and restoring ecosystems requires some level of "base datum" for understanding how the land functions in a healthy condition - reference conditions (Fulé et al., 1997; Swetnam et al., 1999). There are a multitude of studies specific to southwest ponderosa pine and to the Coconino/Kaibab spanning the last six decades. These studies show that the fire regime in southwestern ponderosa pine was a frequent fire return interval of low intensity/low severity surface fire. That does not necessarily mean there was no crown fire, but it was the exception. Additionally, it is/was the effects of land management (including fire suppression) over the last century that allowed the forest structure to become unnaturally dense, resulting in the potential for large, high intensity fires over large areas (Allen et al., 2002; Cooper, 1960; Covington and Moore, 1994; Fulé et al., 1997; Fulé et al., 2001; Heinlein et al., 2005; Mast et al., 1999; Savage and Mast, 2005; Weaver, 1951). Estimates of the fire return interval in the project area range from 2 to 22 years (Dietrich and Swetnam, 1998; Fulé et al., 1997; Fulé et al., 2003; Swetnam, 1990; Swetnam and Baison, 1996; Van Horne and Fulé, 2006). However, in Odion and Hanson 2008, there is no specificity in terms of the types of forest. 'Conifer' forests are not all equal in fire regimes, so the information in that paper is irrelevant and it incorrectly infers that, in effect, all conifer forests can be classified together regarding fire regimes. Odion et al. (2004) discusses fire in northern California. Odion et al. 2010 discusses the relationship of sclerophyllous vegetation with 'forested' areas in north-western California. Ponderosa pine has distinct variabilities within its geographic range (refer to Oliver, W.W. and R.A. Ryker. 1990. Pinus ponderosa. Pp. 413-424 in R.M. Burns and B.H. Honkala (technical coordinators) Silvics of North America, Vol. 1. Agri. Handbook 654, USDA For. Serv., Washington, D.C.), and the populations of ponderosa pine in northern Arizona have some fundamental genetic differences (Conkle and Critchfield, 1988 Genetic Variation and Hybridization of Ponderosa Pine' in Symposium Proceedings). Miller et al. (2012) state that fire size and frequency are on the rise but, though fire size and frequency are important, they do not necessarily scale with ecosystem effects of fire, as different ecosystems have different ecological and evolutionary relationships with fire. They further conclude that the percentage of high-severity fire in 'conifer-dominated' forests was generally higher in areas dominated by smaller-diameter trees than in areas with larger-diameter trees. Additionally, they found that "where fire has been excluded for many years, less severe effects	

			are frequently noted in mature Douglas-fir forests than in mature ponderosa pine forests…”. VanWagtendonk et al. (2012), concluded that “*At the lowest elevations, the lower montane zone…consists of a mix of ponderosa pine…and Douglas-fir…and white fir… . Low to moderate severity surface fires are relatively frequent in the lower montane zone…*. That is the only reference to ponderosa pine. Douglas-fir and ponderosa pine have very different morphologies, producing very different flammability. Douglas-fir has smaller, denser needles and branches, making it a much more effective ladder fuel than ponderosa pine. Overall, these findings support the conclusions of the 4FRI analysis though, as stated above.	

Pg / comment	**Cara**	**Comment/ Issue**	**Response – What do the DEIS and report say? Is there an additional analysis that covered this? What did it say?**	**Analysis/ Conclusion. Changes to FEIS or specialists' report/s? Why? Why not?**
3-2	Cara 180 & 204 CBD	“This is best accomplished…include both severe and moderate (*e.g.,* 97th and 85th percentile…) fire weather…potential treatments (see “fuel treatments” below)	There is no literature cited to support this statement. When weather percentiles are modeled, it is less representative of real fire behavior than modeling the conditions under which a large fire has actually occurred. Additionally, when modeling percentile, there is no way to check to be sure the modeled behavior is likely to reasonably represent potential fire behavior. When modeling a fire that has actually occurred, it is possible to calibrate the model so there is more assurance that modeled behavior has some relation to expected behavior under conditions that have produced a large, high severity fire. From Appendix D in the Fire Ecology report: Generally, 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 (as opposed to modeling fire behavior at the X%ile of temperature, humidity, or some other individual factor). Sometimes fire behavior is modeled, but it is more useful for 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	This and other requests addressing weather percentile modeling indicated a need to add more details on what it is and why it isn't appropriate for 4FRI. A short analysis (as indicated above) was completed and added to Appendix D

			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 …Callibration 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." While there are weather indices, such as Energy Release Component (ERC), or Burning Index (BI), which are sometimes modeled by percentiles, and there are specific weather variables for each of these percentiles. Using the 97th percentile ERC or BI, and using the weather parameters associated with it is not the same as modeling the 97th weather percentiles. We used FireFamily Plus to analyze 12 years of data (2001 – 2012) from the Flagstaff Automated Weather Station (RAWS). Using data from 1968 through 2012, we determined 97th percentile weather for two periods of time during the fire season. The first period was from April 15th though July 15th, in order to roughly correspond with the most extreme fire season (Partial). The other period was from April 15th though September 15th, to include monsoon and some post-monsoon (Full). There are numerous variables that could be included. We used Maximum Temperatures (MxT); Minimum Relative Humidity (MinRH), Wind Speed (WS), and fuel moisture for 1 and 10 hour dead fuels because these parameters are the most important to fire spread. Of the 1,836 days between April 15th and September 15th, there were no days on which all weather factors reached the 97th percentile for either the Partial or Full periods. Wind is the single most important fire weather factor for wildfire spread in the project area. The 97th percentile wind occurred on 16 days for the full period (0.9% of the days), and 11 days of the partial (0.6% of the days). 97th percentile wind was 22 mph for the full period, and 23 for the partial. 97th	in the Fire Ecology report.

			percentile winds co-occurred with up to two other variables on 7 days (0.4% of days) for the Full period, and for none of the Partial period. Concern has been expressed that using 20 mph wind is not representative. For the Full period, 20 mph was the 95th percentile, and for the Partial it was ~91%ile. We have added columns to Table 2 in the Fire Ecology report for the percentiles on the day of the Schultz Fire, as well as 97th percentile weathers as described above. In the project area, wind is the single most important weather factor. 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. Regarding the suggestion that configurations of different 'fuel' treatments be considered – that would be appropriate if this was a fuels reduction project. Since 4FRI is a restoration project, treatments were determined based on site potential, habitat, and other restoration objectives, not specifically to change fire behavior. Decreased fire behavior one of the results of restoration in the project area.	
7-1	Cara 180 & 204 CBD	Most old growth forests that historically….Large tree removal is not necessary or beneficial to restoration of fire-adapted forest ecosystems (Arno 2000, Allen at al. 2002)	The closest references in Arno (2000) that could be considered relevant to this discussion are on page 103 of Arno (2000): "*…Silvicultural cutting and pile burning or removal of excess small trees may be necessary to allow successful application of prescribed fire and to return to more open structures dominated by vigorous trees of seral species* (Arno and others 1995a)". In this context, the assumption is, apparently, that the discussion of 'removing small trees' implies that no other trees should be removed. There is no discussion of 'large' trees in Arno (2000). In the two papers cited within Arno (2000) (which CBD did not cite (Arno and others 1995a and Arno and others 1995b)), the only reference to 'large' trees is of trees greater than 30 inches in diameter. Additionally, those two papers specifically discuss ponderosa pine in western Montana, where fire regimes in ponderosa pine are significantly longer than in the southwest, and forest structure would, therefore, differ somewhat from ponderosa pine forests with more frequent fire regimes. Arno (2000), states: "*…ponderosa pine type in western Montana, mean fire intervals averaged between 25 and 50 years (Arno and others 1995b.)* "*Failed attempts to restore more natural stand conditions with prescribed burning alone may result from inappropriate use of fire as a selective thinning tool in dense, fire-excluded stands, or from burning too little or too much of the accumulated forest floor fuels*". This is one of the few references to thinning in the papers cited by Arno (2000) and, clearly, does not support any specifics in regards to tree size and thinning.	No changes or additions are needed, though some of these references could be added to the DEIS and/or specialists' reports. Their citations don't support the conclusions they state.

			"The frequent disturbance cycles can also produce and maintain large old trees characteristics of pre- 1900 forests and of high value…using a modified selection system and periodic burning can be used to maintain remnant old growth stands and to create future old growth (Fiedler 1996, Fiedler and Cully 1995)." We agree that frequent disturbance (in the form of fire) can produce and maintain large, old trees, and that large, old trees were a dominant characteristic of historic forests in the project area. Pgs 104 - 120 of this reference discuss Redwoods, Oregon Oak Woodlands, Doug-fir, California Red Fir, and other forest types that do not occur in the project area. Allen et al., 2002, mentions 'large' trees in the following contexts: "*Uncertainties in the reconstruction of forest stand composition and spatial structure result from missing evidence, such as logs and stumps removed by fire, logging, and decay (M. M. Moore, D. W. Huffman, W. W. Covington, J. E. Crouse, P. Z. Fule, and W. H. Moir, unpublished report to USDA Forest Service, Rocky Mountain Station, Flagstaff, Arizona). Reconstruction of the density and location of large trees is far more reliable than of small-diameter stems and seedlings that decompose rapidly…"* We agree with this statement. The ephemeral quality of seedlings and saplings is attributable to the disturbance regime (including fire), and leaves few tangible signs. Old trees and large trees were more likely to leave evidence as to what their historic role/s were in forest structure, as well as a record of some components of climate and disturbance in the form of tree rings and fire scars. *"Utilize existing forest structure. – Restoration efforts should incorporate and build upon valuable existing forest structures such as large trees and groups of trees of any size with interlocking crowns…Since evidence of long-term stability of precise tree locations is lacking, the selection of "leave" trees and tree clusters in restoration treatments can be based on the contemporary spatial distribution of trees, rather than pre-1900 tree positions. Historical forest structure conditions can be restored more quickly by maximizing use of existing forest structure. Leaving some relatively dense within-stand patches of trees need not compromise efforts to reduce landscape-scale crown fire risk"* The proposed treatments in 4FRI do exactly this, and are described in more detail in the implementation guide (Appendix D in the DEIS). The existing condition of the project area includes areas where trees have grown large by CBD definitions (>16" dbh), though they may be decades or even centuries younger than other trees nearby – which may actually have a	

