Santa Fe Mountains Landscape Resiliency Project

Watershed Resources Effects Analysis

Heidi Klingel
Watershed Specialist with the USFS Enterprise Program (WO)

Española and Pecos Ranger Districts, Santa Fe National Forest
January 19, 2021

Contents

Issues Addressed 1
Methodology 2
Affected Environment 2
Spatial and Temporal Bounds 2
Field Assessment 3
Data 7
Models 7
Literature Review 8
Environmental Consequences 8
No-Action Alternative 8
Direct and Indirect Effects of the No-Action Alternative 8
Summary of Effects by the No Action Alternative 11
Proposed Action Alternative 12
Direct and Indirect Effects of the Proposed Action 14
Cumulative Effects of the Proposed Action 23
Summary of Effects by the Proposed Action Alternative 32
Consistency with Relevant Laws, Regulations, and Policy 37
Land and Resource Management Plan 37
Other Relevant Law, Regulation, or Policy 42
Federal Law 42
Executive Orders 43
State and Local Law 43
Policy 44
Conclusion 45
References Cited 46
Appendix A: Best Management Practices, Design Criteria, Mitigations, and Monitoring Measures 49

Tables and Figures

Table 1: Analysis Watersheds 3
Table 2: Project Area Watersheds, Current Conditions, and Proposed Treatments 13
Table 3: WEPP Model Erosion and Sedimentation Results Summary 17
Table 4: Cumulative Watershed Effects (CWE) Risk Summary 25
Table 5: SFMLR Project Compliance with the 1987 Santa Fe National Forest LRMP 38
Table 6 Waterbar Construction Guidelines 53

Figure 1: Hydrography of the SFMLR Project Area 4
Figure 2: Project Area Map North 5
Figure 3: Project Area Map South 6
Figure 4: Fall Burn Strategy for Avoiding CWE 35
Figure 5: Spring Burn Strategy for Avoiding CWE 36

Issues Addressed

This section includes issues pertaining to watershed resources that have been identified for detailed analysis. "An issue is a statement of cause and effect linking environmental effects to actions" (Forest Service Handbook 1909.15). Watershed resources are soil (productivity), water (water quality), and watersheds (flow regime).

1. Project activities could DEGRADE SOIL PRODUCTIVITY by disturbing, compacting, and sterilizing the soil.
2. Project activities could cause INCREASED PEAK STREAM FLOWS, which may flood private property and infrastructure downstream.
3. Project activities could DEGRADE WATER QUALITY through physical and chemical processes that add pollutants to water.
4. Project activities use FUEL AND CHEMICALS which could contaminate water, including the sources within the city of Santa Fe's municipal watershed.

The effects of some proposed actions were not analyzed because they were not found to cause unique (different effects from those analyzed within this report) or significant issues for watershed resources. They are:

- Riparian thinning
- Riparian planting
- Invasive species removal[1]
- Road closure

[1] Actions will tier to the Invasive Plant Control Project FEIS decision (6-13-2018) which authorizes:
- Hand pulling, grubbing with hand tools or hand operated power tools, mowing and disking, girdling, or
- plowing with tractor-mounted implements
- Biological control using insects or plant pathogens introduced into the weed habitat
- Controlled grazing using goats and sheep to intensively and repeatedly graze weeds
- Herbicide application using hand or vehicle-mounted sprayer applications
- Prescribed burning using limited pile or broadcast burning to eliminate seed heads and resident populations of weeds
- Reseeding or replanting after the initial treatment

https://www.fs.usda.gov/nfs/11558/www/nepa/54698_FSPLT3_4357827.pdf

Methodology

This section includes a description of the methods and data used in this analysis.

Affected Environment

The project overlaps ten "subwatersheds" (USGS HUC12s; interchangeably referred to within this report as "watersheds") (See Figure 1 and Table 1). A subwatershed encompasses between 9,600 and 40,000 acres. The current watershed conditions reflect a range of variability from natural pristine (functioning properly) to degraded (severely altered state or impaired). Properly functioning watersheds exhibit high geomorphic, hydrologic, and biotic integrity relative to their natural potential condition. They have terrestrial, riparian, and aquatic ecosystems that capture, store, and release water, sediment, wood, and nutrients within their range of natural variability for these processes. At risk watersheds exhibit moderate geomorphic, hydrologic, and biotic integrity relative to their natural potential condition while these qualities are extremely degraded within impaired watersheds (USDA, 2011). The condition of project area watersheds were evaluated in 2016 by Santa Fe National Forest staff; eight were found to be functioning at risk, one is functioning properly, and one was not rated because few acres are managed by the Forest Service (see Table 2 for watershed specific information).

Three project area watersheds have waterbodies which are not meeting state water quality standards for their designated beneficial uses (Figure **1**):

- Headwaters Santa Fe River- The Santa Fe River (within the municipal watershed) is listed as impaired (303d) for aluminum (thought to be naturally occurring).
- San Cristobal Arroyo-Galisteo Creek- Galisteo Creek is listed (303d) for temperature, although it has a Total Maximum Daily Load (TMDL[2]) prescribed.
- Glorieta Creek- Glorieta Creek is listed (303d) for flow regime modification[3]

Spatial and Temporal Bounds

The direct, indirect and cumulative effects analyses were conducted at the 12-digit hydrologic unit code (HUC12) watershed scale (9,600 to 40,000 acres); analysis watersheds are shown in Table 1.

Short-term effects are those which occur and disappear within five years. Long-term effects are those which may occur within five years, but which persist much longer. Cumulative effects consider the past 15 years, and 15 years into the future.

[2] A TMDL defines the amount of a pollutant a waterbody can assimilate without violating a state's water quality standards. It allocates that load capacity to known point sources and nonpoint sources at a given flow. It further identifies potential methods, actions, or limitations that could be implemented to achieve water quality standards.
[3] The NM Office of the State Engineer has authority over water rights which affect stream flow and the flow regime; this impairment is therefore not discussed further in this report.

Table 1: Analysis Watersheds

Watershed Name (HUC 12)	Total Watershed Acres	Percent of the Watershed Area Managed by the Forest Service
Arroyo Hondo	16,417	20%
Dry Gulch-Pecos River	27,274	86%
Glorieta Creek	21,431	42%
Glorieta Creek-Pecos River	20,267	55%
Headwaters Rio Tesuque	26,072	57%
Headwaters Santa Fe River (municipal watershed)	34,798	46%
Rio Nambe	31,685	75%
Rio Tesuque-Pojoaque Creek	27,838	21%
San Cristobal Arroyo-Galisteo Creek	38,018	32%
San Marcos Arroyo	26,434	Very small

Field Assessment

Several project specific field trips were made to assess upland and riparian areas within the proposed project area. These site visits were undertaken to field truth remotely sensed riparian data and analysis, assess road conditions, look for invasive species, review watershed effects from previous thinning and prescribed fire areas. Visited areas include the Rio en Medio riparian, the Rio Tesuque riparian, the Pacheco canyon treatment (thin and burn), the road systems above the La Cueva neighborhood near Pecos, the Rio Hondo riparian, the Santa Fe Municipal Watershed and hillslopes near the Santa Fe Ski Basin and Hyde State Park; See Figure 2 and Figure 3.