			smaller dbh. The proposed treatments distinguish between 'old' trees and 'large' trees, as described in this example from the Implementation Plan on page 614 of the Implementation Plan (Appendix D in the DEIS): ***"Manage for the sustainability of individual/isolated old ponderosa pine trees as defined in the old tree implementation strategy by reducing crown competition and increasing growing space adjacent to these trees. Remove ponderosa pine trees up to 18 inches dbh that do not meet the old tee definition and whose crowns are outside the old tree crown drip line: (1) within a 50-foot radius that are in the intermediate or suppressed crown positions and (2) that would eliminate direct crown competition on two of the rour sides of the old tree. No trees larger than 24-inch dbh would be cut."*** Additionally, the Forest Service has incorporated the Old Growth Protection and Large Tree Retention Strategy (OGPLTRS), developed by the Stakeholders, into the Implementation Plan included in the DEIS. That describes in detail the conditions under which trees greater than 16" could be cut if necessary to meet treatment objectives. *"Retain trees of significant size or age.—Large and old trees, especially those established before ecosystem disruption by Euro-American settlement, are rare, important, and difficult to replace. Their size and structural complexity provide critical wildlife habitat by contributing crown cover, influencing understory vegetation patterns, and providing future snags. Ecological restoration should protect the largest and oldest trees from cutting and crown fires, focusing treatments on excess numbers of small young trees. Given widespread agreement on this point,* ***it is generally advisable to retain ponderosa trees larger than 41 cm (16 inches) dbh and all trees with old-growth morphology regardless of size (i.e., yellow bark, large drooping limbs, twisted trunks, flattened tops). Despite the heterogeneity of forest site and stand conditions in the Southwest, cutting of larger trees will seldom be ecologically warranted as ''restoration'' treatments at this time due to their relative scarcity. Following this guideline would significantly reduce hazards of stand-replacing fires in most cases and also favor the development of future old-growth forest conditions (Moir and Dieterich 1988, Harrington and Sackett 1992).*** *Public concern about forest manipulation would also be reduced by ensuring that ''large'' trees are not being targeted."* See previous response. *"In Southwestern ponderosa pine ecosystems this means reducing tree density and ladder fuels along with associated crown fire risk, protecting large trees, restoring surface fires, and increasing herbaceous ground cover and overall biodiversity levels…Existing forest structures, such as tree groups and large trees, should not be removed simply to recreate historical tree*	

			spatial patterns…" We are distinguishing between large trees and old trees and, as written in the DEIS and the Implementation Plan, there are only two conditions under which an old tree may be cut (safety or the expectation of greater ecological disturbance if the tree is not cut). Conditions under which trees >16" dbh) MAY be cut if needed to meet treatment objectives are specified as described in the OGPLTRS, and would be evaluated on a site by site basis. Finally, refer to CBD's comment letter, page 11, paragraph 29 which states "*it meets the purpose and need by actively managing hazardous fuels and forest structure, even to the extent that it specifically allows for removal of large trees in limited circumstances, as distinct from a broad "diameter cap*." While this does not give specifics for when/which trees should be cut, it clearly implies that sometimes large trees will need to be cut.	
11-1	Cara 180 & 204 CBD	c) "Thus, large tree structure enhances forest resistance to severe fire effects (Arno 2000, Omi and Martinson 2002, Pollett and Omi 2002) whereas removing them may undermine forest resilience (Brown et al. 2004, Countryman 1955, Naficy et al. 2010).	c) See response on page 7 Naficy et al. (2010) describe a difference in forest structure between areas that were logged and had fire exclusion, and areas that were logged prior to 1960 and had fire exclusion. Their data show that areas that were logged and had fire "…have higher average stand density, greater homogeneity, more standing dead trees, and a greater abundance of fire-intolerant trees than the unlogged, fire-excluded stand…propose that ponderosa pine forests with these distinct management histories likely require a distinct restoration approach…" However, this research was done in the northern Rockies, and the response could be different in southwestern ponderosa pine and the associated climate. The 4FRI proposed treatments were developed stand by stand, to take into consideration the conditions of each stand, as well as soil type, landscape patterns, and special designations (such as MSO habitat). Omi and Martinson (2002) found that diameter and height are critical variables associated with tree resistance to fire damage, and that' "fuel treatments" that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management'. They also concluded that 'crown fire propagation is dependent on the abundance and horizontal continuity of canopy fuels…'. The proposed treatments in 4FRI are intended to restore, or put on a trajectory towards restoration of, historic forest structure, including groups and interspaces. The interspaces would be expected to provide sufficient discontinuity in canopy fuels so that, if a group of trees experienced crown fire, it would drop to the ground before the fire reached another group of trees.	No changes or additions are needed.
11-2	Cara 180 & 204	Research demonstrates no advantage in fire hazard mitigation resulting from treatments that remove	See response to comment 6. In places where large trees potentially would be removed, the objective would not be 'fire hazard mitigation'…or anything very close to that. It would be restoration of forest structure, which	No changes or additions are needed.

	CBD	large trees compared to treatments that retain them. Treatments that removed only trees smaller than 16-inches diameter were marginally more effective at reducing long-term fire hazard than so-called “comprehensive” treatments that removed trees in all size classes (Fiedler and Keegan 2002). Thinning small trees and pruning branches of large trees to increase canopy base height significantly decreases the likelihood of crown fire initiation (Graham et al. 2004, Keyes and O’Hara 2002, Omi and Martinson 2002, Perry et al. 2004, Pollett and Omi 2002), which is a precondition to active crown fire behavior (Agee 1996, Graham et al. 2004, Van Wagner 1977). Low thinning and underburning to reduce surface fuels and increase canopy base height at strategic locations effectively reduces fire hazard at a landscape scale and meets the purpose and need. (2) Large tree retention	would have a side benefit of improving potential fire behavior and effects. The description in the comment about cutting small trees and pruning branches of large trees is described as ‘thinning from below’, and has few applications to restoration. If this was done at a landscape scale, there would be large areas of closed-canopy forest as these areas continued to mature, and the canopies continued to close up. Pollett and Omi (2002) determined that removing small diameter trees may be beneficial for reducing crown fire hazard. This research was specifically done in reference to fuels treatments and, though the principle is clearly sound in regards to a method of reducing the immediate potential for crown fire initiation, it is not a prescription for how to implement restoration of ponderosa pine ecosystems. There is an important difference between groupy stand structure with interspaces and even- aged removal of small trees. The Fire and Fuels extension to the Forest Vegetation Simulator as used in the fire behavior/fuels analysis and in the Fiedler and Keegan 2002 study cited here by CBD, is not spatial, which makes it unable to quantify changes in spatial distribution of fuels. It can only provide stand averages, so that fuel characteristics are modeled as if they are evenly distributed across a stand. FlamMap outputs are spatial and, by using Landfire data, fire behavior can be represented across a 30m x 30 m grid. Finney (2001) assumes a post treatment fuel model that will not readily carry fire. This is not a result expected or observed in project area ecosystems and therefore is not applicable to this project. Additionally, Finney’s analysis was conducted specifically with an objective of reducing fire behavior and hazard, not restoration. The removal of a few larger trees may sometimes be needed to meet treatment objectives for improving habitat and/or restoring the structure, pattern and/or composition of the landscape. Furthermore, these cited studies (Pollet and Omi 2002) deal specifically with fuels reduction while the objectives of the 4FRI are to restore composition, structure and functions that support ecological functions across the landscape. Prescribed fire will be used along with thinning with the expectation that it would raise canopy base heights, address surface fuels, and thin seedlings and some small saplings as indicated in the Finney 2001 study, along with multiple other functions of fire that are discussed in the Fire Ecology Report. This project was planned using site-specific (stand-level) forest vegetation/fuels data. The effects of the alternatives on stand structure and fire behavior have been examined and disclosed using this site-specific information as the basis for the analysis. The best available science, methodology and analysis tools were utilized (Forest Vegetation Simulator and the Fire and Fuels Extension for forest vegetation and fuels, Flammap for fire behavior, and numerous other models and data described in detail in the Fire Ecology and Air Quality Report in the ‘Methodology’ section). This analysis documents decreases in undesirable fire behavior and effects for alternatives B, C, and D. This analysis is far more relevant to the project landscape than the non-local research cited by CBD.	Cited references were cherry-picked and/or are not applicable – non-local data where there is local data available.

		avoids significant cumulative impacts.		
11-3	Cara 180 & 204 CBD	Large trees are not abundant at any scale in ponderosa pine or mixed conifer forests in the Southwestern Region (Covington and Moore 1994, Fulé et al. 1997, USDA 1999, USDA 2007a, USDOI 1995). They are the most difficult of all elements of forest structure to replace once they are removed (Agee and Skinner 2005). The ecological significance of old growth forest habitat and large trees comprising it is widely recognized (Friederici 2003, Kaufmann et al. 1992). There is no scientific basis for extracting large trees to promote fire resistance in ponderosa pine and mixed conifer forest (Allen et al. 2002, Brown et al 2004, DellaSala et al. 2004).	See response to page 7, which includes Allen et al. 2002. Comments addressing mixed conifer are not pertinent to this proposed action since there are no treatments proposed in mixed conifer. Brown et al. 2004 state "Diameter limits, such as restricting removal to trees <30 cm (12") or <50 (20") cm is one way to approach the problem, but the limit should vary by site. Trees that invaded some forests after fire exclusion became effective can exceed 50 – 60 cm (20 – 24") diameter, whereas on other sites trees that are 200 years old can be well below this size…third principle is to decrease crown density by thinning overstory trees, making tree-to-tree crowning less probable" So, while Brown et al. 2004 explicitly do not advocate the cutting of large, fire resistant trees, they clearly do advocate the thinning of some overstory trees in some cases. Depending on the definition of 'large tree', this is likely to include some 'large' trees. DellaSala et al. 2004 discuss concerns (largely credited to Brown et al. 2004) about harvesting of 'large, fire resistant trees' and all references in this paper are credited to Brown et al. 2004. A particularly clear statement: "Retention of large and old trees can be a particularly contentious issue. In generally, however, removal of large, old trees is not ecologically justified and does not reduce fire risk…". As discussed earlier, 4FRI does not expect to be cutting old trees with two exceptions: 1) Safety and 2) If not cutting a tree results in greater ecological disturbance, such as moving a road. Large trees could only be cut under circumstances described in detail in the LTRS, and would not be targeted. As discussed earlier, treatments proposed under the 4FRI distinguish between large trees and old trees, with each being treated differently, and both having more restrictions than smaller and/or younger trees.	No changes or additions needed. Comment cherry-picks papers and makes conclusions not supported by cited papers.
11-4 runs on to pg 12	Cara 180 & 204 CBD	In addition to their rarity, a variety of factors other than logging threatens the persistence of the remaining large trees in Southwestern conifer forests. Prescribed fire can	Broadcast burning will be conducted under conditions expected to meet treatment objectives, including minimizing damage to old trees. We acknowledge that throughout the life of this project, it is likely that some large and/or old trees would be damaged or killed by prescribed fire. It would not be possible to mitigate every large and/or old tree on 40,000 acres of fire units each year. However, implementation strategies are included that would mitigate these effects as documented in the DEIS Appendix B.	No changes or additions are needed. Concerns here are already addressed in

		injure exposed tree roots that have migrated into accumulated duff layers and cause high levels of post-treatment mortality among large trees (Sackett et al. 1996)…	Alternative A analyzes the potential effects of not thinning and burning. Alternative D analyzes the potential effects of just thinning in most forested areas (no prescribed fire would be implemented).	the DEIS as cited.
12-1	Cara 180 & 204 CBD	McHugh and Kolb (2003) describe unplanned and prescribed fire effects on ponderosa pine forest structure in northern Arizona…	McHugh and Kolb (2003) compared the Dauber Prescribed Fire and the Side and Bridger-Knoll Wildfires. The Dauber prescribed Fire data suggested that as diameter increased, mortality decreased, but findings in the wildfires showed as diameter increased mortality increased. The DEIS addresses the expected surface, passive, and active crown fire under each plan alternative under burning parameters that would be expected to produce an undesirable fire behavior and effects under current conditions. Under prescribed fire conditions, fire behavior and effects would be significantly decreased under prescribed fire parameters. The DEIS (Appendix C; FE12 in Table 111) and the Fire Ecology, Fuels, & Air Quality Specialist Report (Appendix E) describe mitigations when burning in areas with large or old trees as follows: "When practicable, damage or mortality to old trees, and large trees would be mitigated by implementing prescription parameters, ignition techniques, raking, wetting, thinning, compressing slash, or otherwise mitigating fire impacts to the degree necessary to meet burn objectives and minimize fireline intensity and heat per unit area in the vicinity of old trees. Trees identified as being of particular concern (e.g. trees with known nests or roots for herons, eagles, osprey, or other raptors, occupied nest cores, or critical areas in PACs) would be managed in accordance with wildlife design features (see wildlife). Prepare old trees 1 year or more before a burn if possible."	No changes or additions are needed. The concerns described are addressed in the DEIS and the Fire Ecology/Air Quality report.
25-1	Cara 180 & 204 CBD	The work of Prather and others (2008) is particularly relevant to this analysis because it is: (1) specific to the project area; (2) consistent with the purpose and need; (3) representative of the best available science…	Treating as little as possible is not an objective of the 4FRI. The intent is to evaluate restoration needs on a landscape scale, and propose treatments accordingly. We are in consultation with FWS, and our proposed treatments are expected to improve habitat, not degrade it. One of the reasons Prather gives for not treating more acres is the limitations of the USFS (as of 2008) to treat more acres. "…Arguments that treatments within owl habitat are generally unnecessary are short-sighted. Treatments within MSO habitat could result in considerable benefits, both for communities and MSO habitat…some treated areas can be managed for future owl habitat…Mexican spotted owls require large diameter trees and snags…Low-intensity thinning of such areas…" We are doing this…	No changes or additions needed. The cited literature does not contradict our proposed actions, and can be used to support it.
28-1 goes on to pg.	Cara 180 &	The density, composition and structure of intermediate fuel	We agree that crown fuel structure is a critical component for predicting the potential for crown fire. The Crown Bulk Density (CBD) metrics used are from FVS outputs, determined from Common Stand Exam data. The desired condition for CBD is based on the Rim Lakes analysis	No changes or additions needed.

29	204 CBD	strata…Prediction s bout the relationship of forest structure…information based on field observations… The environmental analysis should ensure professional and scientific integrity with site-specific information based on field observations (Weatherspoon and Skinner).	(Nicolet, 2011), for which a similar analysis was done, ***and for which there were no objections***. An average across the treatment area is a very coarse measure intended to indicate movement towards desired conditions. It is expected that there would be a great deal of variability within the treatment area. The stand data used is located in the project record in the silvicultural data and in the fire modeling data. Stand data were used to inform the Landfire data used for fire modeling. Stand data are the best data available for modeling forest structure. In the process of the fire modeling, multiple field trips were taken to verify, to the degree possible over 600,000 acres, the accuracy of the data. The literature cited for the sentence "The environmental analysis should ensure professional and scientific integrity with site-specific information based on field observations (Weatherspoon and Skinner 1995)" is a study from Northern California that determined Fire Damage Classes (FDC) for a variety of forest types based on scorch and consumption of tree crowns in plantations and in uncut and partial-cut stands. They used aerial photos to determine crown damage. They had no site-specific data, and did no ground truthing of their data because "…To do an adequate job of on-site sampling of the large area and great diversity of conditions included in our study would have required time and resources far beyond those available to us…" . Their conclusion was "Thus the variability of fuels within the strata, and associated variability in fire behavior and fire damage, evidently were sufficient to mask any detectable effect of recorded fuel loadings. If this assumption is correct, it points to a need for more site-specific data on fuels."	There's nothing here to address, except the implication that the data/process used did not have 'professional and scientific integrity' or was not site-specific or was not based on field observations.
29-1 goes on to pg. 30	Cara 180 & 204 CBD	Omi and Martinson (2002: 22). That research was retroactive and the scale of observed fire events confounds replication. However, it noted that results can be extrapolated to sites other than those studied…	Omi and Martinson found that CBD did correlate with observed fire effects, specifically crown scorch, a significant indicator of tree mortality. Omi and Martinson (2002) stated: "Agee (1996) has suggested a crown bulk density threshold of 0.1 kg/ha as a general determinant for active crowning under extreme fire conditions. It is notable that all of our treated areas averaged at or below this threshold, while all untreated areas averaged above…However, crown bulk density was not the fuel hazard variable most strongly correlated to fire severity at our study sites; in fact it was significantly correlated only to crown volume scorch. Instead, height to live crown, the variable that determines crown fire initiation rather than propagation (Van Wagner 1977), had the strongest correlation to fire severity in the areas we sampled. Like Pollet and Omi (2002), we also found the more common stand descriptors of stand density and basal area to be important factors. But especially crucial are variables that determine tree resistance to fire damage, such as diameter and height. Thus, "fuel treatments" that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management." Fire modeling, a necessary part of this kind of NEPA, does not use stand density or basal area. It is difficult to monitor the change in crown fire potential (active or passive), since the real test comes in the form of a wildfire, so modeling changes to fuel characteristics are often used as a proxy. Canopy bulk density is an important variable in modeling fire for determining the potential for active crown fire (Stratton 2009).	No changes or additions are needed. No new data are presented, nor are there requests for any analyses that have not been completed.

29-2	Cara 180 & 204 CBD	Active management of the arrangement and volume of surface fuels…	We agree that managing fuel loading and structure are critical components of restoration. The components listed (surface fuel structure, canopy base height, topography, and weather), are the components in the fire behavior triangle: fuel, topography, weather. This is basic fire behavior science, and is included in the analysis and in the modeling that was used. If large trees are removed, it would be under conditions described in the incorporation of the Large Tree Retention Strategy which was written by the Stakeholder group.	No changes or additions are needed.
31-2 goes on to pg. 32	Cara 180 & 204 CBD	The direction of fire spread (backing, flanking, heading) is an important consideration because fire interacts with weather, topography, and vegetation to "back" and "flank" around certain conditions, or "head" though others as it spreads (Graham et al. 2004).	There are no 'fuel treatments' proposed by the 4FRI, they are restoration treatments (differences are described in the response to paragraph 29 of the CBD comment letter). Treatment intensities were designed based on soil types, landscape patterns, land designations, and other considerations, including potential fire effects and behavior. Fire behavior is a primary objective in NEPA projects for which the primarily purpose is fuels reduction, and improved fire effects are a side-benefit of addressing fire behavior. Fire effects are a primary objective when restoration is the purpose of the project and, in ponderosa pine, decreased fire behavior is a side-benefit of restoration treatments. The analysis did include different treatments in different locations, but based it on restoration need and habitat, not strictly on potential fire behavior. See response to page 10 on fuel treatments vs. restoration treatments. 'Fuels treatments' are not a part of this project. The management of unplanned ignitions is out of the scope of this project, but is covered in the forest plans for both the Coconino and Kaibab National Forests.	No changes or additions are needed.

Pg/	**Cara, Name**	**Comment/ Issue**	**Response – What do the DEIS and report say? Is there an additional analysis that covered this? What did it say?**	**Analysis, Conclusion. Changes in the FEIS or specialists' report/s? Why? Why not?**
7/1	Cara 109 Firstenberg	1. Woods, K.W. et al. 2012. Carbon Commodities Funding Forest Restoration Draft Report. Prepared for M. Selig. Grand Canyon Trust. (cited on page 323) This is a draft of an unpublished report—not even a study—that is unavailable and is apparently based on	**1. Woods et al 2012** **DEIS pg 323:** "Burn Frequency and Carbon Storage: 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. Figure 47 displays carbon storage per acre comparing a no action "baseline" scenario with 10- and 20-year fire return intervals in a ponderosa pine forest of northern Arizona (adapted from Woods et al. 2012)." **Fire Ecology pg 252:** ""…Woods et al. (2012) found that, although burn frequency affectd the rate and total amount of carbon storage in a ponderosa pine	No changes or additions are needed. No new concerns or information are presented that are not already addressed in the EIS or specialists reports.