Figure 1: Hydrography of the SFMLR Project Area

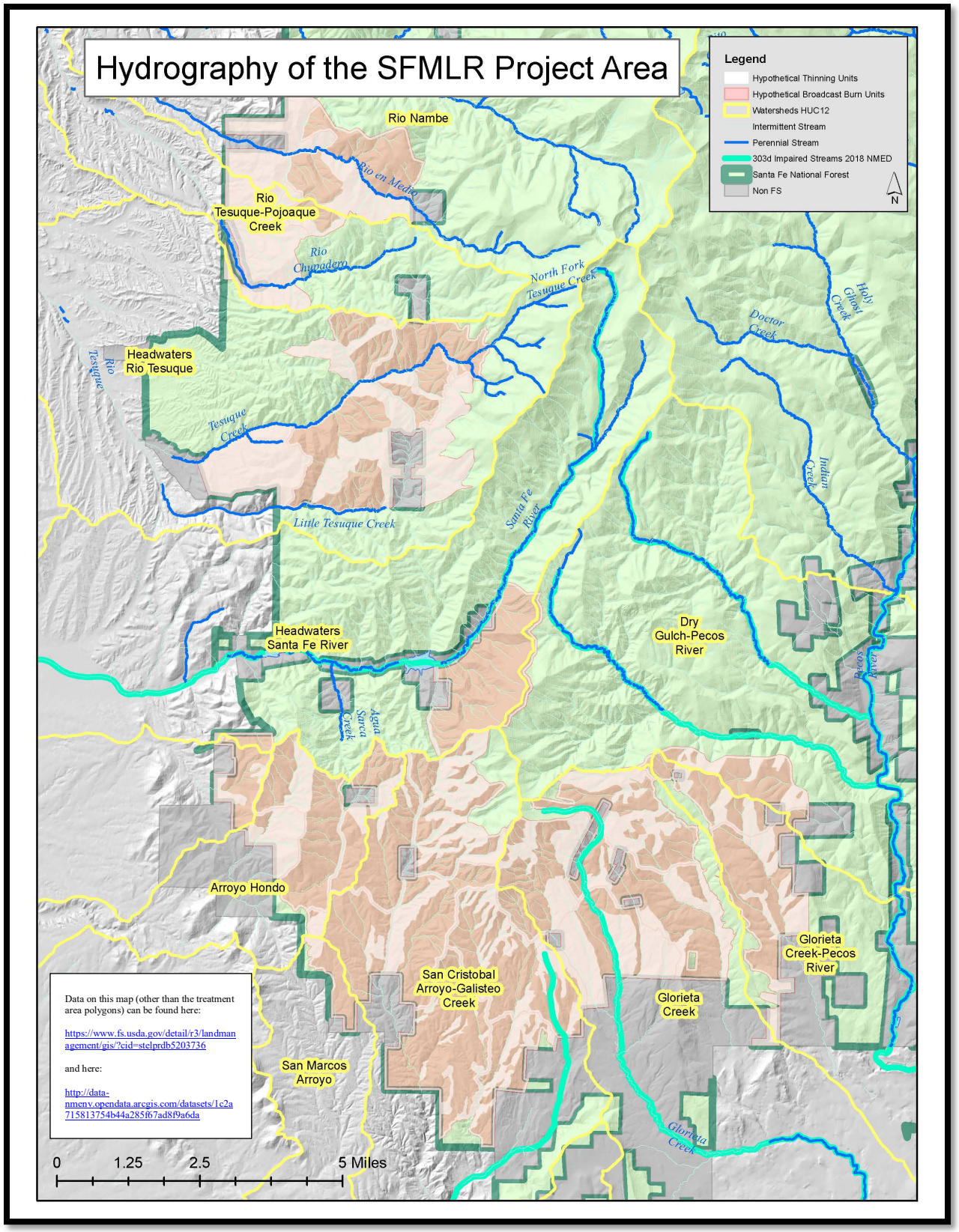


Figure 2: Project Area Map North

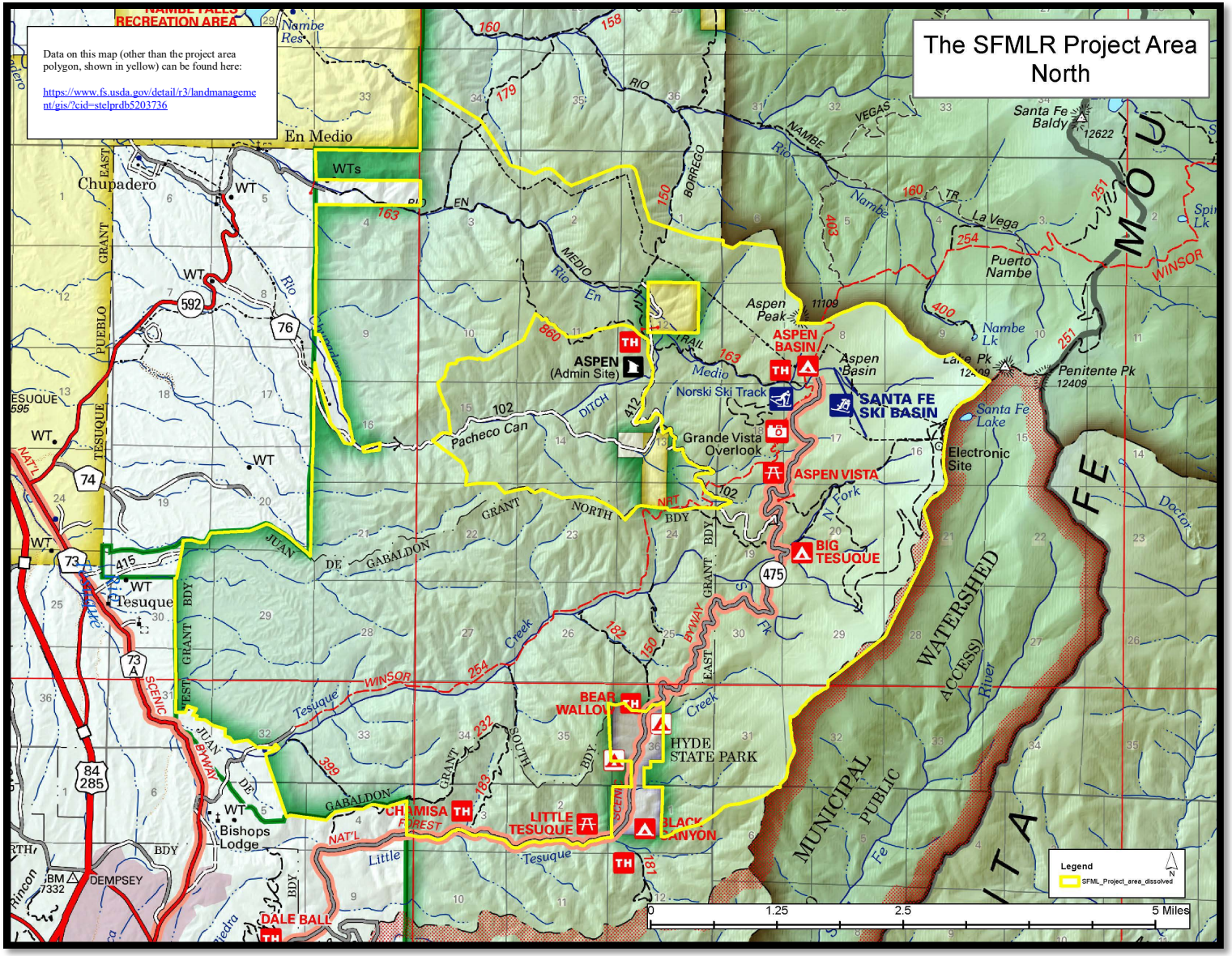
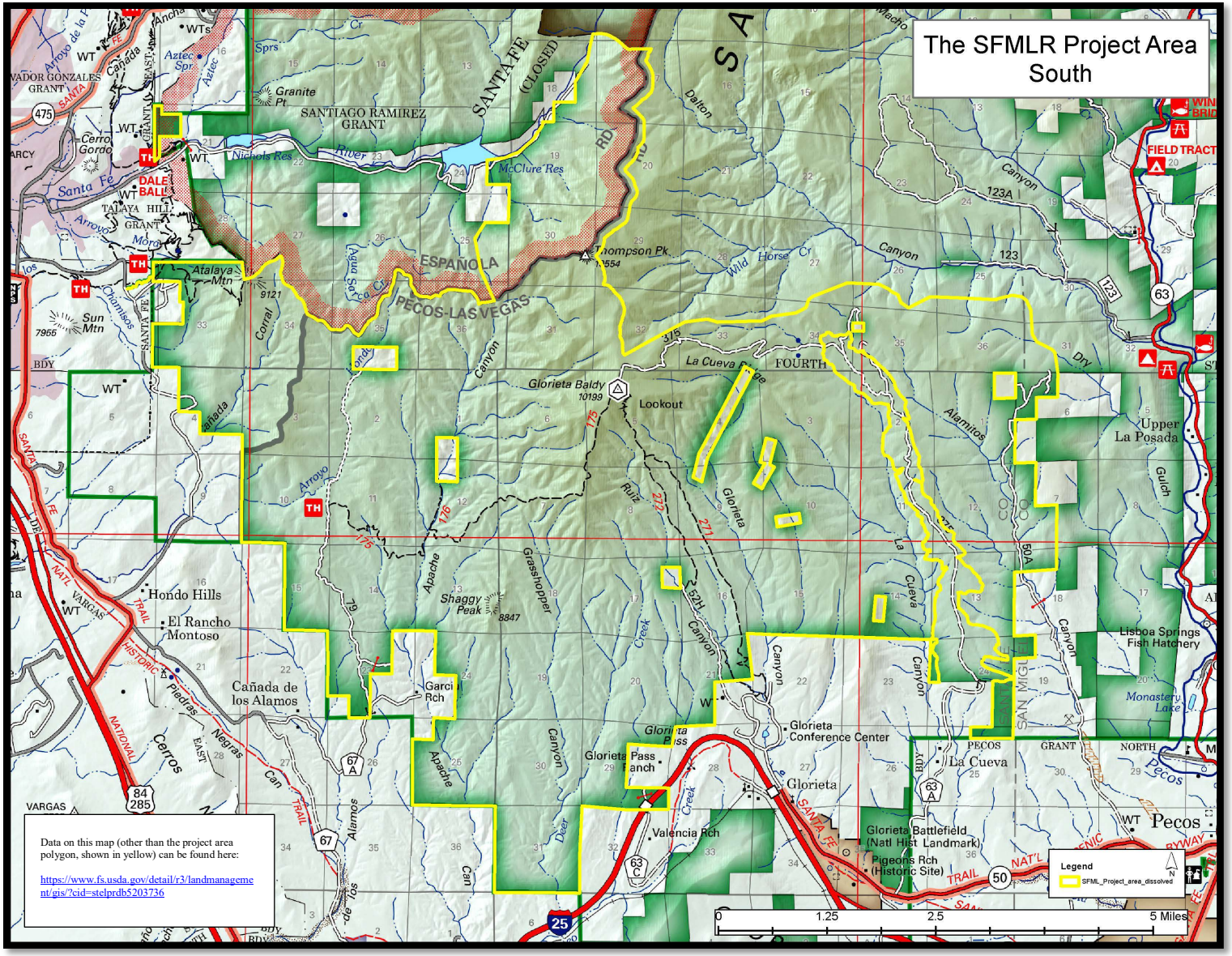


Figure 3: Project Area Map South



Data

Data sources used included:

Proposed Action shapefiles- two shapefiles were created to represent the most likely treatment areas for thinning, and broadcast burning. Treatment areas were identified using institutional knowledge, vegetation type, digital aerial photos and topographic layers. The treatment areas are only approximate and are subject to site specific assessment as implementation would be based on fuel and forest stand conditions.

Forest GIS database- an extensive repository of Forest specific geospatial data which were overlaid on HUC12 subwatersheds (mapped by the US Geological Survey[4]) to identify features of interest. HUC12 subwatersheds were intersected with the proposed action shapefiles and slope gradient data to analyze acres per watershed and mechanical treatment acres. FACTS[5] database of completed vegetation management treatments were intersected with the project area watersheds to generate acres of previous treatment, by watershed, for the cumulative watershed effects analysis.

City of Santa Fe water quality data-The City of Santa Fe routinely samples the Santa Fe River, McClure and Nichols reservoirs as part of their city water management activities in the Upper Santa Fe River watershed. The City shared their 2007, 2011, and 2017 sampling data with the author of this report (available in the project record). The data were used to better understand water quality after prescribed fire.

Models

Two models were used to assess the potential for increased erosion and sedimentation by thinning, prescribed fire, and wildfire.

The USFS Enterprise Program Wetness model runs within a GIS platform. It uses hillslope gradient, soil, aspect, existing vegetation, and solar radiation data to identify areas with soil and topographic conditions most sensitive to disturbance; wetter, steeper areas are generally more sensitive. Documentation on this model can be found in the project record.

The FS Water Erosion Prediction Project soil erosion (WEPP) model (Elliot et al. 2000), Disturbed WEPP interface was used to assess erosion and sedimentation volumes by the No Action and Proposed Action alternatives. It allows one to easily describe numerous disturbed forest and rangeland erosion conditions. The WEPP model uses local climate data, soils, hillslope, ground cover, and treatment information to generate runoff, erosion, and sediment (per acre). The annual climate is based off of 45 years of record from the nearest weather station (Las Vegas, NM); WEPP interpolates the climate for the project based off of the station's weather. The model output includes the probability of a given level of erosion occurring the year following a disturbance. More information about the model and the outputs for this project can be found in the project record.

---

[4] Information on the USGS Watershed Boundary Dataset can be found here: https://www.usgs.gov/core-science-systems/ngp/national-hydrography/watershed-boundary-dataset

[5] FACTS (Forest Service Activity Tracking System) database can be viewed here: https://data.fs.usda.gov/geodata/edw/datasets.php

Literature Review

A literature review was conducted in order to incorporate the best available science on the restoration of frequent fire ecosystems, effects to watershed resources by prescribed fire and heavy equipment. Much of the information was incorporated and cited within the analysis sections below. Digital copies of the literature cited are available in the project record.

Environmental Consequences

No-Action Alternative

Under the No Action Alternative, current management plans would continue to guide management of the project area. No prescribed burning, vegetation or riparian restoration treatments would be implemented to accomplish project goals within the project area, unless approved through a separate NEPA document and decision.

Without implementing the proposed treatments, forest conditions within the project area would continue to depart from desired conditions. Forest structure would continue to be somewhat homogenous and would continue to be dominated by a single age class. Forests would lack the desired level of diversity in structure, composition, and density and forest susceptibility to insects and disease (e.g. bark beetles and mistletoe) would continue to increase. Consequently, the risk of uncharacteristic fire intensity would also continue to increase. While high intensity[6] wildfire is possible under every alternative, the risk would be higher, and the extent likely larger, by the No Action alternative; effects discussed below intend to recognize this increased risk but do not intend to suggest the No Action Alternative is an assumption of an intense wildfire.

As forest characteristics move away from desired conditions, and the risk of high intensity wildfire increases, watershed function and the ability to provide water to plants, animals and humans during drought (and climate change) are threatened. The affected watershed resources of concern, analyzed below, are soil (productivity), water (water quality), and watersheds themselves (flow regime).

Direct and Indirect Effects of the No-Action Alternative

The direct and indirect impacts of the No Action alternative to watershed resources are described for each identified issue below.

Could the No Action alternative degrade SOIL PRODUCTIVITY?

Yes, soil productivity is likely to be adversely affected, should the No Action alternative be selected.

Where the forest canopy cover is dense, and as it becomes denser, vegetative groundcover is expected to remain low, or decline. Vegetative ground cover is important to soil generation and protection, promoting soil productivity. A decline in soil quality (moving away from desired conditions) is therefore expected by the No Action alternative.

[6] Fire intensity refers to the rate at which a fire is producing thermal energy. Intensity is a function of climate, temperature, rate of spread, heat yield, and fuels. The higher the intensity, the more severe the soil burn severity, and the impacts to watershed resources (Neary et al., 2003).

Soil productivity is further threatened by the risk of high intensity wildfire. Intense fire behavior is most likely to occur during dry periods, when fuel and soil moistures are very low. Dry soil transfers heat more efficiently, making it more susceptible than moist soil to physical and chemical alteration. The physical and chemical alteration of soils make them less able to infiltrate water, increasing overland flow. With more runoff, denuded soil is likely to become entrained, eroding and transporting to stream channels (e.g., by debris flow). With less soil and less productive soil on the hillslopes, vegetation has less substrate in which to grow. In addition, existing fuel loads are likely to promote long-duration soil heating, which promotes soil heating, killing small and large roots, increasing vegetation regeneration time (Busse et al., 2014). Depending on pre-existing soil properties and topography, soil productivity may be adversely affected by high intensity wildfire for at least 12 years (Certini, 2005), likely much longer.

Could the No Action alternative cause INCREASED PEAK STREAM FLOWS and flooding?

Yes, increased peak stream flows and flooding are likely to result should the No Action alternative be selected.

Where the forest canopy cover is dense, and as it becomes denser, vegetative groundcover is expected to remain low, or decline. Vegetative ground cover promotes the infiltration of precipitation because it slows the flow of water over the ground. Without widespread groundcover, watersheds receiving intense precipitation (e.g., monsoon rains) are less able to absorb it.

The risk of high intensity wildfire further threatens the ability of a watershed to absorb precipitation and avoid downstream flooding. Intense wildfire affects streamflow by altering a watershed's water-balance (i.e., evapotranspiration is reduced, infiltration is reduced, soil moisture storage is reduced, groundwater recharge is reduced); by decreasing the other water pathways, overland flow and streamflow are increased (exacerbated by the formation of hydrophobic soil layers, common to high intensity wildfires). A high intensity wildfire in the project area would likely kill the majority of vegetation (ground cover, mid-story, and canopy) as well as alter soil properties (as described above) within its boundaries. Without ground cover and riparian vegetation, overland flow is rapidly transmitted down hillslopes and stream channels, typically resulting in larger peak flows, flooding (Neary et al., 2003), stream channel alteration, and debris flows. Bolin and Ward (1987; in Neary et al., 2003) reported a 100-fold increase in peak flow after a wildfire in a ponderosa pine and pinyon juniper forest (New Mexico); the project area is especially susceptible to flood response after wildfire because of the intense convective storms which build over the Sangre de Christo mountains (USWRPC, 1951). Adverse effects to human safety, infrastructure and aquatic ecosystems can be expected to result from high intensity wildfire; watersheds would remain susceptible to increased peak flows until soil properties recover, and vegetation is re-established. The recovery period to pre-disturbance peak flow levels ranges from one year to decades, depending on the intensity of disturbance, geologic, vegetative, and topographic factors (Neary et al., 2003).

Could the No Action alternative degrade WATER QUALITY?

Yes, water quality (and aquatic habitat) are likely to be adversely affected should the No Action alternative be selected.

Where the forest canopy cover is dense, and as it becomes denser, vegetative groundcover is expected to remain low, or decline. Vegetative ground cover protects soil from erosion because it binds the soil with its roots and slows the flow of water of the ground surface (decreasing its erosive power). Without widespread groundcover, soils are more prone to erosion and waterbodies are more likely to receive sediment pollution. The risk of high severity wildfire further threatens water quality through physical and chemical processes as well as the use of man-made chemicals.

Physical and chemical processes

Erosion and sedimentation-

As discussed above, high intensity wildfire is likely to super-heat the soil, altering its physical properties, resulting in decreased infiltration and increased overland flow. Without protective ground cover to cover and bind the soil with roots, soil and debris are easily dislodged and transported downslope to stream channels (e.g., debris flows).

Because high intensity (and large extent) wildfire is likely if the No Action alternative is implemented, modelling the erosion generated by such fires helps to give context to this Alternative. A steep (>60% slope) hillside above McClure reservoir was analyzed because it was found to be the most vulnerable to erosion by the USFS Wetness model[7] and is located immediately above a value at risk (the reservoir). By using predicted erosion results from this small hillside, the potential erosion risk of the No Action alternative can be extrapolated to the larger project area.

The Watershed Erosion Prediction Project model (WEPP; Elliot et al., 2000) analyzed erosion and sedimentation from the hillside as if a high intensity wildfire burned it. The results (see Table 3) indicate the hillslope is likely to produce 0.02 tons of sediment per acre, within the first year following a high intensity wildfire, given an average precipitation year (22"). If an above average precipitation year (29"; 15-year return period) were to occur, 0.14 tons of sediment per acre would be produced. And if a significant precipitation year were to occur (31"; 30-year return period), erosion and sedimentation increases to 0.21 tons per acre; a ton of sediment is approximately equivalent to one dump-truck load.