		Hurteau and North 2009 (below). 2. Hurteau, M., and M. North 2009. Fuel treatment effects on tree-based forest carbon storage and emissions under modeled wildfire scenarios. (cited on page 328) **a**: this is a study from the moist Sierra Nevada, not the dry Southwestern desert, and **b**: its conclusion at any rate is the opposite of what the DEIS claims, because the DEIS fails to consider soil carbon. "When totaled over a century and added to the wildfire emissions, total released C{arbon} was greater than in the non-burn treatments," say Herteau and North. "Current C{arbon} accounting practices can be at odds with efforts to reduce fire intensity," they say. 3. Hurteau, M. et al. The carbon costs of mitigating high-severity wildfire in southwestern ponderosa pine. *Global Change Biology* (2011) 17:1516-1521. (cited on p. 325) All this study claims to say is that there is 2.3 times as much carbon in our forests today	forest, both 20 year and 10 year fire return intervals produced forests that were net carbon sinks, while the no action alternative forest bcame a net carbon source…" **Fire Ecology pg 254**: "In the long term (e.g.100 years) the action alternatives would create more resilient forests, less prone to stand replcing events and subsequently able to store more carbon by an increased availability of live trees, longer lived wood products (in the form of large trees), and energy products created from resulting slash which are used in the place of fuels (North and Hurteau 2011, Soreson et al. 2011, Woods et al. 2012). ***Response***: The final report was issued later in 2012, with no changes in conclusions, and the reference has been updated in the final report. Reviews and syntheses of multiple research studies have always been a valuable source of information. Combining and/or comparing multiple datasets in one document can produce added value because the studies can be viewed in context with others, and the combined data sets may strengthen or weaken conclusions from the individual studies, and/or produce new conclusions by remixed data and conclusions. Woods et al. (2012) took data and results from published studies (mostly from Northern Arizona) and synthesized a new study to estimate the potential for restoration efforts (4FRI in particular) to mitigate the risk of catastrophic wildfire and stabilize carbon storage in ponderosa pine forests. The study specifically addressed the area proposed for treatment by the 4FRI, so is certainly pertinent. This study received… This report is available upon request and is in the project record. **<u>2. Hurteau and North 2009</u>** **DEIS pg. 327: "**The low to moderate effects that would result from alternatives B-D should afford for greater carbon storage in southwestern fire-adapted ecosystems over time (Hurteau and North 2009). Research by Hurteau and North (2009) has also shown that the long-term gains acquired through prescribed fire and mechanical thinning outweigh short-term losses in sequestered carbon. In the long term (e.g., 100 years), thinning and burning would create more resilient forests less prone to stand-replacing events and, subsequently, able to store more carbon in the form of large trees." **Fire Ecology pg 252**: "Fuel treatments (e.g. thinning, prescribed fire) as identified in the proposed action, promote low-density stand structures, characterized by	

		than there was in 1876, and that therefore we can afford to remove half the carbon from today's forests to restore "original" conditions – a questionable conclusion based on questionable assumptions about conditions in 1876, and one that does not say that burning a forest turns it into a carbon sink. 4. Savage, M. and J. N. Mast. How resilient are southwestern ponderosa pine forests after crown fires? *Canadian Journal of Forest Research* 35: 967 – 977 (2005). (cited on p. 325) Although cited in the DEIS in support of a statement about carbon emissions, this study does not even contain the word "carbon." 5. Finkral, A. J. and A. M. Evans. The effects of a thinning treatment on carbon stocks in a northern Arizona ponderosa pine forest. *Forest Ecology and Managgement* 255 (2008) 273 – 2750. (cited on p. 327) a) These authors actually say: "How restoration of fire-adapted forests will affect the balance of carbon stocks remains an open question."	larger, fire resistant trees. This strategy should afford for greater carbon storage and southwestern fire adapted ecosystems over time (North et al. 2009, Hurteau and North 2009)." **Fire Ecology pg. 303** "Forests serve as significant carbon reservoirs; however, large-scale fire events can counter this benefit by releasing significant amounts of carbon into the atmosphere. Fuel treatments (e.g., thinning, prescribed fire), as identified in the proposed action, promote low-density stand structures characterized by larger, fire resistant trees. This strategy should afford greater carbon storage in southwestern fire-adapted ecosystems over time (North et al. 2009, Hurteau and North 2009)." ***Response*:** **a**: The objective of the study was to model the amount of live and dead tree based carbon stored and released over 100 years with and without wildfire in the Sierra Nevad mixed conifer after fuel reduction treatments. We agree that mixed conifer is not the same as ponderosa pine, though there can be similarities. (We would also like to point out that the 4FRI area is not 'the dry Southwestern desert'.) The study simulated prescribed fire at "20-year intervals to match the historic fire regime for the Sierran mixed conifer (McKelvey and Busse 1996; North et al. 2005). This is approximately twice the natural fire regime of the ponderosa pine within the area proposed for treatment by the 4FRI. **b**: Hurteau and North state that "Model runs show that, after a century of growth without wildfire, the control stored the most C. However, when wildfire was included in the model, the control had the largest total C emission and largest reduction in live-tree-based C stocks. In model runs including wildfire, the final amount of tree-based C sequestered was most affected by the stand structure initially produced by the different fuel treatments. In wildfire-prone forests, tree-based C stocks were best protected by fuel treatments that produced a low-density stand structure dominated by large, fire-resistant pines." The sentence following the quote Mr. Firstenburg provided in reference to "…greater than non-burn treatments" is: "Recent research suggests that immediate wildfire emissions may only be a portion of actual C losses, if the fire leaves few surviving trees (Kashian *et al*. 2006). Auclair and Carter (1993) calculated that high-intensity, postwildfire C release was approximately three times the	

		b) Their study area was near Flagstaff, in the region of this project, and they estimated a 2.8% annual risk of fire in the area. This is a 36-year fire rotation, contradicting the frequent-fire assumption that the Forest Service is using to justify burning the area every 5 years. 7. Wiedinmyer, C. and M. D. Hurteau. Prescribed Fire as a means of Reducing Forest Carbon Emissions in the Western United States. Even this study does not say what the Forest Service wants it to say. These authors caution that "this work does not address important considerations such as the feasibility of implementing wide-scale prescribed fire management or the cumulative emissions from repeated prescribed burning."	direct release of CO2 during the fire event. In ponderosa pine, direct flux measurements found higher CO2 emissions from a high-intensity burn than those from an unburned site, even 10 years after fire (Dore *et al*. 2008). Future research may more effectively incorporate these C losses associated with high-intensity fire into models, but, in this paper, we compare only direct C emissions occurring during the fire." The final paragraph of the paper is "In forests that historically burned with high frequency and low severity, adding to the C baseline by increasing stocking levels may exacerbate the modern shift toward high-severity fire produced by fire suppression and climate change. Current C accounting practices can be at odds with efforts to reduce fire intensity in many western US forest types. Although the concept of restoring forests in the western US to some pre-settlement target may not be feasible as the climate changes, reducing fire severity and increasing and stabilizing tree-based C storage may be achieved with fuel treatments that promote low-density, large pine-dominated stand structures." We think there are sufficient similarities in the 4FRI area and in the area modeled in this study (particularly those areas with pine dominated stands) *in regards to carbon sequestration*, that this study, when combined with others, provides some valid information that is pertinent to the analysis. **3. Hurteau et al. 2011** **DEIS pg 325: "**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). In alternative A, 34 percent of the area would have the potential for high-severity fire effects from crown fire. Large-scale fire events that could occur with no treatment (alternative A) could release significant amounts of carbon into the atmosphere." **Fire Ecology pg. 252**: "Although fire-excluded forests contain higher carbon stocks, this benefit is outweighed in the long term by the loss that would result from uncharacteristic stand replacing fires (Hurteau et al. 2011)" **Fire Ecology pg. 303**: (same as page 252 – straight out of the Kaibab forest plan). ***Response*****:** The stated purpose of this study was to "determine if current	

			aboveground forest carbon stocks in fire-excluded southwestern ponderosa pine forest are higher than prefire exclusion carbon stocks reconstructed fom 1876, quantify the carbon costs of thinning treatments to reduce high-severity wildfire risk, and compare posttreatment (thinning and burning) carbon stocks with reconstructed 1876 carbon stocks.” This study is not cited in the DEIS or in the Fire Ecology report as a reference for the idea that ‘burning a forest turns it into a carbon sink’, though it does point out that high severity fire can turn a forest into a carbon source. It is cited to support the statement (which we agree with) that fire-excluded forests contain more carbon that non-fire excluded forests (this is pretty obvious, so we’ll assume Mr. Firtenberg has no problem with that part of the statement. It is also supporting that idea that these forests are at greater risk of high-severity fire than non-fire excluded forests. Mr. Firstenburg finds conclusions and assumptions in the paper ‘questionable’, but does not specify why, so it’s hard to know how to respond. The following is from this paper “The carbon carrying capacity of a forest represents the amount of C that can be maintained in the system given climatic conditions and natural disturbance regimes, and barring human disturbance (Keith et al., 2009, 2010). Fire is a natural disturbance in the ponderosa pine forests of the southwestern United States.”, and we will assume Mr. Firtenburg holds no issues with those statements. The next statement explains that fire regimes in southwest ponderosa pine have been altered by human intervention, causing “a transition from frequently, low-severity fire to infrequent, high-severity fire…”. This statement is supported by the preponderance of research on fires in southwestern ponderosa pine (see page 38 in the Fire Ecology Draft report). **4. Savage and Mast 2005.** **DEIS pg. 59: “**Closed-canopy, single-storied forest stands are more susceptible to crown fires and changes to fire regimes, as well as long-term conversion from forested plant communities to shrub- and herbaceous-dominated vegetation types (Savage and Mast 2005).**”** **DEIS pg. 155**: “In 2020, no RUs would meet desired conditions for fire behavior, ranging from 42 percent (RU 1) to 14 percent (RU 6) (table 55). In RU 1, there is potential for 60,000 acres of ponderosa pine to burn with high severity (potential crown fire combined with the potential for high severity surface fire), a subset of	

			which would convert to a nonforested vegetation type (Savage and Mast 2005).” **Fire Ecology pg. 41**: “Current conditions inhibit the survival and recruitment of large trees though competition and threaten the maintenance of ecological systems by fueling increasingly extensive crown fires. These fires have the potential to alter the successional trajectories of post-burn vegetation creating entirely different communities than those existing before such events (Savage and Mast 2005…” **Fire Ecology pg. 66**: “…It would be expected that some of the ponderosa habitat that burns with high severity would have potential to go though a type conversion, becoming non-forested (Savage and Mast 2005).” **Fire Ecology pg. 109**: “…High severity fires in ponderosa pine may cause changes to vegetation type/species composition are likely to persist for decades or longer… It is unlikely that many dense stands of ponderosa pine could be sustained for long, so the true “no-action” alternative is extensive mortality through fire or pathogens. Post-mortality biomass may be a different type of ecosystem, such as a persistent shrub type, grass-dominated system, or unnaturally dense ponderosa pine (Savage and Mast 2005).” **Fire Ecology pg. 111**: “…Where high severity fire occurs in pine/oak, the result in some areas may be persistent oak brush fields where oak and other shrubs are likely to sprout (Ffolliott and Gottfried 1991, Savage and Mast 2005).” **Fire Ecology pg. 251**: “Savage and Mast (2005) showed that these conditions can persist for decades.” ***Response***: Is Mr. Firstenburg suggesting that the integrity of a forest structure and species composition is not relevant to carbon sequestration or climate change dynamics? **5. Finkral et al. 2008** **DEIS pg. 327**: “Mechanical treatment 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 (Finkeral and Evans 2008, Wiedinmyer and Hurteau 2010).” **Fire Ecology pg. 252:** “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)…" ***Response*:** a) The statement, as posed, is intended to set up the relevance of their study in the introduction. They discuss some of the research that has been done on restoration and carbon sequestration, and point out that "…dense forests have become a sink for carbon and an offset to the rising concentrations of greenhouse gases in the atmosphere…', but conclude that in a stand-replacing fire, a thinned stand would release 2410 kg C ha_1 less to the atmosphere than an untreated stand. However, the thinning treatment resulted in stand structural changes that make the stand less likely to support a crown fire and therefore more likely to avoid the carbon releases associated with crown fires, even under extreme fire conditions. So the decrease in C released would be even lower. b) The 2.8% number includes all the successful suppression efforts over the 15 years used to calculate the annual risk (1986 – 2000), and only included fires >50 acres. The actual number of ignitions is much greater than that, and forest conditions that support high severity/high intensity fire have increased in the 14 years since the (Sisk et al. 2004) study was completed. It is unclear where the 'every 5 years' number comes from that Mr. Firstenburg uses to describe what he thinks the USFS has been doing. Regardless of the source, Fire Rotation and 'every 5 years' are not the same thing. Fire Rotation is the length of time necessary for an area equal to the entire area of interest to burn. Fire Return Interval (implied by 'every 5 years') is the period of time between fires at a given point, or the arithmetic average of all fire intervals in a given area over a given time period. The 4FRI analysis does not discuss Fire Rotation, as it is not relevant to the analysis. The preferred Average Fire Return Interval in the ponderosa pine in the project area is 10 years. This is supported by the preponderance of published scientific literature (see Fire Ecology Report pg. 48). **7. Wiedinmyer and Hurteau 2010.** **DEIS pg. 327**: "Mechanical treatment 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 (Finkeral	

			and Evans 2008, Wiedinmyer and Hurteau 2010).” **Fire Ecology pg. 252**: “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). They found that while the treatment initially produced a 30% reduction in the carbon held in 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. “ **Fire Ecology pg. 303**: “Prescribed burning helps to mitigate the negative impacts of stand-replacing fire in dry, dense forests by consuming less biomass and releasing less carbon into the atmosphere (Wiedinmyer and Hurteau 2010).” ***Response***: Wiedinmyer and Hurteau (2010) begin their abstract with the following: “Carbon sequestration by forested ecosystems offers a potential climate change mitigation benefit. However, wildfire has the potential to reverse this benefit. In the western United States, climate change and land management practices have led to increases in wildfire intensity and size. One potential means of reducing carbon emissions from wildfire is the use of prescribed burning, which consumes less biomass and therefore releases less carbon to the atmosphere.” The complete sentence, of which the first half is quoted by Mr. Firstenburg is as follows: “Although this work does not address important considerations such as the feasibility of implementing wide-scale prescribed fire management or the cumulative emissions from repeated prescribed burning, it does provide constraints on potential carbon emission reductions when prescribed burning is used.” The sentence before this one is conclusive: “Wide-scale prescribed fire application can reduce CO2 fire emissions for the western U.S. by 18-25% in the western U.S., and by as much as 60% in specific forest systems.” The conclusions of this study support the actions proposed in the 4FRI EIS, and was not cited in relation to operations/ implementation. It’s hard to understand how Mr. Firstenburg would imply it doesn’t support actions proposed by the 4FRI.	

9/3	Cara 109 Firstenberg	Not only do the cited studies not support what is claimed, but there is good science, ignored in the DEIS, saying in no uncertain terms that burning the forests contributes to climate change. Sebastiaan Luyssaert et al., Old-growth forests as global carbon sinks, Nature 455: 213-215 (2008), says that forests up to 800 years old, if left alone, remain net carbon sinks. Campbell, J.L. et al., Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions? Frontiers in Ecology and the Environment 10:83-90 (2012), concludes that ten acres must be treated with prescribed fire to prevent one acre from burning in a wildfire, and therefore that prescribed fire, if practiced on a large scale, is a significant source of carbon emissions contributing to climate change.	**Sebastiaan et al. 2008** discusses old growth forests and, as Mr. Firstenburg points out, forests up to 800 years old, if left alone, remain net carbon sinks. Unfortunately, the caveat 'if left alone' is highly pertinent to the 4FRI landscape. In the last 100 – 150 years grazing, fire suppression, and logging have significantly decreased the resilience of this landscape to natural disturbances, including wildfire. This study generalizes conditions across the globe, and is not sufficiently site specific, or vegetation type specific to be useful for this analysis. **Campbell et al. 2012** evaluated the effects of fuel treatments and wildfire on forest C stocks. With the exception of 535 acres of fuel reduction in a WUI area, the 4FRI is proposing restoration treatments, not fuel treatments. They state: "…removing fine canopy fuels (i.e. leaves and twigs) practically necessitates removing the branches and boles to which they are attached, conventional fuel-reduction treatments usually remove more C from a forest stand than would a wildfire burning in an untreated stand…". The treatments proposed in the 4FRI are not at all 'conventional fuel-reduction' treatments. They are restoration treatments which are designed to produce and/or promote multi-story/multi-age stands. Campbell et al. state that: "A full accounting of C would also include the fossil-fuel costs of conducting fuel treatments, the longevity of forest products removed in fuel treatments, and the ability of fuel treatments to produce renewable "bioenergy", potentially offsetting combustion of fossil fuels." They go on to describe limits on the potential contributions of fossil fuel costs, forest products, and biofuels. Other research efforts (Finkral and Evans 2008, Bagdon and Huang 2014, Hurteau and North 2009, Hurteau et al. 2008, Sorensen et al. 2011).	No changes or additions are needed. No new concerns or information are presented that are not already addressed in the EIS or specialists reports.
10/1	Cara 109 Firstenberg	The truth is that "Removing canopy trees leads to a hotter, drier, windier microclimate." (William L. Baker, Forest Ecology in Rocky Mountain Landscapes, Island Press, Washington, D.C., 2009, p. 373). Thinning closed-canopy	If all else is the same (surface fuel loading, etc.), we agree there can be more intense fire in an area that is thinned. The following is from the Fire Ecology report (pgs. 28 – 29): "Reducing canopy fuel loading may increase surface fire behavior because more wind and sunlight can reach the surface, however overall fire behavior is more significant: "Modifying canopy fuels as prescribed in this method may lead to increased surface fire intensity and spread rate under the same environmental conditions, even if surface fuels are the same before and after canopy treatment. Reducing	No changes or additions are needed. No new concerns or information are presented that are not already addressed in the EIS or specialists reports.

		forests leads to higher fire intensity because of lower fuel moisture and higher wind speed. (R.V. Platt et al. Are wildfire mitigation and restoration of historic forest structure compatible? A spatial modeling assessment. Annals of the Association of American Geographers 96:455-70 (2006).	CBD to preclude crown fire leads to increases in the wind adjustment factor (the proportion of 20-ft windspeed that reaches midflame height). Also, a more open canopy may lead to lower fine dead fuel moisture content. These factors increase surface fire intensity and spread rate. Therefore, canopy fuel treatments reduce the potential for crown fire at the expense of slightly increased surface fire spread rate and intensit. However, critical levels of fire behavior (limit of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires, as all crown fires are uncontrollable. Though surface intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally controllable" (Scott 2003). However, following prescribed fire, surface fuel loading would be lower, effectively decreasing the potential fire intensity."	
10/2	Cara 109 Firstenberg	Removing half the volume of a western white pine stand in northern Idaho lowered fuel moisture by about one-third (L.G. Hornby. Fuel type mapping in Region One. Journal of Forestry 33:67-71 (1935), increased wind speed six- to ten-fold, and increased the number of critical fire days four-fold (G.M. Jemison. The significance of the effect of stand density upon the weather beneath the canopy. Journal of Forestry 32:446-51 (1934)). No published science supports the Forest Service's misguided opinion.	See above.	No changes or additions are needed. No new concerns or information are presented that are not already addressed in the EIS or specialists reports.
11/1	Cara 109 Firstenberg	On page 180, it is said that in the no-action alternative, "understory development would remain suppressed and continue to decline." This contradicts page 187, which emphasizes that "ladder fuels," i.e. understory development,	Ladder fuels and understory are not equivalent. Ladder fuels are any fuels that can provide sufficient fire intensity (flame lengths) for a surface fire to transition into a crown fire. 'Understory', in this case (page 180), refers to the herbaceous understory and will be changed to clarify the intent.	No changes or additions are needed. No new concerns or information are presented that are not already addressed in the EIS or specialists reports.

		need to be eliminated. Which is it? Is there too much or too little understory development under current conditions?		'Understory' needs to be changed to 'Herbaceous understory' on page 180 where Mr. Firtenberg references it.