Expanding upon this (assuming a high intensity wildfire burns the entire project area; 50,566 acres), between 1,011 and 10,619 tons of sediment could be generated the first year following the event. If it were divided evenly between the 10 analysis watersheds (see Table 1), as much as 1,062 tons of sediment could be delivered to each of these important streams: the Santa Fe River, the Rio Tesuque, Glorieta Creek, the Pecos River and the Rio Nambe. This large sediment load would adversely affect water quality in these waterbodies (both suspended and bed-load sediments), affecting aquatic habitat and water treatment costs for many years (potentially decades).

Stream temperature-

High intensity wildfire consumes most vegetation and causes significant erosion and sedimentation. Because vegetation around stream channels is a critical source of shade, when it is ubiquitously removed, stream temperatures can increase. In addition, deposited rock , soil, and debris within stream channels increases the surface area of the water, exposing more of it to warm air and solar radiation. As stream temperature increases, other water quality parameters are adversely affected (e.g., dissolved oxygen decreases) causing biological stress (e.g., increased metabolic rates, susceptibility to infection and pollution; Lynch, 1984).

For Galisteo Creek, already considered impaired for not meeting NM state water quality temperature standards for high quality cold water (303d listed; NMED, 2017), a high intensity wildfire would be extremely detrimental, exacerbating an existing problem, making reducing stream temperatures (and

[7] The USFS Enterprise Wetness Model is based on hillslope gradient, soil, aspect, existing vegetation, and solar radiation data (USDA, 2018).

therefore meeting state standards) very difficult for many years (likely decades). Similarly, water quality and aquatic habitat within other streams would also significantly decline.

Water chemistry-

High intensity wildfire releases ions, metals, and nutrients from wood and soil which are then mobilized during precipitation events and delivered to stream channels. Some of the primary constituents of concern are nitrate (NO3 -), phosphate (PO43-), calcium (Ca2+), magnesium (Mg2+) and potassium (K+) because they are nutrients to algal growth (which can cause water to become depleted in oxygen). Other major concerns are dissolved organic carbon (DOC), shown to increase after high intensity wildfire which reacts with chlorine during water purification treatment, forming byproducts known to cause cancer (Hohner et al., 2019). DOC also prevents water from reacting well with chemical coagulants, the primary method of water purification in the Santa Fe municipal watershed (Johansen, 2020). Changes in concentrations of sulfate, pH, total dissolved solids (e.g., ash), chloride, iron, manganese, and aluminum have also been measured (Stednick, 2010). Elevated concentrations of these constituents are likely to seasonally pulse in the project area with spring runoff (Spencer et al., 2003).

While prescribed fire can increase nutrient and chemical constituent levels in streams, measured concentrations are generally lower after prescribed fire than after wildfire (Stednick, 2010); the difference likely related to the extent of watersheds burned, a persistent decrease in ground cover and the corresponding increase in runoff (Rhoades et al., 2011). Altered water chemistry by a high intensity wildfire can be expected to last at least fourteen years (Rhoades et al., 2019).

Fuel and chemicals

Petroleum fuel and fire retardant-

Large wildfires are commonly fought and controlled with fire retardants and the application of fire itself. Fire retardant is typically a mixture of water, fertilizer (ammonium phosphate and ammonium polyphosphate), colorants, anti-corrosive material, thickeners (e.g., clay), stabilizers, and bactericides (e.g., Phos-chek). It is non-toxic to humans and other mammals but very toxic to aquatic life and can cause algal blooms in waterbodies (USDA, 2015). Under the No Action alternative, adverse impacts to aquatic life are possible given the occurrence of a high intensity wildfire and the use of fire retardant.

Petroleum fuel is used to ignite backburns and power equipment during firefighting operations. Best management practices for fuel handling and use are less likely to be effectively applied during an emergency scenario (in comparison to a planned, prescribed burn). While care is taken to avoid contaminating waterbodies, adverse effects to water quality by fuel and chemicals under the No Action Alternative can be expected.

Summary of Effects by the No Action Alternative

Without treatment to fuels and forest structure, ground cover would be expected to remain deficient beneath areas of dense canopy, and the persistent and elevated risk of large, high intensity wildfire would continue to threaten water quality, soil productivity, and flooding (Rhoades et al., 2019; Neary et al., 2003). The No Action alternative would therefore result in watersheds that are 1) less resilient to climate change (i.e., less able to hold and slowly release water during dry periods) and 2) are not moving towards desired conditions (“properly functioning” as defined by USDA, 2011; and the forthcoming Santa Fe National Forest Land and Resource Management Plan, expected 2021).

Because the No Action Alternative is the same as the existing condition, cumulative effects by the No Action Alternative are not analyzed.

Proposed Action Alternative

The likelihood of treatment by the Proposed Action is based on vegetation type (Ecological Response Units [ERUs]), vegetation density (aerial photo assessment), and topography (aspect, slope gradient). For every watershed intersecting the project area boundary, there would be more acres burned than thinned (burn units overlap thinning units). In terms of need for treatment (area treated) the following watersheds are the most departed from (vegetation) desired conditions and are therefore most likely to be treated (see Table 2):

- Glorieta Creek
- Headwaters Rio Tesuque
- San Cristobal Arroyo-Galisteo Creek

The Proposed Action is expected to reduce the risk of high intensity wildfire; the effects analysis below attempts to analyze this and does not assume wildfire would be prevented. Should a wildfire occur however, the intensity and extent are expected to be reduced.

Table 2: Project Area Watersheds, Current Conditions, and Proposed Treatments

Watershed (HUC12)	Total Watershed Acres	Percent of the Watershed Area Managed by the Forest Service	2016 WCF Rating	Percent Area Proposed Prescribed Fire	Percent Area Proposed *Hand* Thinned	Percent Area Proposed *Mechanically* Thinned
Arroyo Hondo	16,417	20%	Properly Functioning	19%	3%	5%
Dry Gulch-Pecos River	27,274	86%	At Risk	4%	1%	1%
Glorieta Creek*	21,431	42%	At Risk	32%	5%	12%
Glorieta Creek-Pecos River	20,267	55%	At Risk	13%	2%	4%
Headwaters Rio Tesuque	26,072	57%	At Risk	25%	9%	6%
Headwaters Santa Fe River* (municipal watershed)	34,798	46%	At Risk	6%	1%	0.3%
Rio Nambe	31,685	75%	At Risk	9%	3%	2%
Rio Tesuque-Pojoaque Creek	27,838	21%	At Risk	6%	3%	3%
San Cristobal Arroyo-Galisteo Creek*	38,018	32%	At Risk	28%	5%	5%
San Marcos Arroyo	26,434	Very small	Not Rated	2%	0%	0.5%
*Denotes a watershed with a 303d impaired waterbody						

Direct and Indirect Effects of the Proposed Action

The potential direct and indirect impacts to watershed resources by the Proposed Action (See Chapter 2 of this EA) are addressed for each identified issue below. The watershed resources of concern are soil (productivity), water (water quality), and watersheds (flow regime).

The proposed Forest Plan Amendments would provide specific guidelines regarding how vegetation will be manipulated within Mexican Spotted Owl and Goshawk habitats; these guidelines are not expected to result in significantly different effects to watershed resources than those likely by the proposed actions themselves; soil disturbance, impacts to water quality, and a reduced risk of high intensity wildfire are possible outcomes with or without the Plan amendments. Therefore, the proposed amendments are not independently analyzed for watershed resources; all further analysis is focused on the physical impacts to these resources by vegetation management activities and prescribed fire, in general.

Project activities could DEGRADE SOIL PRODUCTIVITY by disturbing, compacting, and sterilizing the soil.

Mechanical treatments (where heavy equipment is used for thinning vegetation) have the potential to disturb and compact soil making it more susceptible to erosion, less able to absorb water, and less productive (Stednick, 2010). In addition to soil compaction, skidders and bobcats may adversely affect the soil by removing ground cover and furrowing, making it more susceptible to erosion by gullying.

A 2004 study (Hatchett, et al., 2006) in the Lake Tahoe basin (Sierra Nevada, California) investigated the soil compaction and runoff effects of a masticator (excavator on tracks, with a masticator head mounted on the arm) used to accomplish fuels reduction. They found that while the masticator did compact the soil beneath the tracks and for some distance surrounding the machine, the effect on runoff and erosion was ameliorated by the ground cover (mulch) generated by the machine. Another Sierra Nevada study (in Ponderosa pine forest) investigated the effects of fuels treatments on ground cover and mid-story vegetation. The researchers found mastication and hand removal treatments aided in reducing mid-story fuels but did not increase understory plant diversity. The additional treatment of prescribed burning not only further reduced fire hazard, but also exposed mineral soil, which likely promoted native plant diversity above pre-treatment levels (Kane et al., 2010).

Proposed mechanical treatments (mastication, skidding, machine piling with bobcats) would occur only on slopes with gradients less than 40% (which significantly limits mechanical treatment acres within each watershed). For example, vegetation analysis shows, before prescribed fire, Glorieta Creek watershed likely needs 3,643 acres thinned (17% of the watershed area); slope analysis indicates that 2,571 of those acres (12%) of the watershed area could be treated mechanically, with the remaining treatments being conducted by hand (see Table 2). Limiting (by slope constraint) the acres of mechanical treatment per watershed would help to ensure adverse impacts to soil (and watershed processes) are minimal at the watershed scale. Furthermore, while soil compaction can last for up to 50 years, it is repaired by a frequent freeze-thaw cycle (Greacon and Sands, 1980; Webb et al., 1986) which pushes soil particles away from one another as ice expands. Freeze-thaw commonly occurs many times throughout the winter within the middle and lower elevations which occur in the project area. The long-term benefits (fuels reduction, promotion of ground cover and biodiversity) of using heavy equipment for project implementation (e.g., masticators) are therefore expected to outweigh the temporary adverse effects by compaction, when compared with the No Action Alternative (watersheds less resilient to climate change).

The proposed action also includes pile and broadcast burning which can adversely affect the soil when it is super-heated. Soil productivity and watershed processes can be affected by changes in soil fertility, organic matter content, water infiltration, soil mineralogy, and nutrient availability. Soil heating is

minimized by high soil moisture (>65% by volume) and short burn duration (dependent on fuel type) (Busse et al., 2014). The proposed action would implement prescribed fire activities when soil moistures are high enough (e.g., fall and spring months) to minimize soil heating.

The potential for adverse effects to soil and watershed processes by mechanical equipment and prescribed fire would be further diminished by the effective implementation of Best Management Practices and project design criteria (e.g., installing waterbars on fire-line, excluding heavy equipment from riparian areas, controlling pile composition). Adverse effects to watershed resources are therefore expected to be minimal, short term, and insignificant when compared with the adverse effects of high intensity wildfire.

Project activities could cause INCREASED PEAK STREAM FLOWS, which may flood private property and infrastructure downstream.

Stream flow from a watershed can be thought of as a balance; inputs must equal the sum of outputs. Therefore, precipitation within a watershed (input) must equal the sum of evapotranspiration, sublimation, soil moisture storage, groundwater recharge, and stream flow (outputs). Changes to watershed properties (e.g., ground cover, canopy cover, infiltration) can affect the outputs that govern how quickly and how much water reaches the stream. Given a large enough storm event and diminished output, flooding (i.e., extreme streamflow) can occur.

Amy Lewis (contracted hydrologist) set up a nine year (2009-2017), paired-basin study within the Upper Santa Fe River watershed (above McClure Reservoir; Lewis, 2018). Within the study basins (~450 acres) she evaluated the effects of thinning and burning on the water balance by measuring precipitation, streamflow, soil moisture, groundwater recharge, and evapotranspiration. She compared measurements of these elements for a basin that had been treated (thinned in 2004, burned in 2010 and 2011) with those in an adjacent untreated basin in an effort to investigate how thinning and prescribed fire affect water yield. Her study showed surprising results relevant to peak flows.

In general, the treated basin did not exhibit greater streamflow than the control basin. In fact, a record-setting rainfall event (September 2013; 9.8 inches of rain) resulted in total water yield from the control basin equal to about five times that from the treated basin. In addition, the storm caused a debris flow within the control basin, but no sediment delivery from the treated basin. While Lewis attributed some of the differences in water balance between basins to inherent basin characteristics (e.g., topography, aspect, and geology), she concluded the difference in water yield between basins was due to increased ground cover (grasses and forbs) in the treated basin (resulting from a thinner canopy cover) (Lewis, 2018). An increase in ground cover would improve basin infiltration, diminish overland flow, and increase the time it takes for a drop of water to reach the watershed outlet.

Several aspects of the proposed action are expected to retain and promote ground cover: 1) the overstory would be thinned, increasing light on existing areas of bare soil, 2) prescribed fire (low to moderate intensity) would promote the establishment of grasses and forbs (Kane et al., 2010), with these types of understory vegetation able to re-sprout within 1 year (Sackett and Haase, 1998), and 3) the typical timing of prescribed fire (e.g., October) would allow seeds enough time to become established before the monsoon season (e.g., July) when overland flow is most likely. Further, implemented BMPs and design criteria (e.g., felling trees on the contour, preserving riparian vegetation, the cessation of grazing in burned areas for *at least* one year) would assist in slowing overland flow as well as retaining seeds and soil on hillslopes (see Appendix A). In comparison with the potential effects to soil and ground cover by high intensity wildfire, those by the proposed action are expected to be insignificant making the probability of increased flooding unlikely (Neary et al., 2003).

Project activities could DEGRADE WATER QUALITY through physical and chemical processes that add pollutants to water.

Erosion and sedimentation

Forest thinning activities have the potential to cause erosion and sedimentation where they physically disturb the soil. Where trees and brush are cut by hand, human footsteps can dislodge soil particles, especially on steep slopes. Trees and brush dragged across a hillslope can furrow the soil, making it more susceptible to erosion.

Prescribed fire and pile burning can remove or reduce ground cover from the soil surface, making it less resistant to erosion by overland flow. Areas of prescribed fire which burn with higher intensity (vegetation consumption) are more likely to cause sedimentation because they remove all (or nearly all) the existing ground cover, consume roots up to (0.25 cm in diameter) inhibiting grass and forb regeneration, as well as decrease or eliminate future needle-cast (fire affected needles fall on the ground) over the soil. Lower intensity burns do not fully consume duff layers or plants and burned limbs generally maintain needles for immediate ground cover (USDA, 2016).

Heavy equipment, such as masticators (fuels reduction), bobcats (fire-break construction) and UTVs (transportation) compact the soil, increasing its density (Greacen and Sands, 1980; Hatchett et al., 2006). Water is less able to infiltrate denser soil, resulting in increased overland flow and subsequent erosion (Greacen and Sands, 1980).

The risk of degrading water quality by sedimentation is increased where thinning and burning occurs immediately adjacent to stream channels and other types of water bodies. Treatments within the municipal watershed are particularly consequential because they may affect water supply and infrastructure. Suspended sediment is not only expensive to remove, but also hosts other contaminants (e.g., total organic carbon, metals) which can affect the city's ability to treat and purify the water (Meixner and Wohlgemuth, 2004). Reservoir sedimentation decreases water storage and therefore threatens water supply and the ability of the city to provide water during drought periods.

Erosion Model Results

Effects to erosion and sedimentation processes by project activities were assessed using two models; the USFS Enterprise Wetness Model and the USFS Disturbed WEPP model. The Enterprise Wetness model was used to identify the hillslopes within the project area which are most vulnerable to erosion and mass wasting (based on hillslope gradient, soil, aspect, existing vegetation, and solar radiation data; USDA, 2018). The WEPP model (Elliot et al., 2000) was then used to assess potential erosion (in sediment volume) from the identified hillslopes.

The wetness model identified a hillslope (~60% slope gradient) above McClure reservoir (a City of Santa Fe Municipal water source) as particularly sensitive to disturbance; it was selected for further analysis by the WEPP model because it represents the most sensitive terrain in the project area. From this hillslope, potential erosion can be extrapolated for adjacent hillslopes and watersheds as an over-estimate of potential adverse effects.

Four disturbance scenarios on the identified hillslope were modeled with the WEPP interface: proposed thinning, prescribed fire, prescribed fire on slopes more gentle slopes (those typical of the project area; 40% gradient), and wildfire. For each scenario, three annual climates were modeled representing an average year's precipitation, a year with above average precipitation (15-year return interval), and a year with significant precipitation (30-year return interval). Table 3 shows the modeled results of upland erosion and sedimentation into McClure Reservoir for each scenario assessed (for the first year following implementation).

The WEPP model shows background erosion rates in the project area are about 0.000004 tons/acre of sediment annually. Hand thinning is unlikely to cause additional erosion, even if a very wet climate were

to occur the year following treatment. Prescribed fire may cause some erosion (and sedimentation) but is unlikely to cause more erosion on steeper slopes (>60% gradient) than typical slopes (~40% gradient) during an average precipitation year. Given a significant precipitation year, erosion and sedimentation volumes from steeper slopes are more than those from slopes with gradients common to the project area (0.14 vs. 0.12 tons/acre respectively).

Extrapolating to the larger project area makes these results more meaningful. The proposed action limits broadcast burning to 4,000 acres *annually* across the entire project area; if these 4,000 acres were burned in a single watershed, the WEPP model indicates 40 tons of sediment (about 6 dump-truck loads) would be eroded and delivered downstream (assuming an average precipitation year and typical slope gradients 40%). If the climate becomes wetter, erosion and sedimentation would increase to 480 tons. In comparison, given a high intensity wildfire of the same size (4,000 acres), erosion and sedimentation doubles (80-840 tons, depending on the climate); in reality however, wildfires can be much larger than 4,000 acres, resulting in greatly more erosion and sedimentation within a single year.

Sediments eroded and delivered to a waterbody may gradually transport beyond the analysis area within the long-term, depending on sediment volume, climate and scale of flooding as well as ground cover. Sediment eroded by low intensity prescribed fire is not as likely (as that by high intensity wildfire) to be transported to stream channels because of the residual ground cover (Stephens et al., 2004). Because the No Action Alternative is more likely to result in high intensity wildfire than the proposed action (i.e., more erosion and sedimentation as well as less ground cover), adverse effects to water quality (and aquatic habitat) would be expected to last much longer than those by the proposed action.

The WEPP model does not consider the beneficial effects of best management practices (BMPs) or project design criteria which aim to prevent water quality degradation by erosion and sedimentation. Integrated design criteria (e.g., preventing ignition within riparian areas, falling trees on the contour, the cessation of grazing post-burn) and BMPs protect watershed resources from impacts to water quality by protecting or promoting ground cover in addition to halting and diverting overland flow. With the effective implementation of these elements, erosion and sedimentation by proposed activities would be significantly minimized below the erosion and sedimentation volumes predicted by the WEPP model. See Appendix A.

Table 3: WEPP Model Erosion and Sedimentation Results Summary

Treatment	**Average Annual Precipitation** (~2 Year Recurrence) 22 inches	**Above Average Annual Precipitation** (15 Year Recurrence) 29 inches	**Significant Annual Precipitation** (30 Year Recurrence) 31 inches
	Upland Erosion Tons/acre (during the first year following treatment)		
Background	0.000004	NA	NA
Thinning Alone	0.00*	0.00*	0.00*
Rx Fire – 40% slopes Average Project Area Conditions	0.01	0.06	0.12
Rx Fire – 60% slopes Above McClure Reservoir	0.01	0.06	0.14
High Intensity Wildfire	0.02	0.14	0.21
*In addition to background erosion			

Stream Shade and Temperature Pollution

Water temperature is most affected by solar radiation; removing stream-side canopy cover can adversely affect stream temperature by reducing shade(Brown and Krygier, 1970). Thinning treatments within project riparian areas (for fuels reduction and riparian vegetation restoration) are proposed.

Within the project area, Galisteo Creek is listed as impaired by the NM Environment Department for water quality (temperature) because it is not meeting state water quality standards for its designated beneficial use as High Quality Cold Water (HQCW) for aquatic life[8]. Proposed thinning and burning activities, especially those within riparian areas, have the potential to reduce stream shade and increase stream temperatures until riparian vegetation responds to the increased sunlight (~5 years). Best Management Practices and project design criteria would prevent significant reductions in stream shade from occurring; riparian planting activities would help to increase stream shade. For Galisteo Creek, the HQCW standard would be achieved *when the percent total shade is increased from 8% to 81%* (NMED, 2017).

Water Chemistry

Prescribed fire can release ions, metals, and nutrients from wood and soil which are then mobilized during precipitation events and delivered to stream channels. The primary constituents of concern are nitrate/ammonium (NO_3 -, NH_4+), phosphate (PO_4^3-), calcium (Ca^2+), magnesium (Mg^2+) and potassium (K+). Increased concentrations of sulfate (SO_4^2-), pH, chloride (Cl-), iron (Fe), dissolved organic carbon (DOC), particulate organic carbon (POC), and other constituents have also been measured (Stednick, 2010).

Nutrients

Nitrogen, phosphorous, and potassium are the primary nutrients required by plants for growth. Ammonium and nitrate (which contain nitrogen) are easily leached from burned soils; especially ammonium because it binds to soil minerals and is thus transported to streams with eroded soil (Certini, 2005). Phosphorus is also released from soil when fire converts it to orthophosphate, the only form of phosphorous plants and animals can uptake. Phosphorous however, is less of a water quality concern than ammonium because it is quickly taken up by vegetation, or quickly reincorporated into the soil (Certini, 2005). Large amounts of potassium (as well as calcium and magnesium) are released from the soil by fire, but only remains available as an ion (useable nutrients) for a short while (weeks to months; Certini, 2005; Stephens et al., 2004).

Nutrients in waterbodies are an exceptional concern because they can cause algal blooms, eutrophication (Gottfried and DeBano, 1990) and major problems for potable water treatment. The Santa Fe municipal watershed (Upper Santa Fe River) managers had to draw down (i.e., not use) both city reservoirs in 2018 because of an algal bloom (thought to have been related to the extremely warm summer temperatures that year). Nutrients in the municipal reservoirs likely contributed to the problem, although it is unknown if they were present in bottom sediments or suspended in the water column. The degree to which past broadcast burns in the Upper Santa Fe River watershed (implemented 2008-2018) contributed to the bloom is unknown (Hook, 2020b) as some level of nutrient deposition in waterbodies is natural (Smith et al., 2003). With climate change (a significant increase in temperature, especially during summer and fall,

[8] Monitoring data (at Cañoncito between 5/30 and 8/21, 2014) measured a maximum Temperature (Tmax) of 31.8 degrees Celsius and a 4T3 temperature of 30.1 degrees Celsius. 4T3 is defined as the sustained temperature lasting four or more consecutive hours within a 24-hour period, on more than three consecutive days. The NM standards for HQCW aquatic life are a Tmax of 23 degrees Celsius and a 4T3 of 20 degrees Celsius. As of 2017, a TMDL regulates point and non-point source temperature pollution to Galisteo Creek at or below a designated critical flow (the minimum average four consecutive day flow which occurs once every three years; 4Q3). The 4Q3 for Galisteo Creek in the project area is 0.1 cfs (NMED, 2017).

is predicted for the southwest; Cayan et al., 2003), nutrient loading in the municipal reservoirs is a growing concern (Hook, 2020b).

The use of prescribed fire in the municipal watershed (and other project area watersheds with reservoirs; e.g., Rio Nambe), is proposed despite concern for reservoir algal blooms because the potential water quality effects (to streams and reservoirs alike) are significantly less (in terms of concentration (Stednick, 2010; Meixner and Wohlgemuth, 2004), and duration (Rhoades et al., 2019; Stephens et al., 2004) by prescribed fire than by high intensity wildfire, presumably because prescribed fire typically results in lower vegetation and soil burn severity (Certini, 2005). Low intensity prescribed fire also results in less soil erosion and sedimentation of nutrient laden soil (Robichaud, 2000). Further, preservation of the soil structure combined with an increase in nutrient availability (typical of low intensity prescribed fire) promotes the rapid establishment of vegetation ground cover (Certini, 2005), which helps to quickly filter and infiltrate water, reduce erosion, and ameliorate the potential adverse effects to water quality.

Water chemistry changes (to nitrate and other constituents) induced by high intensity wildfire have been shown to last for fourteen years (and likely longer; Rhoades et al., 2019); reestablishment of ground cover is a significant control on this recovery time (Rhoades et al., 2011). Adverse effects to water quality (by nitrate and other constituents) by moderate intensity prescribed fires have been shown to dissipate after only three months (Lake Tahoe basin, Stephens et al., 2004).

Other Contaminants

Changes in pH and increased concentrations of sulfate, chloride, iron, dissolved organic carbon (DOC), particulate organic carbon (e.g., ash), and other constituents can also adversely affect water quality. DOC is especially of concern because it adversely affects the potable water treatment process as well as forms compounds harmful to human health when combined with treatment chemicals (Hohner et al., 2019).

High intensity wildfires (soil-surface temperatures of >612 °C; Robichaud, 2000) have been linked to long-term (>14 years) elevated DOC levels in streams (Rhoades et al., 2019). However, low (soil-surface temperatures of about 119-187 °C; Robichaud, 2000) and moderate intensity wildfire has also been found to release organic carbon from soil (Hohner et al., 2019). Concern for contributing DOC to waterbodies by prescribed fire is therefore warranted as broadcast burns are planned to have low to moderate vegetation (low soil) burn severity.

A study by NM Tech researchers (Shephard and Cadol, 2018) monitored DOC within the upper Santa Fe River (in the municipal watershed) above McClure Reservoir, between March 2016 and June 2018, before and after prescribed fire treatments (248 acres were thinned and then broadcast burned on November 16, 2017). Other monitored parameters included ions (calcium, magnesium, silica, sodium), metals (aluminum, iron), temperature, dissolved oxygen (DO), particulate organic carbon (POC), total carbon (TC), hardness, specific conductivity, and total dissolved solids (TDS).

Water quality sampling prior to thinning and broadcast burning generally revealed high quality surface water in the Santa Fe River although at low flow, when flow is dominated by groundwater influenced baseflows, it is slightly high in ions and metals (e.g., aluminum[9]); snowmelt runoff has lower concentrations of these constituents (Shephard and Cadol, 2018). Interestingly, a pre-burn storm event (October 2017) revealed the most dramatic changes in water quality over the entire study. DOC, POC, and TC samples all increased during the storm event, but returned to pre-storm levels within approximately one month. Metals and TDS concentrations exceeded the EPA drinking water standards

[9] The upper Santa Fe River within the municipal watershed is listed (303 d) as impaired for aluminum; it does not have a TMDL. https://www.env.nm.gov/wp-content/uploads/sites/25/2018/03/Appendix-A-Integrated-List.pdf The Shephard and Cadol, 2018 study suggests aluminum is naturally occurring.

during the rising limb of the hydrograph, but quickly returned to baseline thereafter (Shephard and Cadol, 2018).

Sampling post burn showed POC concentrations were instantly higher than pre-burn levels (but decreased to pre-burn levels within 5 days); the increase was attributed to entrained ash. POC concentrations however were not alarmingly high and were in fact less than those during the measured pre-burn storm event (Shepard and Cadol, 2018). DOC concentrations did not immediately increase following the burn but had slightly increased when sampled again in April of 2018 (possibly due to dissolving ash in the riverbed sediments); the increase was similar to but less than the concentration registered during the large October 2017 storm. The DOC and POC concentrations had returned to pre-burn levels when sampled again in July of 2018. Organic carbon concentrations were found to correlate with stream discharge throughout the study. Metal and ion concentrations were apparently not affected by the burn; DO decreased daily as temperatures increased, but these changes were not clearly attributable to the burn. All post-burn increases were less than the EPA's maximum contaminant levels for drinking water quality (Shepard and Cadol, 2018). Overall, for the water quality constituents studied, the post-fire watershed response to the monitored 2017 broadcast burn was not largely adverse, was very short lived (<1 year), and was less than that by a large natural stormflow event (Shepard and Cadol, 2018).