Cara / Commenter	**Reference**	**Comment**	**Response**
Cara 207 Attach 7 2013-0529liningerCBD_1606mst Pgs. 2 - 5	Westerling, A. L., H. G. Hidalgo, D. R. Cayan, T. W. Swetnam. 2006. 'Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity'. *Science* 313, 940	Referenced once. Page 3: "Foreseeable climate change and chronic drought are likely to influence wildland fires to become larger and more frequent at a landscape scale (Running 2006, Seager and Vecchi 2010, Westerling et al 2006)."	Cited in the Fire Ecology/Air Quality specialists' report.
Cara 207 Attach 7 2013-0529liningerCBD_1606mst Pgs. 6 - 10	Pollet, J., and P. N. Omi. 2006. 'Effect of Thinning and prescribed burning on wildfire severity in ponderosa pine forests'. *International Journal of Wildland Fire* 11:1 - 10	Referenced as follows: 1) "Thus, large tree structure enhances forest resistance to severe fire effects (Arno 2000, Omi and Martinson 2002, Pollett and Omi 2002), wheras removing them may undermine forest resilience…" pg. 11 2) "Thinning small trees and pruning branches of large trees to increase canopy base height significantly decreases the likelihood of crown fire initiation (Graham et al. 2004, Keyes and O'Hara 2002, Omi and Martinson 2002, Perry et al. 2004, Pollett and Omi 2002), which is a precondition to active crown fire behavior (Agee 1996, Graham et al. 2004, Van Wagner 1977)." pg. 11 3) "Others question the premise of that	1) From the response to comments: "The description in the comment about cutting small trees and pruning branches of large trees is described as 'thinning from below', and has few applications to restoration. If this was done at a landscape scale, there would be large areas of closed-canopy forest as these areas continued to mature, and the canopies continued to close up. Pollett and Omi (2002) determined that removing small diameter trees may be beneficial for reducing crown fire hazard. This research was specifically done in reference to fuels treatments and, though the principle is clearly sound, it is not a prescription for how to implement restoration of ponderosa pine ecosystems." 2) From the response to comments: "Furthermore, these cited studies (Pollet and Omi 2002) deal specifically with fuels reduction while the objectives of the 4FRI are to restore composition, structure and functions that support ecological functions across the landscape. Prescribed fire will be used along with thinning with the expectation that it would raise canopy base heights, address surface fuels, and thin seedlings and some small saplings as indicated in the Finney 2001 study, along with multiple other functions of fire that are

		contention on the basis that fire weather can overwhelm any effect of fuel treatments on fire behavior (*e.g.*, Perry et al. 2004, Pollett and Omi 2002). To accurately assess fuel treatment effects on the likelihood of crown fire initiation and spread, it is necessary to consider: (1) surface fuel density and arrangement; (2) canopy base height; (3) local topography; and (4) weather patterns (Graham et al. 2004, Hunter et al. 2007). The former two factors can be actively managed in ponderosa pine and dry mixed conifer forest to significantly decrease the likelihood of crown fire initiation and spread without resort to large tree removal in most cases (Fielder and Keegan 2002, Keyes and O'Hara 2002, Omi and Martinson 2002, Perry et al. 2004, Pollett and Omi 2002)." Pg. 29 4) "Prescribed burning is the only treatment that effectively reduces activity fuels and fire hazard below pre-logging conditions (Stephens 1998, van Wagtendonk 1996). "Periodic underburns and programs for restoring natural fire are critical to maintain these post-harvest stands" (Pollett and Omi 2002: 9)." Pg. 31	discussed in the Fire Ecology Report." 3) We agree that managing fuel loading and structure are critical components of restoration. The components listed (surface fuel structure, canopy base height, topography, and weather), are the components in the fire behavior triangle: fuel, topography, weather. This is basic fire behavior science, and is included in the analysis and in the modeling that was used. If large trees are removed, it would be under conditions described in the incorporation of the Large Tree Retention Strategy which was written by the Stakeholder group. 4) We agree with this statement and, although the 4FRI does not provide any direction for managing unplanned ignitions, treatments are expected to improve the decision space and flexibility for line officers deciding how to manage wildfires. This reference is also cited in specialists' report.
Cara 207 Attach 7 2013-0529 CBD_160 6mst Pgs. 11 - 25	Naficy, C., A. Sala, E. G. Keeling, J. Graham, and T. H. DeLuca. 2010. 'Interactive effects of historical logging and fire exclusion on ponderosa pine forest structure in the northern Rockies'. *Ecological Applications* 20(7): 1851 - 1864	1) "Thus, large tree structure enhances forest resistance to severe fire effects, (Arno 2000, Omi and Martinson 2002, Pollett and Omi 2002), whereas removing them may undermine forest resilience (Brown et al. 2004, Countryman 1955, Naficy et al 2010). Pg. 11 2) "Logging slash produces higher flame lengths and more intense surface fires that can increase the probability of crown fire initiation compared to fuels that pre-exist logging operations (Dodge 1972, Naficy et al. 2010, Stephens and Moghaddas 2005). Pg. 30	1) From the response to comments: "Naficy et al. (2010) describe a difference in forest structure between areas that were logged and had fire exclusion, and areas that were logged prior to 1960 and had fire exclusion. Their data show that areas that were logged and had fire "…have higher average stand density, greater homogeneity, more standing dead trees, and a greater abundance of fire-intolerant trees than the unlogged, fire-excluded stand…propose that ponderosa pine forests with these distinct management histories likely require a distinct restoration approach…" However, this research was done in the northern Rockies, and the response could be different in southwestern ponderosa pine and the associated climate. The 4FRI proposed treatments were developed stand by stand, to take into consideration the conditions of each stand, as well as soil type, landscape patterns, and special designations (such as MSO habitat).."

		3) “Such features may include natural openings, meadows, relatively open ridges, moist riparian areas, mature forest patches with shaded and cool microclimates and little or no history of past logging (*e.g.*, Countryman 1055, Naficy et al. 2010), and areas where fuel treatments already have been completed. Pg. 32	2) The comment was made as part of a description of how CBD interprets the results of implementation of Alternative D. We generally agree with them, and the assertion that slash would increase flame lengths/fireline intensity is real. 3) The context under which it is used here is out of the scope of the 4FRI (‘compartmentalized landscape fire management’)
Cara 207 Attach 7 2013-0529lining erCBD_16 06mst Pgs. 31 - 70	Omi, P. N., and E. J. Martinson. 2002. ‘Effect of Fuels Treatment on Wildfire Severity’. Western Forest Fire Research Center, Colorado State University	1) “Thus, large tree structure enhances forest resistance to severe fire effects (Arno 2000, Omi and Martinson 2002, Pollett and Omi 2002), whereas removing them may undermine forest resilience…” Pg. 11 2) “Thinning small trees and pruning branches of large trees to increase canopy base height significantly decreases the likelihood of crown fire initiation (Graham et al. 2004, Keyes and O’Hara 2002, Omi and Martinson 2002, Perry et al 2004, Pollett and Omi 2002)., which is a precondition to active crown fire behavior…”. Pg. 11 3) “The former two factors can be actively managed in ponderosa pine and dry mixed conifer forest to significantly decrease the likelihood of crown fire initiation and spread without resort to large tree removal in most cases (Fielder and Keegan 2002, Keyes and OHara 2002, Omi and Martinson 2002, Perry et al. 2004…”. Pg. 29 4) “Omi and Martinson (2002) measured the effect of fuel treatments on fire severity in highly stratified forest sites in the western United States and reported a strong correlation of crown base height with “stand damage” by fire. Importantly, crown bulk density did not	1 & 2) Omi and Martinson (2002) found that diameter and height are critical variables associated with tree resistance to fire damage, and that’ “fuel treatments” that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management’. They also concluded that ‘crown fire propagation is dependent on the abundance and horizontal continuity of canopy fuels…’. The proposed treatments in 4FRI are intended to restore, or put on a trajectory towards restoration of, historic forest structure, including groups and interspaces. The interspaces would be expected to provide sufficient discontinuity in canopy fuels so that, if a group of trees experienced crown fire, it would drop to the ground before the fire reached another group of trees. 3 & 4) Omi and Martinson found that cbd did correlate with observed fire effects, specifically crown scorch, a significant indicator of tree mortality. Omi and Martinson (2002) stated: “Agee (1996) has suggested a crown bulk density threshold of 0.1 kg/ha as a general determinant for active crowning under extreme fire conditions. It is notable that all of our treated areas averaged at or below this threshold, while all untreated areas averaged above…However, crown bulk density was not the fuel hazard variable most strongly correlated to fire severity at our study sites; in fact it was significantly correlated only to crown volume scorch. Instead, height to live crown, the variable that determines crown fire initiation rather than propagation (Van Wagner 1977), had the strongest correlation to fire severity in the areas we sampled. Like Pollet and Omi (2002), we also found the more common stand descriptors of stand density and basal area to be important factors. But especially crucial are variables that determine tree resistance to fire damage, such as diameter and height. Thus, “fuel treatments” that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management.”

		strongly correlate with observed fire effects: *[H]eight to live crown, the variable that determines crown fire initiation rather than propagation, had the strongest correlation to fire severity in the areas we sampled...* *[W]e also found the more common stand descriptors of stand density and basal area to be important factors. But especially crucial are variables that determine tree resistance to fire damage, such as diameter and height. Thus, "fuel treatments" that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management.* Omi and Martinson (2002: 22)." Pgs 30 & 31	
Cara 207 Attach 7 2013-0529 CBD_160 6mst Pgs. 93 - 103	Stephens, S. L., and J. J. Moghaddas. 2005. 'Silvicultural and reserve impacts on potential fire behavior and forest conservation: Twenty-five years of experience from Sierra Nevada mixed conifer forests'. *Biological Conservation* 125: 369 - 379	1) "Logging slash produces higher flame lengths and more intense surface fires that can increase the probability of crown fire initiation compared to fuels that pre-exist logging operations (Dodge 1972, Naficy et al. 2010, Stephens and Moghaddas 2005)." Pg. 30 2) "Activity fuels may persist for decades: "*In both even aged and un-even aged treatments, it is often assumed that harvest related slash will decompose over time thereby reducing fire hazards. In reality, logging slash may persist for long periods, and therefore, will influence fire hazards for extended periods. Rates of woody fuel decay are highly variable (Lahio and Prescott, 2004). The rates of decomposition of understory fuels are primarily dependant upon several factors including temperature, soil moisture, insect activity, and material size (Lahio and Prescott, 2004). Decaying conifer activity fuels have been reported to persist for30 years in xeric forest environments (Stephens, 2004).* Stephens and Moghaddas (2005: 377)." Pg. 31	This paper refers exclusively to mixed conifer in the Sierra Nevada. There are probably some similarities in some features of fuel loading, there are sufficient data from ponderosa pine systems, that it is not necessary to try to sort out which features are probably the same and which are different.