Water Quality Summary

Because prescribed fire consumes vegetative ground cover and heats the soil, it can adversely affect water quality through erosion and sedimentation as well contribute nutrients and other water quality constituents (e.g., carbon and heavy metals) to streams. Water quality is also adversely affected when vegetation providing stream shade is consumed, resulting in increased stream temperatures. For the following reasons, adverse effects to water quality by the physical and chemical processes associated with the proposed action (low to moderate intensity prescribed fire; broadcast and pile burning) are not expected:

Range-1. Numerous project design criteria would protect soil from erosion; see the Best Management Practices and Design Criteria section below.

Range-2. Low to moderate soil heating by prescribed fire retains soil and root structures which makes soil more resistant to erosion and sedimentation (Busse et al., 2014; Certini, 2005).

Range-3. Low to moderate soil heating by prescribed fire does not kill all vegetation or seed in the soil (Busse et al., 2014); where vegetation was present before prescribed fire, given precipitation, revegetation is expected.

Range-4. An increase in nutrient availability (released from the soil by a low to moderate intensity prescribed fire) would promote the rapid establishment of ground cover vegetation (Certini, 2005). Once ground cover is established, it would help to diminish erosion, as well as filter and infiltrate water (Stednick, 2010). Ground cover has been shown to reduce the delivery of soil and other contaminants to streams (Stednick, 2010).

Range-5. Within affected pastures, grazing would be deferred for at least one year; longer if vegetative ground cover is not thriving and adequate to protect the soil from erosion (a project design feature).

Range-6. The duration of potential water quality impacts by prescribed fire are largely controlled by fire intensity and ground cover regeneration (Rhoades et al., 2019; Rhoades et al., 2011; Stednick, 2010); broadcast burns are planned to be low to moderate intensity and are expected to result in an overall increase in vegetative ground cover.

Range-7. Local to the proposed project area, study results (Shepard and Cadol, 2018) found a 2017 broadcast burn in the Upper Santa Fe River watershed did not have any significant adverse effects on water quality by monitored constituents; increases in dissolved organic carbon and particulate organic carbon, were not found to be larger than the EPA maximum contaminant levels for drinking water; the increases were very short lived (<1 year), and were less than that by a large natural stormflow event. No increase in heavy

metals or other ions were detected Shepard and Cadol, 2018. The proposed action is expected to have similar results because soils and topography within the 2018 study are similar to those in the proposed project area; also burn severity and vegetative ground cover response should be similar.

Range-8. Project design criteria will protect shade along stream channels, thereby preventing adverse impacts to stream temperature (Brown and Krygier, 1970)-

Range-9. Riparian species would not be cut or removed.

Range-10. Trees on or immediately adjacent to streambanks would not be cut.

Range-11. If deficient or affected, riparian vegetation would be planted to increase stream shade.

Range-12. Riparian areas would not be ignited but prescribed fire would be allowed to creep into these areas.

Project activities use FUEL AND CHEMICALS which could contaminate water, including the sources within the city of Santa Fe's municipal watershed.

Petroleum based fuel

Petroleum fuels would be used in many aspects of project implementation. Hand thinning is accomplished with chainsaws, fire-line and piles are ignited with drip-torches, and gasoline powered UTVs provide remote transportation.

There is a risk of contaminating surface and groundwater, should fuel spill. Risks are elevated where fuel is handled or stored in close proximity to surface water. Effects to aquatic habitat and drinking water quality would vary depending on the location and volume of fuel spilled. The potential effects to surface water would be expected to last until the next significant rain event dilutes the contaminant concentration (possibly several months to years). The potential effects to groundwater would be expected to last much longer (years), depending on subsurface properties. The effective implementation of numerous Best Management Practices (BMPs) and design criteria would be used to prevent spills, protecting water quality from the potential for adverse effects; see Appendix A.

Aerial Ignition Devices

Plastic ping-pong balls filled with highly flammable potassium permanganate would be injected with ethylene glycol (antifreeze) and dropped from a helicopter. Within 30 seconds, the chemicals in the ball should react, igniting fine fuels where the ball lands on the forest floor. The reaction creates Potassium Carbonate, Manganese Dioxide, Carbon Dioxide and water. Manganese, a mineral component of some sedimentary rocks, is also naturally present within the Upper Santa Fe River watershed, at approximately the Nichols reservoir location (Wells, 1918).

Ethylene glycol $(CH_2OH)_2$ is moderately toxic (large doses are fatal) to humans and animals. However, it breaks down in air in about ten days, and in water or soil in a few weeks. It also burns, releasing carbon dioxide and water. Ethylene glycol is not thought to adversely affect water quality because 1) there is very little ethylene glycol used during a broadcast burn, 2) very few ping-pong balls do not combust, and 3) when ethylene is burned, the resulting compounds are harmless.

The first aerial ignitions (using potassium permanganate) in the municipal watershed occurred in 2008. When McClure reservoir was routinely sampled for water quality in 2011, some manganese was found (0.00142-0.00148 mg/L; NMED). In October of 2016, the largest ever prescribed burn block (2,500 acres) within the municipal watershed was implemented, using aerial ignition. Subsequently, water quality was monitored the following summer (August 2017). The results (HEAL, 2017) showed manganese levels of 0.4 mg/L to 0.015 mg/L (with the highest samples taken between McClure and Nichols reservoirs, and below Cerro Gordo road).

Regardless of origin (natural or related to aerial ignition activities), the measured manganese concentrations are generally below toxic levels (healthy intake levels are 0.003 mg/day for infants and 2.3

mg/day for adult males; USDHHS, 2012). While the Safe Drinking Water Act requires that manganese does not exceed 0.05 mg/L in drinking water, the raw water at the municipal treatment plant's intake is typically above 0.1 mg/L. Concentrations of manganese have not dramatically increased over time (suggesting a naturally elevated background level), and the raw water is treated to standard before it is considered potable (Johansen, 2020).

To date, there is no evidence that aerial ignition devices are contaminating the City's surface water supply; manganese is naturally occurring at slightly elevated levels within the watershed (Wells, 1918). In addition, sodium permanganate is actually used at the City's water treatment plant to improve drinking water quality (Hook, 2020a). It is a strong oxidant which improves taste, odor, and color, as well as controls the formation of trihalomethanes and biological growth within the plant's infrastructure. Further, manganese dioxide, the un-combusted compound within the aerial ignition devices, is easily removed at the water treatment plant along with other solids. Therefore, if some devices fail and do not ignite, the treatment plant is able to easily remove the compound from the raw water (Johansen, 2020).

Beyond human health, it is important to understand how these chemicals may affect aquatic biota and their habitat. In 2008, Rainbow trout were sampled within the municipal watershed. Tissue was analyzed for various bioaccumulating constituents, including heavy metals. Manganese was detected in their tissue, but not at levels greater than the regional statistical reference (i.e., background). Further, no fish (or amphibian) kills have ever been observed, before or after thinning and burning treatments (Hook, 2020b).

Given manganese is naturally occurring within the municipal watershed (Wells, 1918), and raw water samples in the watershed have been high in manganese since before aerial ignition devices were deployed (Puglisi, 2020), the continued use of these tools are thought not to adversely affect water quality. In addition, after prescribed fires were ignited by aerial ignition, water quality samples showed manganese levels are within the range of the naturally occurring continental background levels[10]. This supports the use of aerial ignition devices in other project area watersheds, as it suggests manganese concentrations in waterbodies are not significantly increased. Further, adverse effects to aquatic species have not been observed (Hook, 2020b).

[10] Surface waters in the United States contain a median manganese level of 0.016 mg/L, with 99th percentile concentrations of 0.4–0.8 mg/L. Groundwater in the United States contains median manganese levels of 0.005 to 0.15 mg/L, with the 99th percentile at 2.9 or 5.6 mg/L in rural or urban areas, respectively (USDHHS, 2012).

Cumulative Effects of the Proposed Action

Introduction

Cumulative effects result when the effects of the proposed action are combined with effects from past, present and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes the action (40 CFR 1508.7).; analyzed actions and effects are limited to those which have the potential to adversely affect watershed resources (soil productivity, water quality, and watersheds/flow regime).

A cumulative watershed effect (CWE) is a project-induced impact that, when added to the effects of other past, present, and reasonably foreseeable future actions, results in an incremental effect on watershed resources. Cumulative effects are discussed in terms of changes in the existing condition due to present and foreseeable activities, including the effects of the proposed action. The spatial context for this analysis is bounded by the 12-digit hydrologic unit code watersheds which overlap the project area (see Table 1).

Short-term effects are those which occur and disappear within five years. Long-term effects are those which may occur within five years, but which persist much longer. Cumulative effects analysis considers activities which have occurred within the past 15 years. The CWE analysis timeframe is based on documented effects to water quality by high intensity wildfire which have persisted for at least 14 years (Rhoades et al., 2019).

Past, Present, and Reasonably Foreseeable Activities Relevant to Cumulative Effects Analysis

Together with proposed activities, Table 4 displays past, present, and reasonably foreseeable actions within analysis watersheds.

Past activities include reported acres of implemented land management actions within the past thirty years. Activities reported are:

- Broadcast burning,
- Pile burning,
- Invasive species treatments,
- Pre-commercial thinning,
- And thinning for fuels reduction

Potential adverse effects by these activities include increased erosion and sedimentation, soil compaction, soil and water contamination by fuel, nutrients, carbon and heavy metals, loss of soil productivity (by soil heating), as well as increased peak flows and flooding.

Past disturbance (within the last 15 years) includes wildfires in the analysis watersheds:

- Soldier Fire- 2009
- Pacheco Fire- 2011
- Pequeño Fire- 2011
- Tres Lagunas Fire- 2013
- McClure Fire- 2016
- Medio Fire -2020

Potential adverse effects by these activities include increased erosion and sedimentation, soil and water contamination by fuel and retardant, nutrients, carbon and heavy metals, loss of soil productivity (by soil heating), as well as increased peak flows and flooding.

Ongoing activities are most likely to contribute adverse cumulative watershed effects because many are constant, involve many entities (e.g., public recreationists, permittee holders, government bodies,

developers), depend on fluctuating federal budgets, or may be beyond Forest Service control. Ongoing activities within project area watersheds include:

- The USFS Pacheco and Hyde thinning and prescribed fire projects (to date, the projects have cumulatively implemented about 50% of the 4,040 acres proposed)
- Hyde Memorial State Park thinning and prescribed fire (NM Forestry); 172 acres of prescribed fire remain.
- The USFS La Cueva Fuelbreak Project (to date, all thinning work has been completed on 995 acres; 1,100 acres still planned for pile and broadcast fire).
- The USFS Santa Fe Municipal Watershed fuels reduction project (thinning activities are complete; up to 1000 acres/year of maintenance burning may occur into the near future).
- The Vigil Grant thinning and prescribed fire project (Pueblo of Tesuque; 158 acres have been thinned; maintenance burning will occur for the next 10 years).
- The Aspen Ranch thinning and prescribed fire project (Pueblo of Tesuque; 160 acres have been thinned; all prescribed fire and maintenance burning activities remain)
- The Aztec Springs fuels reduction project (City of Santa Fe and the Nature Conservancy; 150 acres/treatment is ongoing)
- Grazing allotments
- The Santa Fe ski area activities
- Existing roads and trails
- Developed and dispersed recreation
- Urban and rural development (e.g., the city of Santa Fe)

The potential adverse effects to watershed resources by these ongoing land-uses are many. The potential adverse effects by the Pacheco and Hyde thinning and prescribed fire projects are described above, are the same as those by past activities in the watersheds, and the proposed action. Grazing can diminish soil productivity, cause erosion and sedimentation, contaminate water bodies with nutrients and biological pathogens (e.g., giardia), and diminish wetland, riparian, and stream channel ecosystem services (e.g., filtering water, providing quality habitat). The ski area has adversely affected soil productivity where clear-cuts have removed the organic layer from the soil. Clear cuts at the ski area are eroding, likely contributing to sedimentation. Parking area management may contribute fine sediment and salts to stream channels when these areas are treated with scoria and subsequently plowed. Existing roads and trails contribute sediment to streams where drainage is poorly managed causing erosion of the road surface. Developed and dispersed recreation (e.g., campgrounds and campsites) typically concentrate people along stream banks and waterbodies, causing erosion and sedimentation as well as water pollution (e.g., E. coli bacteria, petroleum fuels). Urban development includes large areas of impermeable surface (e.g., paved parking lots) which result in erosive storm-flow surges within streams. Urban and rural developments also contribute many chemical pollutants to waterbodies.

Reasonably foreseeable actions are limited to those that overlap project area watersheds, with a proposed action or existing decision, a commitment of resources/funding, or a formal proposal; several projects were analyzed:

- The Pecos Bike Trails project (USFS Pecos Ranger District) proposes to develop a network of mountain bike trails in the Canada de Los Alamos/Glorieta area. The trails may be new construction, or road to trail conversions (or a mixture of both).
- The USFS Northern New Mexico Riparian, Aquatic, and Wetland Restoration Project (NNMRAW; Forest-wide) proposes a suite of restoration activities (e.g., riparian planting, beaver habitat restoration) aimed at improving aquatic and riparian habitats. Activities also include upland treatments (e.g., road decommissioning) aimed at reducing sedimentation in waterbodies. The project is conditions based; no specific treatment areas have been identified to date.

- The USFS Rowe Mesa II fuels reduction and healthy forest and grassland project and the Southern Rowe Mesa Restoration Project propose to treat approximately 17,500 acres by thinning and prescribed burning.
- The USFS Santa Fe Municipal Watershed Pecos Wilderness Prescribed Burn Project proposes to broadcast burn between 200 and 2,100 acres of the Pecos Wilderness in a single effort. Vegetation includes ponderosa pine and mixed conifer stands.

The potential adverse effects of a new mountain bike trail system include increased erosion and sedimentation in waterbodies, especially if these new trails do not receive regular maintenance. There may however be some beneficial effects, as this network could convert old eroding Forest roads to trails, shrinking the erodible surface to a single track. Increased attention by trail users may result in decreased erosion and sedimentation, if followed by increased trail maintenance.

The potential adverse effects by the thinning and prescribed fire projects are described above, are the same as those by past activities in the watersheds, and the proposed action.

The NNMRAW project is likely to have some short-term adverse effects to water quality (erosion and sedimentation) during project implementation but would result in significant long-term benefit to watershed resources (the purpose and need is based on improving the condition of riparian and aquatic ecosystems).

Table 4: Cumulative Watershed Effects (CWE) Risk Summary

Watershed (HUC12)	Total Watershed Acres	Existing Condition WCF Rating	% Watershed Proposed Treated	Adverse CWE Factors	Beneficial CWE Factors	CWE Potential Risk
Arroyo Hondo	16,417	Properly Functioning	19%	Past treatments- 13% of the watershed Poor trail and road conditions (WCF) Pecos Bike Trails Project -new mountain bike trails likely Ongoing grazing- 26 head on 3,354 acres (129 acres per cow/calf pair); 20% of the watershed is grazed.	NNMRAW** Some reduced risk of high intensity wildfire Riparian conifer thinning and planting (by this proposed action)	Mod
Dry Gulch-Pecos River	27,274	At Risk	4%	Past treatments- 10% of the watershed • Soldier Wildfire (2009)- 90 acres; <1% of the watershed area • Pequeño Wildfire (2011)- 35 acres; <1% of the watershed area • Tres Lagunas Wildfire (2013)- 331 acres; 1% of the watershed area Ongoing grazing- 25 head on 19,352 acres (714 acres per cow-calf pair); 71% of the watershed is grazed	NNMRAW**	Low

Table 4 continued…

Watershed (HUC12)	Total Watershed Acres	Existing Condition WCF Rating	% Watershed Proposed Treated	Adverse CWE Factors	Beneficial CWE Factors	CWE Potential Risk
Glorieta Creek	21,431	At Risk	32%	Past treatments- 7% of the watershed Ongoing La Cueva Fuelbreak project- 1,100 acres (5% of the watershed area) Ongoing thinning and prescribed fire on Rowe Mesa (approximately 30% of the watershed area) Ongoing grazing- 26 head on 7,777 acres (299 acres per cow-calf pair); 36% of watershed is grazed	NNMRAW** Significant reduced risk of high intensity wildfire	High
Glorieta Creek-Pecos River	20,267	At Risk	13%	Past treatments- 3% of the watershed Ongoing grazing- 63 head on 10,152 acres (161 acres per cow-calf pair) 50% of the watershed is grazed Poor trail and road conditions (WCF)	NNMRAW** Some reduced risk of high intensity wildfire	Mod.
Headwaters Rio Tesuque	26,072	At Risk	25%	Past treatments- 2% of the watershed Ongoing USFS Hyde Project- 1,840 acres of thinning and prescribed fire Ongoing Hyde Memorial State Park thinning and prescribed fire (276 acres; 1% of the watershed) Poor condition roads and trials Ongoing grazing = 53 head on 851 acres (16 acres per cow-calf pair) 3% of the watershed is grazed	NNMRAW** Significant reduced risk of high intensity wildfire Riparian conifer thinning and planting (by this proposed action)	High

Table 4 continued…

Watershed (HUC12)	Total Watershed Acres	Existing Condition WCF Rating	% Watershed Proposed Treated	Adverse CWE Factors	Beneficial CWE Factors	CWE Potential Risk
Headwaters Santa Fe River* (municipal watershed)	34,798	At Risk	6%	Past thinning and burning treatments- 44% of the watershed Ongoing prescribed fire (up to 1000 acres/year); maintenance burning Ongoing Aztec Springs thinning and prescribed fire activities (150 acres; 0.4% of the watershed) Future Pecos Wilderness prescribed fire (up to 2,100 acres; 6% of the watershed) McClure Wildfire (2016)- 8 acres; <1% of the watershed area Poor road condition Urban development- City of Santa Fe	NNMRAW** Watershed closed to grazing and other land uses. Reduces potential for erosion and sedimentation on high risk hillslopes above water source infrastructure (McClure Reservoir)	Mod.
Rio Nambe	31,685	At Risk	9%	Past treatments- 2% of the watershed Pacheco Wildfire (2011)- 9598 acres; 30% of the watershed area Ongoing Pacheco Project- fuels reduction and prescribed fire on 2,200 acres Ongoing grazing- 93 head. on 22,738 acres, (244 acres/ cow calf pair) 72% of the watershed area is grazed Ongoing Aspen Ranch thinning and prescribed fire (160 acres; 0.5% of the watershed) Ongoing Vigil Grant thinning and prescribed fire (158 acres; 0.5% of the watershed) Developed recreation – Santa Fe Ski area	NNMRAW** Some reduced risk of high intensity wildfire	Mod.

Table 4 continued…

Watershed (HUC12)	Total Watershed Acres	Existing Condition WCF Rating	% Watershed Proposed Treated	Adverse CWE Factors	Beneficial CWE Factors	CWE Potential Risk
Rio Tesuque-Pojoaque Creek	27,838	At Risk	6%	Past treatments- 8% of the watershed Poor road and trail conditions. Ongoing grazing- 93 head of cattle on 5,453 acres; (59 acres per cow/calf pair) 20% of the watershed is grazed.	NNMRAW** Some reduced risk of high intensity wildfire	Low
San Cristobal Arroyo-Galisteo Creek*	38,018	At Risk	28%	Past treatments- 3% of the watershed TMDL for stream temperature- risk of reducing stream shade through proposed action Pecos bike trails project- new mountain bike trails likely Ongoing grazing- 146 head on 12,328 acres; (84 acres/cow calf pair) 32% of the watershed is grazed	NNMRAW** Significant reduced risk of high intensity wildfire	High
San Marcos Arroyo	26,434	Not Rated	2%	Past treatments- 0% of the watershed Suburban development- El Dorado Subdivision Pecos bike trails project- new mountain bike trails likely Ongoing grazing- 26 head grazed on 515 acres (20 acres/cow calf pair) 2% of the watershed is grazed	NNMRAW** Some reduced risk of high intensity wildfire	Low

*Denotes a watershed with a 303d impaired waterbody

**Riparian areas, aquatic habitat, upland sediment sources, and non-native invasive species likely addressed by NNMRAW

CWE Risk Analysis

The information below is summarized by Table 4.

High Risk

The following watersheds are at high risk for cumulative watershed effects by the proposed action: Glorieta Creek, Headwaters Rio Tesuque, and San Cristobal Arroyo-Galisteo Creek. The determined risk within these watersheds is largely affected by the percentage of watershed area likely to be treated by the proposed action; 25% or more of these watersheds are likely to be thinned and burned over the next ten years.

The Glorieta Creek watershed is likely to have 32% of its area treated by the proposed action (thinning and prescribed fire) over the next 10 years. Combined with effects by ongoing grazing (36% of the watershed is grazed), and some past vegetation/fuels treatments (covering 7% of the watershed area), there is a high risk of adverse CWEs. Beneficial CWEs are expected by the proposed action because it would significantly reduce the risk of high intensity wildfire. In addition, the NNMRAW may implement actions within the watershed which would improve riparian and aquatic ecosystems' condition and function.

The Headwaters Rio Tesuque watershed also contains the Hyde project, which will treat an additional 1,840 acres by thinning and prescribed fire; combined with the proposed action, a total of 31% of the watershed will be treated within the next 10 years. Poor road and trail conditions, in addition to some grazing in the watershed contribute to the high risk for adverse effects in this watershed. Beneficial cumulative effects are likely to result if the proposed action improves riparian condition and function (see the riparian resource report) while also significantly reducing the risk of high intensity wildfire. If NNMRAW activities are implemented in the watershed additional long-term beneficial effects to watershed resources are expected.

The San Cristobal Arroyo-Galisteo Creek watershed would have 28% of its area treated by the proposed action. These activities have the potential to reduce stream shade on a waterbody currently not meeting state water quality standards for temperature. Together with some past vegetation and fuels treatments (3% of the watershed area), ongoing grazing (32% of the watershed is grazed), and a new trail system (Pecos mountain bike trails), the watershed is at high risk for cumulative effects. Beneficial CWEs are expected by the proposed action because it would significantly reduce the risk of high intensity wildfire. In addition, the NNMRAW may implement actions within the watershed which would improve riparian and aquatic ecosystems' condition and function

The long-term beneficial cumulative watershed effects are expected to outweigh any short-term adverse effects. For example, the WEPP model (see effects analysis above) showed erosion and sedimentation from thinning and fuels treatments would be half that expected from a high intensity wildfire. The potential for most adverse effects by the proposed action (and therefore adverse CWEs) would be diminished or eliminated with the effective implementation of BMPs and design criteria (see Appendix A). In addition, the implementation strategy defined below would guide the timing of activities to further protect against adverse CWEs.

Moderate Risk

The following watersheds are at moderate risk for incurring cumulative watershed effects: Arroyo Hondo, Glorieta Creek-Pecos River, Headwaters Santa Fe River, and Rio Nambe. Moderate risk watersheds would have fewer acres treated by the proposed action (only 6-19% of watershed area are likely to be treated), diminishing the likelihood of adverse CWEs from high to moderate.

The Arroyo Hondo watershed has had some past vegetation and fuels treatments within the watershed (13%). Ongoing grazing (20% of the watershed area) and poor trail and road conditions adversely affect watershed resources. New mountain bike trails within the watershed are likely to be built. Together with

the proposed action, these activities have the potential for adverse CWEs. Beneficial cumulative effects are likely to result if the proposed action improves riparian condition and function (see the riparian resource report) while also somewhat reducing the risk of high intensity wildfire. If NNMRAW activities are implemented in the watershed, additional long-term beneficial effects to watershed resources are expected.

The Glorieta Creek-Pecos River watershed has had a small amount of past vegetation and fuels treatments (3% of the watershed area), has poor road and trail conditions, and ongoing grazing (50% of the watershed is grazed).

In addition to the proposed action, the Rio Nambe watershed will have 2,200 acres thinned and burned by the Pacheco project (totaling 9% of the watershed area, including the proposed action). These activities, in addition to some past vegetation/fuels treatments (2% of the watershed area), wildfire (30% of the watershed was burned in 2011 by the Pacheco Fire), ongoing disturbance at the Santa Fe Ski Area and seasonal grazing (72% of the watershed area) have the potential to result in adverse CWEs. Beneficial CWEs are expected within these watersheds because the risk of high intensity wildfire would be reduced by the proposed action, and if implemented, the NNMRAW project would improve riparian and aquatic ecosystems (watershed resources).

The Headwaters of the Santa Fe River (municipal) watershed is inherently riskier because of the values in jeopardy (drinking water supply and infrastructure). The watershed has had significant (44% of the watershed area) vegetation and fuels treatments (largely thinning and broadcast burning), as well as some wildfire within the last 15 years (McClure Fire, 2016; <1% of the watershed area). In addition, the main access road to the reservoirs is in very bad condition, contributing sediment to waterbodies. Within the upper portion of the watershed, most land-uses are prohibited, in the interest of protecting the municipal water supply, water quality and infrastructure. Within the lower portion of the watershed, urban development (the City of Santa Fe) has dramatically altered the flow regime and water quality of the Santa Fe River (the Santa Fe River through the urban area is listed as impaired by several contaminants). While proposed activities are small in area (6% of the watershed), they would have a disproportionate beneficial effect on protecting water quality and infrastructure within the McClure reservoir. This is because proposed activities would reduce the risk of high intensity wildfire on some of the most sensitive terrain in the project area (see the wetness model/WEPP model discussion above; effects to water quality). In addition, if NNMRAW activities are implemented in the watershed, beneficial CWEs to riparian and aquatic ecosystems (watershed resources) would be expected.

For each moderate risk watershed, adverse CWEs would be mitigated through implementation of BMPs and project design criteria (see Appendix A), in addition to the implementation strategy defined below. The long-term beneficial cumulative watershed effects are expected to outweigh any short-term adverse effects.

Low Risk

The following watersheds are at low risk for CWEs: Dry Gulch-Pecos River, Rio Tesuque-Pojoaque Creek, and San Marcos Arroyo. These watersheds have very few acres of treatment by the proposed action (2%-6% of the watershed area would likely be treated) and have had little treatment in the past (<10% area treated); diminishing the likelihood of adverse CWEs from moderate to low.

In addition, these watersheds have few ongoing activities and little disturbance by reasonably foreseeable future activities. Within the Dry Gulch-Pecos River watershed, while 71% of the watershed is grazed, grazing intensity is low with 714 acres per cow-calf pair. Wildfire history in this watershed is also insignificant (but active; three wildfires 2009-2013), with a cumulative disturbance of <2% by area. Within the Rio Tesuque-Pojoaque Creek watershed, poor road and trail conditions and some grazing contribute to adverse CWEs. Within the San Marcos Arroyo watershed, adverse CWEs would largely be contributed by off-Forest land-uses (El Dorado subdivision). Few adverse effects by Forest projects are

expected because so few acres within the watershed are managed by the USFS (i.e., few miles of new bike trail are expected within the watershed and very little grazing).

The proposed action also has the potential to result in some beneficial CWEs within these low risk watersheds. A slightly reduced risk of high intensity wildfire would be expected by the proposed action; combined with the effects of the NNMRAW project (if implemented in this watershed), watershed resiliency, riparian and aquatic ecosystems would likely improve.