Cara 207 Attach 7 2013-0529liningerCBD_1606mst Pgs. 104 - 115	van Wagtendonk, J. W. 1996. 'Use of a Deterministic Fire Growth Model to Test Fuel Treatments'. Sierra Nevada Ecosystem Project: Final report to Congress, Vol. II, Assessments and scientific basis for management options.	1) "Those actions are not likely to reduce the elevated fire hazard that results from creation of activity fuels because mechanical logging generates large quantities of slash fuels by relocating tree stems, branches and needles from the overstory canopy to the ground surface (Graham et al. 2004, Stephens 1998, van Wagtendonk 1996…)." Pg. 30 2) "Van Wagtendonk (1996) modeled the effectiveness of low thinning combined with a pile-and burn slash treatment on flat ground, which yielded nearly identical post-treatment fire behavior as thinning without any slash treatment because pre-existing surface fuels were not significantly reduced. Lop-and-scattering of logging slash "significantly increased subsequent fire behavior" (van Wagtendonk 1996: 1160)." Pg. 31 3) "Prescribed burning is the only treatment that effectively reduces activity fuels and fire hazard below pre-logging conditions (Stephens 1998, van Wagtendonk 1996)." Pg. 31	Van Wagtendonk's conclusions apply to post-treatment conditions but, since this study focused on mixed conifer, there would be some differences. There are sufficient data available for ponderosa pine fuels to complete the analysis without referencing this paper and trying to sort out what would apply to southwestern ponderosa pine and what would be more specific to mixed conifer.
Cara 212 Attach 12 2013-0529liningerCBD_1606mst Pgs. 2 - 11	Brown, R. T., J. K. Agee, and J. F. Franklin. 2004. 'Forest Restoration and Fire: Principles in the Context of Place'. *Conservation Biology* Vol 18(4): 903 – 912.	1) "Thus, large tree structure enhances forest resistance to severe fire effects (Arno 2000, Omi and Martinson 2002, Pollett and Omi 2002), whereas removing them may undermine forest resilience (Brown et al. 2004, Countryman 1955, Naficy et al. 2010)." Pg. 11 2) "There is no scientific basis for extracting large trees to promote fire resistance in ponderosa pine and mixed conifer forest (Allen et al. 2002, Brown et al. 2004, DellaSala et al. 2004)." Pg. 11 3) "It must disclose scientific uncertainty	1 & 2) There is no question that large trees are an important component of restoring ponderosa pine forest, but there are other factors that are considered as well Brown et al. (2004) list four factors that line up well with the treatments proposed by the 4FRI. These four factors are: 1) Manage surface fuels to limit the flame length of a wildland fire that might enter the stand. This is generally done by removing fuel though prescribed fire, pile burning, or mechanical removal. This reduces the potential energy of a wildland fire and makes it more difficult for a fire to jump into the canopy (Scott & Reinhardt 2001). 2) Make it more difficult for canopy torching to occur by increasing the height to flammable crown fuels. This can be accomplished though pruning, prescribed fire that scorches the lower crown, ore removal of small trees. 3) Decrease crown density by thinning overstory trees, making tree-to-tree crowning less probable. This will not be necessary on all sites

		regarding its assumption that proposed logging of large and old trees will meet the purpose and need to restore the ecological condition of ponderosa pine forest and the improve old growth habitat and dependent species that remain (*e.g.*, Allen et al. 2002, Brown et al. 2004, DellaSala et al. 2004).” Pg. 15	and will be effective only if linked to the application of the first two principles (Perry et al. 2004). 4) Keep larger trees of fire-resistant species (Hummel & Agee 2003). The treatments proposed by the 4FRI do all of these. ‘Large tree structure’ will not be ‘removed’, though some large trees may be removed under conditions specified in the adaptation of the Large Tree Retention Strategy as adapted into the DEIS. Additionally, Brown et al. (2004) state: “Mid-seral ponderosa pine stands (roughly 60 – 100 years old) represent a secondary priority for restoration treatments. These stands are often developing old-growth characteristics but are usually too dense. Treatments to help maintain this trend can increase the probability that old-growth habitats are restored more quickly than they would be otherwise. Variable-density thinning mimics the clumped distribution and associated processes found in pre-1850 stands (Franklin et al. 1997, Harrod et al. 1999).” 3) There is no ‘proposed logging of large and old trees’. Large trees may be cut under specific circumstances as described above. Old trees will rarely, if ever, be cut, they are not proposed for logging. CBD is aware of that.
Cara 212 Attach 12 2013-0529liningerCBD_1606mst Pgs. 23 - 29	Noss, R. F., P. Beier, W. W. Covington, R. E. Grumbine, D. B. Lindenmayer, J. W. Prather, F. Schmiegelow, T. D. Sisk, and D. J. Vosick. 2006. ‘Recommendations for Integrating Restoration Ecology and Conservation Biology in Ponderosa Pine Forests of the Southwestern United States’. *Restoration Ecology* Vol.	Not cited in comment letter.	This study produced recommendations for integrating principles and practices of restoration ecology and conservation biology for the restoration of ponderosa pine systems. Recommendations made are well aligned with the actions proposed by the 4FRI, and the manner in which the analysis has been conducted. Noss et al. (2006) state: “Available evidence indicates that planning should occur on a regional scale in order to integrate and reconcile multiple objectives (e.g., biodiversity conservation and restoration of ecosystem health). It is also evident that a variety of restoration treatments should be used to spread the risk of failure of any one approach and that a ‘‘one-size-fits-all’’ approach to forest restoration is inappropriate. Such an active adaptive management approach is sensible, but only if pursued rigorously with a valid experimental design and monitoring plan, and including the comparative testing of multiple hypotheses. Reducing road density across the landscape and protecting the remaining old trees from logging, unnatural stand-replacing fire, and uncharacteristic levels of insect and disease attack are perhaps the most needed conservation measures. Such measures will increase the likelihood that biodiversity will persist into a restored state, when natural fire

	14(1):4-10		regimes and informed management complete the integration of restoration and conservation.”
Cara 212 Attach 12 2013-0529liningerCBD_1606mst Pgs. 30 - 43	Perry, D. A., H. Jing, A. Youngblood, and D. R. Oetter. 2004. ‘Forest Structure and Fire Susceptibility in Volcanic Landscapes of the Eastern High Cascades, Oregon. *Conservation Biology* Vol. 18 (4):913-926	1) “Thinning small trees and pruning branches of large trees to increase canopy base height significantly decreases the likelihood of crown fire initiation (Graham t al. 2004, Keyes and O’Hara 2002, Omi and Martinson 2002, Perry et al. 2004… Pg. 11 2) “Predictions about the relationship of forest structure to crown fire hazard depend, in part, on the validity of crown bulk density calculations and estimates (Perry et al. 2004) Pg. 29 3) “Others question the premise of that contention on the basis that fire weather can overwhelm any effect of fuel treatments on the fire behavior (*e.g.*, Perry et al. 2004…” Pg. 29 4) To accurately assess fuel treatment effects on the likelihood of crown fire initiation and spread, it is necessary to consider: (1) surface fuel density and arrangement; (2) canopy base height; (3) local topography; and (4) weather patterns (Graham et al. 2004, Hunter et al. 2007). The former two factors can be actively managed in ponderosa pine and dry mixed conifer forest to significantly decrease the likelihood of crown fire initiation and spread without resort to large tree removal in most cases (Fielder and Keegan 2002, Keyes and OHara 2002, Omi and Martinson 2002, Perry et al 2004…” 5) “Perry and others (2004) investigated the relationship of forest structure to severe fire effects in ponderosa pine forests of the eastern	1) The description in the comment about cutting small trees and pruning branches of large trees is described as ‘thinning from below’, and has few applications to restoration. If this was done at a landscape scale, there would be large areas of closed-canopy forest as these areas continued to mature, and the canopies continued to close up. Pollett and Omi (2002) determined that removing small diameter trees may be beneficial for reducing crown fire hazard. This research was specifically done in reference to fuels treatments and, though the principle is clearly sound in regards to a method of reducing the immediate potential for crown fire initiation, it is not a prescription for how to implement restoration of ponderosa pine ecosystems. 2) Perry et al. (2004) discuss canopy bulk density (CBD) in terms of ponderosa pine in Washington state being encroached by various species of fir, and the potential uses of ‘multi-story’ CBD measurements. While they do appear to have potential, they are not yet usable for modeling fire behavior/effects. From pages 30 and 31 of the comment letter: “Omi and Martinson (2002) measured the effect of fuel treatments on fire severity in highly stratified forest sites in the western United States and reported a strong correlation of crown base height with “stand damage” by fire. Importantly, crown bulk density did not strongly correlate with observed fire effects: *[H]eight to live crown, the variable that determines crown fire initiation rather than propagation, had the strongest correlation to fire severity in the areas we sampled...[W]e also found the more common stand descriptors of stand density and basal area to be important factors. But especially crucial are variables that determine tree resistance to fire damage, such as diameter and height. Thus, “fuel treatments” that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management.* Omi and Martinson (2002: 22).” Omi and Martinson found that cbd did correlate with observed fire effects, specifically crown scorch, a significant indicator of tree mortality. Omi and Martinson (2002) stated: “Agee (1996) has suggested a crown bulk density threshold of 0.1 kg/ha as a general determinant for active crowning under extreme fire conditions. It is notable that all of our treated areas averaged at

		Cascade Range. Even in areas far departed from historical conditions, "[T]here may be a great deal of landscape heterogeneity in the degree of risk and the treatments required to lower risk …" (Perry et al. 2004: 923). Fuel treatments that reduced surface fuel volume by fifty percent (50%) without any tree thinning prevented torching behavior in 13 of 14 experimental plots with modeled wind speeds exceeding 90th percentile conditions for the study area. A "light thinning" of trees smaller than 12-inches diameter coupled with surface fuel reduction prevented torching in the last plot (Perry et al. 2004: 924)." Pg. 29	or below this threshold, while all untreated areas averaged above…However, crown bulk density was not the fuel hazard variable most strongly correlated to fire severity at our study sites; in fact it was significantly correlated only to crown volume scorch. Instead, height to live crown, the variable that determines crown fire initiation rather than propagation (Van Wagner 1977), had the strongest correlation to fire severity in the areas we sampled. 3) CBD interpreted Perry et al. 2004 data to indicate that Perry et al. did not agree that removing large or dominant trees could reduce the resistance to control of control in extreme weather. However, the following is from page 924 of Perry et al. 2004: "*Our study was not designed to address landscape-level fire risk. However, for a hypothetical landscape with a range of stand structures and crown bulk densities similar to our plots, protecting the entire landscape against such extreme conditions would require levels of thinning ranging from relatively light to relatively heavy, where heavy thinning implies removing all trees up to 60 cm dbh*." They continue on by explaining that cutting large, old trees could exacerbate future risk…however, the 4FRI is not proposing to cut old trees. The 4FRI places high value on conserving large trees and retains large trees as a focus. As an added post treatment benefit, the large trees will be more sustainable and less susceptible to loss from density related mortality and other threats such as insects, disease and uncharacteristically severe wildfire. 4) Graham et al. (2004), and Hunter et al. (2007) describe the Fire Triangle, but break up the fuels portion. The Fire Triangle is basic fire science that describes fire behavior as being determined by fuels, weather, and topography. It is a commonly understood theme, for fire/fuels management, that the fuels 'leg' of the triangle is the only one we can actively manage. See answer to #4 as well. 5) See answer to #4. Additionally, the 4FRI is about more than moderating potential fire behavior. It is about creating/recreating structure in forests that often have none or little, and setting the forests back on a trajectory towards conditions closer to historic conditions that will increase the resilience and restore the pattern, composition, and structure of the forests.
Cara 212 Attach 12 2013-0529 CBD_160	Savage, M., and J. N. Mast. 2005. 'How resilient are southwestern	Not cited in the document.	This is a very relevant paper. It is cited in the Fire Ecology/Air Quality Report six times, as well as in the DEIS.