For each low risk watershed, adverse CWEs would be mitigated through implementation of BMPs and project design criteria (see Appendix A), in addition to the implementation strategy defined below. The long-term beneficial cumulative watershed effects are expected to outweigh any short-term adverse effects.

Strategy for Avoiding Adverse Cumulative Watershed Effects

The following strategy was deemed necessary to avoid adverse CWEs by the proposed action and grazing, while also considering the timing and potential effects of successive proposed treatments within a single watershed. These activities have the most potential to cause adverse CWEs because they both can reduce vegetative ground cover. Vegetative ground cover significantly diminishes the adverse effects of the proposed action by slowing, infiltrating, and filtering runoff. Figure 4 Figure 5 display the strategy described here:

For a watershed of any size, a broadcast burn unit of any size, and once a broadcast burn unit has been implemented[11]-

- Fire managers will communicate vegetation burn intensity to watershed staff; were there any areas of *moderate or high intensity*?
    - *If not, no action.* Prescribed fire can continue within the watershed as soon as a burn window allows; the assumption being that ground cover has not been significantly and adversely affected; is expected to positively respond to the nutrients released by the burn and will become more effective at filtering and infiltrating water (by the next monsoon season).
    - *If the prescribed fire resulted in an area of moderate or high vegetation burn intensity*, and the area is thought to be large enough to potentially have significant effects- an IDT of fire/fuels, watershed and range staff will go to the field to investigate. A BARC map may be used to better understand the extent of potential impacts. Areas of moderate or high intensity will be targeted, especially those near stream channels. Evidence of impacts to water quality (e.g., ash flows, rills, debris flows) will be sought out. Residual ground cover and the potential for needle-cast will be assessed. The potential for winter precipitation and monsoon precipitation will be considered; what is the likelihood winter precipitation will support vigorous growth of ground cover in the spring? What is the likelihood the monsoon season will be very active? What is the risk of erosion during the monsoon season?
        - If there is evidence of impact to water quality *or* soil productivity, *or* there is concern for the regeneration of ground cover- consider delaying burning within

[11] The proposed action applies the following annual limits to implementation:

- Maximum prescribed fire unit would be 2,000 acres
- Annual maximum prescribed fire treatment area would be 4,000 acres (in two sessions; one spring burn and one fall burn, in any one watershed.)
- Annual maximum vegetation thin would be 750 acres

the same watershed. Re-evaluate the burn unit after a wet season; resume burning in the watershed once enough ground cover has been established to eliminate or minimize cumulative adverse impacts.

- If there are no impacts *and* ground cover regeneration is highly likely, consider burning additional blocks within the watershed. Because impacts to water quality are most likely to occur during the monsoon season, the potential for cumulative watershed effects by spring burns will be more difficult to assess than those by fall burns; *therefore, be more cautious when making the decision to burn in the spring (following a prior fall burn).*

- Per the range design feature; where prescribed fire overlaps with a pasture, grazing would be deferred for *at least* one year. Monitoring of forage volume and vigor would determine when grazing would commence. Assessment would be accomplished by an interdisciplinary team of fire/fuels, watershed and range staff.

Cumulative Watershed Effects Summary

For every analyzed watershed, the long-term beneficial cumulative watershed effects are expected to outweigh any potential cumulative adverse effects. This is largely because BMPs and design criteria (see Appendix A) would diminish adverse effects by the proposed action to insignificant levels. Further, the implementation strategy will help to avoid adverse CWEs by grazing, the ongoing (Forest Service managed) activity within these watersheds most likely to result in adverse CWEs because it decreases vegetative ground cover.

Summary of Effects by the Proposed Action Alternative

Implementation of the Proposed Action has the potential to result in short and long-term adverse impacts to watershed resources (soil, water quality, and flow regimes).

Where heavy equipment is used, machinery can disturb and compact the soil, making it more susceptible to erosion, less able to absorb water, and therefore less productive (Stednick, 2010). Further, these impacts can result in flooding if more overland flow reaches stream channels more quickly.

If soil is super-heated beneath burn piles or broadcast fire, changes in organic matter content, water infiltration, soil mineralogy, and nutrient availability would be expected (Busse et al., 2014). These effects would make hillslopes more susceptible to erosion, adversely affecting water quality through sedimentation, nutrients and the contribution of other water quality constituents (Certini, 2005). Nutrients and dissolved organic carbon in waterbodies are exceptional concerns because they can cause algal blooms, eutrophication (Gottfried and DeBano, 1990) as well as cause major problems for potable water management and treatment (Hohner et al., 2019).

Other adverse water quality impacts are possible by the Proposed Action. Where stream-shade is reduced, stream temperatures would be expected to increase (Brown and Krygier, 1970). This would be especially detrimental within Galisteo Creek which is currently not meeting state water quality standards for temperature. The introduction of chemical pollutants from petroleum fuel spills and aerial ignition devices could also adversely affect water quality.

Maintaining or quickly regenerating vegetative ground cover would be an important control on adverse impacts to watershed resources (Busse et al., 2014, Rhoades et al., 2011). While short-term adverse impacts to ground cover are possible (by soil disturbance and prescribed fire), long-term beneficial impacts to vegetative ground cover are expected (e.g., where fire releases nutrients from the soil and where forest thinning results in more sunlight on the ground).

Adverse impacts to watershed resources are expected to be minimal, short term, and insignificant when compared with those by high intensity wildfire. This is because:

- Many best management practices and design criteria, which protect soil from erosion and waterbodies from sedimentation, would be implemented (see Appendix A).
- While soil compaction can last for up to 50 years, it is repaired by a frequent freeze-thaw cycle (Greacen and Sands, 1980; Webb et al., 1986). Freeze-thaw commonly occurs many times throughout the winter within the middle and lower elevations of the project area.
- Slope limitations to heavy equipment operations prohibit operations on gradients steeper than 40%; this means much of the project area would be treated by hand, diminishing wide-spread impacts to soil productivity.
- Best management practices and design criteria will protect riparian vegetation and therefore stream shade; affected areas will be planted with riparian species.
- Prescribed fire by the Proposed Action is intended to be of low intensity. Soil burn severity will be diminished by implementing prescribed fire when soil moistures are high (e.g., fall and spring months; Busse et al., 2014).
- Soil erosion and sedimentation volumes would be diminished by low intensity prescribed fire as compared with high intensity wildfire (WEPP model results; Robichaud, 2000).
- Heavy metals, ions and organic carbon concentrations were monitored after a 2017 broadcast burn in the municipal watershed. The water quality response (for all constituents studied) was not largely adverse, was very short lived (<1 year), and was less than that by a large natural stormflow event. Further, all post-burn increases were less than the EPA's maximum contaminant levels for drinking water quality (Shepard and Cadol, 2018).
- The potential water quality effects to stream nutrients are significantly less in terms of concentration (Stednick, 2010; Meixner and Wohlgemuth, 2004), and duration (Rhoades et al., 2019; Stephens et al., 2004), by prescribed fire than by high intensity wildfire.
- The establishment of ground cover is a significant control on the recovery of water quality (Rhoades et al., 2011) to pre-treatment conditions.
- Most broadcast burns (low to moderate intensity) promote the rapid establishment of vegetative ground cover (Certini, 2005) because they:
    - Preserve soil structure while also increase available plant nutrients.
    - Increase light on existing areas of bare soil once overstory vegetation is thinned.
    - Promote the establishment of grasses and forbs (Rhoades et al., 2011; Kane et al., 2010) which are typically able to re-sprout within 1 year (Sackett and Haase, 1998).
    - Allow seeds enough time to become established before the monsoon season (e.g., July), when overland flow is most likely; broadcast fire is typically implemented during the spring and fall.
    - Protect the soil with residual duff and needles immediately after the burn and later with needles cast off the dead branches in the overstory (USDA, 2016).
- The implementation strategy (see the cumulative watershed effects analysis) would help coordinate interdisciplinary staff to ensure ground cover is protected.
- Design criteria would prohibit grazing any pasture for at least one year following a broadcast burn, potentially longer depending on ground cover response and vitality.
- Aerial ignition devices have not been shown to adversely affect surface water quality (Puglisi, 2020) and some manganese is naturally occurring within the municipal watershed (Wells, 1918). After prescribed fires were ignited by aerial ignition, water quality samples showed manganese levels to be within the range of the naturally occurring continental background levels. Further, manganese is removed during treatment from the potable water supply (Johansen, 2020). And finally, adverse effects to aquatic species have not been observed (Hook, 2020b).
- To protect water quality from fuel spills, best management practices and design criteria would be implemented.

Cumulative watershed effects are expected to have long-term beneficial effects on watershed conditions. Proposed activities within the "properly functioning" Arroyo Hondo watershed (thinning, burning, riparian treatments, and road closure) would help to protect the components of the watershed that have integrity (e.g., water quality, aquatic habitat). Proposed activities within the "at risk" watersheds would help to protect components that are functional while improving the condition of those that are degraded (e.g., vegetative ground cover, riparian vegetation).

Figure 4: Fall Burn Strategy for Avoiding CWE

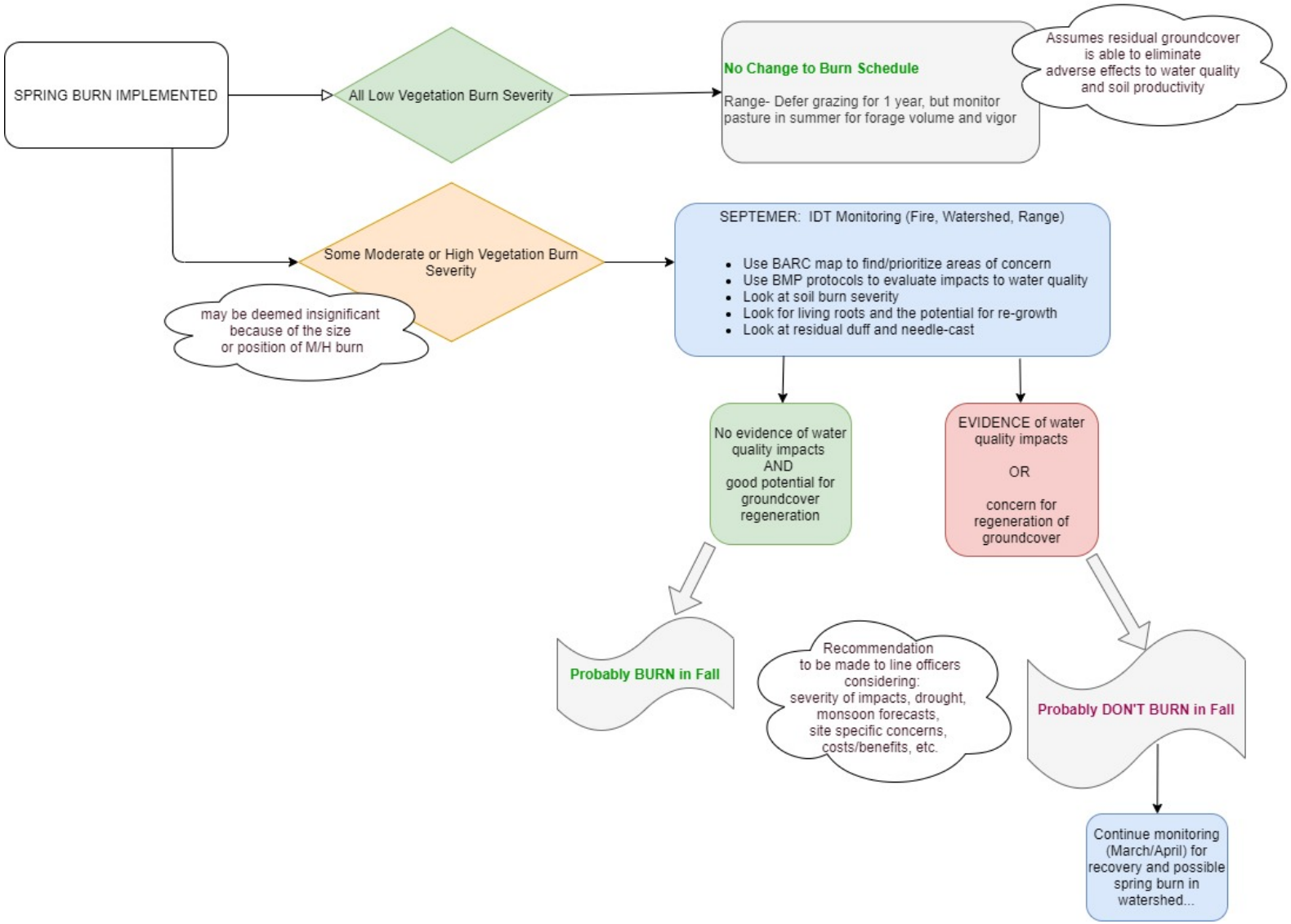
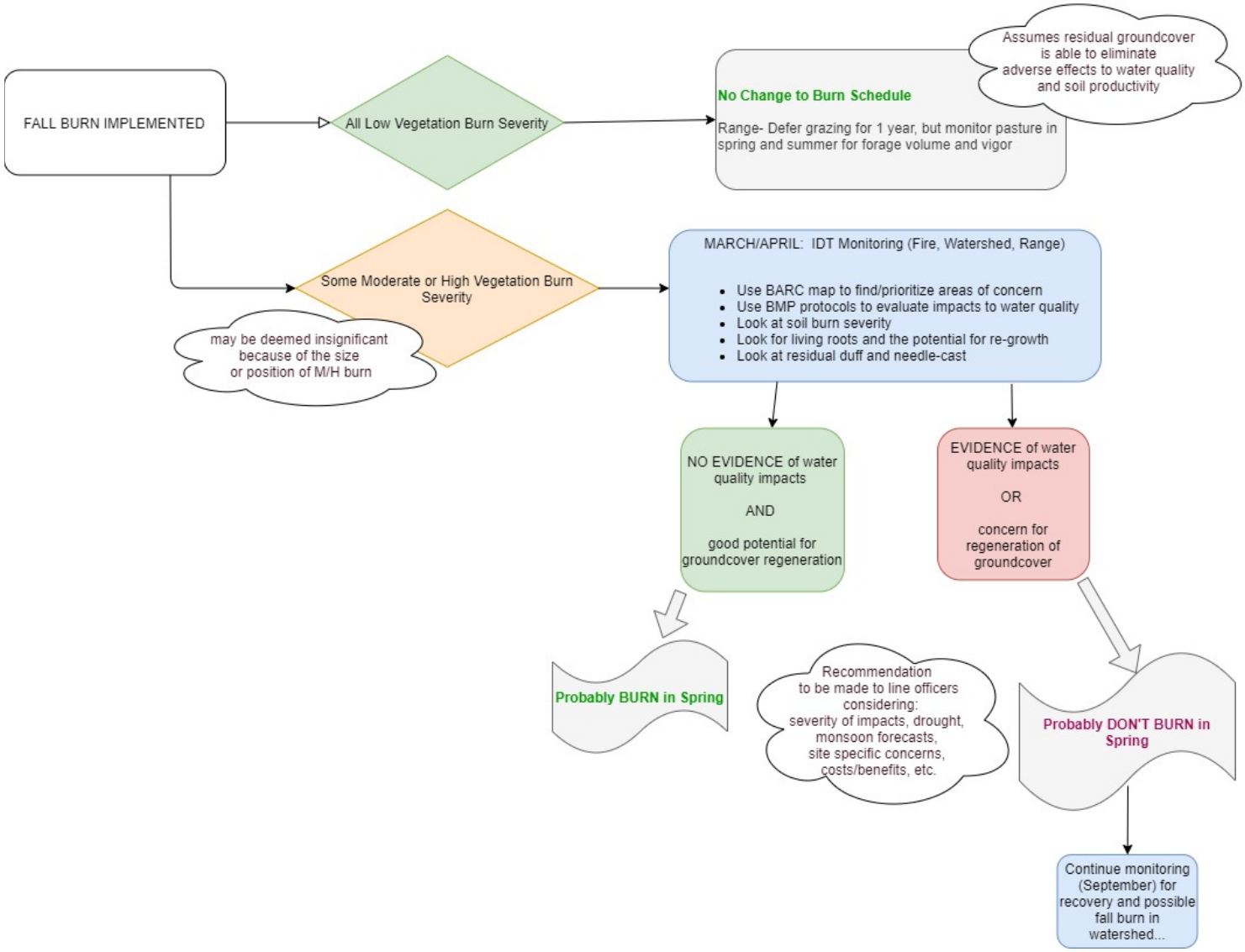