6mst Pgs. 44 - 54	ponderosa pine forests after crown fires? *Canadian Journal of Forestry Research* 35:967 – 977.		
CBD_Cara 209 attachment 9 Pgs 2 - 11	Finney, M. A. 2001. 'Design of Regular Landscape Fuel Treatment Patterns for Modifying Fire Growth and Behavior'. *Forest Science* 47(2).	1) "As a result, severe fire effects often are observed to concentrate at upper slope positions and on ridges, whereas such effects are relatively rare on the lee side of slopes that do not directly receive frontal wind (Finney 2001). Pg. 32 2) "Overlapping fuel treatments that reduce fuel continuity can fragment extreme fire effects into smaller patches if they disrupt heading fire behavior and increase the area burned by flanking and backing fires (Finney 2001)" Pg. 32	We have updated the FEIS and the Fire Ecology/Specialists' report to clarify the difference between 'fuel' treatments and 'restoration' treatments. This paper by Finney is one of the foundations of our current state of the knowledge for fuels treatments and fire modeling. The main premise of which is generally on the mind of modelers and managers when considering how fire might move across a landscape. Nonetheless, the 4FRI treatments were developed primarily with restoration in mind, not moderating fire behavior. There is, however, a significant overlap in the fire behavior objectives for fuel management and restoration in ponderosa pine systems in the southwest. In both cases, the objectives result in reduced potential for fire behavior, with the majority of fire behavior reverting to surface fire. 1 & 2) Finney (2001) assumes a post treatment fuel model that will slow the spread rate of a fire. This may or may not be the case in the proposed treatments by the 4FRI. From the Fire Ecology/Air Quality specialist report: "…Decreasing the horizontal and vertical continuity of canopy fuels (direct effect) would allow sunlight to reach the surface, increasing surface temperatures, and decreasing dead fuel moisture content at the surface. This, combined with increased surface winds with fewer trees blocking the wind, could increase surface fire intensity, flame length, and rate of spread even if surface fuels were the same before and after thinning (Omi and Martinson 2004, Scott 2003)…." Finney's 2001 analysis was conducted specifically with an objective of reducing fire behavior and hazard, not restoration. This study specifically addressed fuel management: "*The goal of fuel management is to preemptively modify wildfire behavior through changes to the fuel complex. Fuel management has received increasing interest for mitigating fuel hazards (U.S. Department of the Interior and Department of Agriculture 1996, U.S. General Accounting Office 1999), some of which were created by nearly a century of fire suppression on millions of acres in the western United States (Arno and Brown 1991). Fuel treatments are intended to help limit wildland fire sizes and severity by directly mitigating fire behavior and*

			indirectly by facilitating suppression." Prescribed fire will be used along with thinning with the expectation that it would raise canopy base heights, address surface fuels, and thin seedlings and some small saplings as indicated in the Finney 2001 study, along with multiple other functions of fire that are discussed in the Fire Ecology Report.
CBD Cara 209 attachment 9 Pgs 23 - 32	Fiedler, C. E., and C. E. Keegan. 2003. 'Reducing Crown Fire Hazard in Fire-Adapted Forests of New Mexico'. USDA Forest Service Procedings RMRS-P-29	"Treatments that removed only trees smaller than 16-inches diameter were marginally more effective at reducing long-term fire hazard than so-called "comprehensive" treatments that removed trees in all size classes (Fiedler and Keegan 2002)". Pg. 11	The 'comprehensive' treatment mentioned consisted of "trees are marked for leave in the sizes, numbers, species, and juxtaposition that will go furthest toward restoring a sustainable structure, given existing stand conditions. Most of the 40 to 50 ft2/acre target reserve basal area is comprised of larger trees, although some trees are marked for leave throughout the diameter distribution, if available." This supports the proposed action where the selection of trees to be cut is not based solely on their diameter, but on the best sustainable structure. Statistically, there was no difference immediately post treatment (though the restoration treatment appeared to do slightly better that the dbh cap), and the dbh cap appeared to do slightly better over 30 years (though statistically there was no difference). The restoration treatment could set the forest on a trajectory for management within its historic fire regime (frequent, low severity), while the diameter limit would leave less structural diversity.
CBD Cara 209 attachment 9 Pgs 23 - 33	Keyes, C. R., and K. L. O'Hara. 2002. 'Quantifying Stand Targets for Silvicultural Prevention of Crown Fires'. Western Journal of Applied Forestry Vol. 17(2):101-109	1) "Thinning small trees and pruning branches of large trees to increase canopy base height significantly decreases the likelihood of crown fire initiation (Graham et al. 2004, Keyes and O'Hara 2002, Omi and Martinson 2002, Perry et al 2004, Pollett and Omi 2002), which is a precondition to active crown fire behavior…" Pg. 11 2) "If significant reductions of crown bulk density are necessary to meet the purpose and need then it is unlikely that the project will maintain habitat for threatened and sensitive wildlife species associated with closed-canopy forest (Beier and Maschinski 2003, Keyes and O'Hara 2002…" Pg. 12 3) "The former two factors can be actively	1) We agree that stand structure plays a critical role in crown fire susceptibility. If creating crown fire-resistant stands in the short term was the primary objective, and restoration and the long-term trajectory of the forest was not, it might be appropriate to use only 'low thinning' and pruning. As illustrated by modeling in the Silvicultural and Fire Ecology/Air Quality reports, the proposed treatments would reduce the potential for high severity fire, while setting the forest on a trajectory towards resilience and health. 2) Keyes and O'Hara state: "A silvicultural approach to reducing crown fire hazard may not be compatible with all forest objectives. For example, habitat management for a wildlife species that requires a complex, multilayered canopy will not be compatible with a low-thinning regime to reduce ladder fuels. However, the silvicultural practices described here – pruning and thinning – are consistent with stand management objecives that emphasize stand growth, wood quality, and individual tree vigor for pest and disease resistance."

		managed in ponderosa pine and dry mixed conifer forest to significantly decrease the likelihood of crown fire initiation and spread without resort to large tree removal in most cases (Fielder and Keegan 2002, Keyes and O'Hara 2002…" Pg. 29 4) "Keyes and O'Hara (2002: 107) agreed that raising canopy base height is an important factor in reducing fire hazard and noted, "[P]running lower dead and live branches [of large trees] yields the most direct and effective impact." They also noted the incompatibility of open forest conditions created by "heavy" thinning treatments designed to maximize horizontal discontinuity of forest canopies with management objectives to conserve threatened wildlife population and prevent rapid understory initiation and ladder fuel development." Pg. 30	The 4FRI is not taking an approach focused on' reducing crown fire hazard', but, rather, an approach that is based on the more site specific potential, based on current condition, special designations (habitat, proximity to infrastructure, soils, watershed/slope, etc). 3) 'The former two factors' mentioned are (1) surface fuel density and arrangement and; (2) canopy base height. As illustrated by modeling in the Silvicultural and Fire Ecology/Air Quality reports, the proposed treatments would reduce the potential for high severity fire, while setting the forest on a trajectory towards resilience and health. 4) We will be adding this as a reference to the Fire Ecology/Air Quality specialists report to support the need for maintenance burning. Thank you for sending it. See response to #1 above for Keyes and O'Hara.
CBD Cara 209 attachment 9 Pgs 34 - 49	McHugh, C. W., and T. E. Kolb. 2003. 'Ponderosa pine mortality following fire in northern Arizona'. *International Journal of Wildland Fire* 12:7-22	McHugh and Kolb (2003) describe unplanned and prescribed fire effects on ponderosa pine forest structure in northern Arizona reflecting a "U-shaped" tree mortality curve in which mortality was lowest among trees sized 30 – 60 centimeters ("cm") (approx. 12" – 24") diameter, and highest among the smallest trees as well as in the 75 – 80 cm (~29.5" – 31.5") diameter (Figure 3 above). Resistance to fire-induced mortality was greatest among trees sized 35 – 75 cm diameter. Mortality effects occurred despite relatively uniform "crown damage" across tee size classes, indicating that cambial injury and root scorch fire effects were most significant among the smallest and largest trees, whereas intermediate-sized trees were relatively uninjured and may have benefited from the disturbance (McHugh and Kolb 2003).	We recognize that there are risks for using fire of any kind and, as stated in Appendix C of the DEIS, and for each alternative in the Fire Ecology/Air Quality report: "*Where site specific mitigation is needed to limit damage or mortality to large or old trees, it is best accomplished by reducing accumulations of fuels within the dripline and in the immediate vicinity of the trees. These fuels may include litter, duff, accumulations of woody fuels, ladder fuels, or any fuel that could produce sufficient heat to lethally damage a tree. This can be accomplished manually, mechanically, or though fire treatments. Potential measures include implementing prescription parameters, ignition techniques, raking, wetting, leafblowing, thinning, or otherwise mitigating fire impacts to the degree necessary to meet burn objectives. Throughout the life of this project, it is likely that some large and/or old trees would be damaged or killed by prescribed fire. It would not be possible to mitigate every large and/or old tree over 30,000 to 40,000 acres of prescribed fire units each year*."

CBD Cara 209 attachment 9 Pgs 50 - 57	Sandberg, D. V., R. D. Ottmar, and G. H. Cushon. 2001. 'Characterizing fuels in the 21st Century'. *International Journal of Wildland Fire* 10:381-387	The bulk density (weight within a given volume) of ground fuels (*e.g.*, grasses, shrubs, litter, duff, and down woody material) influences frontal surface fire behavior (heat output and spread rate) more than fuel loading (weight per unit area) (Agee 1996, Sandberg et al. 2001).	This paragraph is a factual statement of some of the physics that apply to fire. We see this as supportive to the methods of analysis that we have used.