Figure 5: Spring Burn Strategy for Avoiding CWE



Consistency with Relevant Laws, Regulations, and Policy

The SFMLR Project will comply with relevant law, regulation, and policy by:

- Implementing Forest Plan guidance;
- Consulting the Forest Service Manuals and Handbooks for implementation guidance;
- Observing federal laws and regulation;
- Observing state and local laws, regulation, and policy.

A review of the following applicable and relevant laws, regulations and policies has been conducted to ensure the proposed action compliance.

Land and Resource Management Plan

The Santa Fe National Forest Land and Resource Management Plan (forest plan; LRMP) (1987, as amended 1992, 1997 and 2010) provides standards and guidelines for watershed resources (soil, water quality, and flow regime) within the project area. Table 6 displays the applicable LRMP management areas, standards and guidelines, SFMLR project activities and compliance.

These management areas overlap the SFMLR project but do not have specific watershed standards and guidelines which would apply to the proposed project activities:

- A: Timber, wildlife
- D: Recreation, Visual Resources, Timber
- E: Dispersed Recreation, Visual Resources, Timber
- L: Semi-Primitive Non-Motorized Recreation

The SFMLR Project is consistent with the Santa Fe National Forest LRMP (as amended).

Table 5: SFMLR Project Compliance with the 1987 Santa Fe National Forest LRMP

LRMP Management Area	LRMP Watershed Related Standard/Guideline	Project Activity Affected	Compliance and Rationale
F Forest Wide	Log landings will be located outside of sensitive land areas, including riparian areas, wetlands, and natural meadows	(Possibly) gathering logs for public firewood distribution	See design criteria #9
	Limit ground based logging equipment to slopes <40%	Mechanical logging equipment will not be used on slopes >40%	See design criteria #8
	Manage to perpetuate or maintain aspen stands along stream course reaches with less than a 6% gradient	Riparian restoration treatments	See design criteria #15
	Improve unsatisfactory watershed condition through a combination of structural methods and management strategies (e.g., road closures)	Project will close road 79W	See proposed action.

Table 6 continued….

LRMP Management Area	LRMP Watershed Related Standard/Guideline	Project Activity Affected	Compliance and Rationale
F **Forest Wide**	Soil loss due to management activities will be within acceptable tolerance limits by the second year following the activity	Some erosion is expected after thinning and prescribed fire activities	See all BMPs and Design Criteria (Appendix A); effective implementation would minimize or prevent erosion.
	Riparian areas should be managed to meet the following guidelines- • Ground cover should be 80% of natural • Shade should be 80% of natural per 2 mile reach • Bank Cover should be 80% of natural, especially woody shrubs • Streambank sedimentation should exceed natural by less than 20% • Plant composition- 60% of the riparian area should have >3 woody riparian species • Plant Structure- should include 3 age classes (with at least 10% seedling and 10% mature/over-mature) • Crown Cover- should be 80% of natural levels within a 2 mile reach	Proposed Action includes: • Hand thinning in the riparian management zone (RMZ) • Limited pile burning in the RMZ • Limited broadcast burning in the RMZ • Planting in the RMZ • Invasive species removal in the RMZ • Protection by fencing (from graze and browse) of the RMZ	See the riparian analysis section within the EA See Appendix A; numerous BMPs and design criteria are aimed at protecting and enhancing the RMZ.

Table 6 continued….

LRMP Management Area	LRMP Watershed Related Standard/Guideline	Project Activity Affected	• Compliance and Rationale
F **Forest Wide**	Water quality and soil monitoring will be done in key areas to aid in identifying and correcting resource problems	See monitoring plan in the EA	• Water quality monitoring for: Temperature in Galisteo Creek • Nutrients in the Santa Fe River and municipal watersheds • Ground cover within allotment pastures (e.g., on different aspects, for different soil types, coverage and recovery period) • BMP effectiveness monitoring
O **Municipal Watershed** **Water Quality Protection**	Closed to all use (except the operation of the municipal water system) by the Secretary of Agriculture (1932) for the purposes of protecting a quality water supply • No grazing • No recreation, no public access • Limited motorized access	Approximately 2,500 acres are likely to be treated by hand thinning, hand (fire) line, and broadcast fire within the municipal watershed	See all BMPs and Design Criteria (Appendix A); effective implementation would minimize or prevent impacts to water quality. The implementation strategy would help to prevent cumulative watershed effects through interdisciplinary monitoring, planning for the current climate, and ground cover assessment.

Table 6 continued….

LRMP Management Area	LRMP Watershed Related Standard/Guideline	Project Activity Affected	Compliance and Rationale
O **Municipal Watershed** **Water Quality Protection**	Use fireline construction methods which have the least impact on water quality values	Ridgetop fireline would be constructed by hand (at Thompson Peak ridgeline) Fireline on slopes and valley bottoms would be constructed by hand	See BMPs and design criteria (Appendix A), especially numbers: 12, 13, 30, and 31
	Prescribed fire may be used to reduce fuels to an acceptable level while protecting watershed values	Pile burning and broadcast fire would be used to reduce fuels	Fire would be low intensity, with pockets of moderate intensity; burning would occur when soils are moist so as to prevent super-heating. See design criteria #32 and #43.

Other Relevant Law, Regulation, or Policy

The SFMLR Project will comply with relevant law, regulation and policy in doing the following:

- Coordinate with the City of Santa Fe municipal water utility in planning activities within the municipal watershed and monitoring for potential impacts after implementation.
- Coordinate with the State of New Mexico Environment Department in the protection and improvement of 303d listed waterbodies and meeting the terms of the TMDL for Galisteo Creek.
- Implementing Best Management Practices to control non-point source pollution, thereby meeting the terms of the Clean Water Act.
- Protecting and/or improving floodplains and wetlands through riparian treatment, mitigation and avoidance.
- Consulting the Forest Service Manuals and Handbooks for implementation guidance.

Federal Law

Water Resources Planning Act of July 22, 1965: Encourages the conservation, development, and utilization of water and related land resources of the United States on a comprehensive and coordinated basis by the Federal government, states, localities, and private enterprises.

Watershed Protection and Flood Prevention Act of August 4, 1954: Establishes policy that the Federal government should cooperate with states and their political subdivisions, soil or water conservation districts, flood prevention or control districts, and other local public agencies for the purposes of preventing erosion, floodwater, and sediment damages in the watersheds of the rivers and streams of the United States; furthering the conservation, development, utilization, and disposal of water, and the conservation and utilization of land; and thereby preserving, protecting, and improving the Nation's land and water resources and the quality of the environment.

The Federal Water Pollution Control Act of 1972: Public Law 92-500, as amended in 1977 (Public Law 95-217) and 1987 (Public Law 100-4) (also known as the Federal Clean Water Act (CWA)): This Act provides the structure for regulating pollutant discharges to waters of the United States. The Act's objective is "…to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," and is aimed at controlling both point and non-point sources of pollution. The U.S. EPA administers the Act, but many permitting, administrative, and enforcement functions are delegated to state governments. In New Mexico, the designated agency for enforcement of the Clean Water Act is the New Mexico Environmental Department (NMED). Relevant sections of the Clean Water Act:

- CWA Sections 208 and 319: recognizes the need for control strategies for non-point source pollution.

- CWA Section 303(d): requires waterbodies with water quality determined to be either impaired (not fully meeting water quality standards for designated uses) or threatened (likely to violate standards in the near future) to be compiled by NMED in a separate list, which must be submitted to EPA every 2 years. These waters are targeted and scheduled for development of water quality improvement strategies on a priority basis.

- CWA Section 305(b): requires that states assess the condition of their waters and produce a biennial report summarizing the findings.

Executive Orders

The following are regulations applicable to the proposed management actions:

Executive Order 11988 (Floodplain Management (42 CFR 26951, May 25, 1977): The purpose of this Order is "…to avoid to the extent possible the long and short term impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." Section 1 states: "Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for (1) acquiring, managing, and disposing of Federal lands, and facilities; (2) Providing federally undertaken, financed, or assisted construction and improvements; and (3) Conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities."

Executive Order 11990 (Protection of Wetlands): …"in order to avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands… Section 1. (a) Each agency shall provide leadership and shall take action to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities for… (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities. Sec. 5: In carrying out the activities described in Section I of this Order, each agency shall consider factors relevant to a proposal's effect on the survival and quality of the wetlands. Among these factors are: (b) maintenance of natural systems, including conservation and long-term productivity of existing flora and fauna, species and habitat diversity and stability, hydrologic utility, fish, wildlife, timber, and food and fiber resources; and (c) other uses of wetlands in the public interest, including recreational, scientific, and cultural uses."

State and Local Law

The following memorandums are between the state of New Mexico and the US Forest Service. They describe how together the US Environmental Protection Agency and the US Forest Service will work to improve water quality.

Memorandum of Agreement on Fostering Collaboration and Efficiencies to Address Water Quality Impairments on National Forest System Lands: Agreement between U.S. Forest Service and the U.S. Environmental Protection Agency signed in 2007: The purpose is to coordinate between agencies and address issues of water quality impairment regarding the 303d list, as well as TMDLs. The leading cause of water quality impairments on National Forest lands includes temperature, excess sediment, and habitat modification. These issues are to be addressed via BMPs to the greatest extent possible.

Memorandum of Understanding. USFS MOU 17-MU-11031600-049/NMED MOU 18-667-2060-0003 6-27-17: NM Water Quality Protection Agreement. Agreement between the U.S. Forest Service Southwestern Region and the State of New Mexico Environment Department. Cooperation between the parties with the common objective of improving and protecting the quality of New Mexico's waters by implementing progressive watershed-based restoration protection programs to meet applicable water quality standards.

Policy

The U.S. Forest Service Directives System (FSM/FSH): Forest Service Manuals and Handbooks codify the agency's policy, practice, and procedure. The system serves as the primary basis for the internal management and control of all programs and the primary source of administrative direction to Forest Service employees. The Forest Service Manual (FSM) contains legal authorities, objectives, policies, responsibilities, instructions, and guidance needed on a continuing basis by Forest Service line officers and primary staff in more than one unit to plan and execute assigned programs and activities. Forest Service Handbooks (FSH) are the principal source of specialized guidance and instruction for carrying out the direction issued in the FSM. Specialists and technicians are the primary audience of Handbook direction. Handbooks may also incorporate external directives with related USDA and Forest Service directive supplements.

Forest Service Manuals

- FSM 2500 – WATERSHED AND AIR MANAGEMENT
    - Region 3 (Southwestern Region): Regional Issuances
- Forest Service Manual 2510 - WATERSHED PLANNING
- Forest Service Manual 2520 - WATERSHED PROTECTION AND MANAGEMENT
- Forest Service Manual 2530 - WATER RESOURCE MANAGEMENT
- Forest Service Manual 2540 - WATER USES AND DEVELOPMENT

Forest Service Handbooks

- Forest Service Handbook 2500 – Watershed and Air Management
    - Region 3 (Southwestern Region): Regional Issuances
- 2509.16 - Water Resource Inventory Handbook
- 2509.21- National Forest System Water Rights Handbook
- 2509.22- Soil and Water Conservation Handbook
- 2509.23- Riparian Area Handbook
- 2509.24- National Forest System Watershed Codes Handbook
- 2509.25- Watershed Conservation Practices Handbook

Conclusion

Without treatment to fuels and forest structure in project area watersheds, the persistent and elevated risk of large, high intensity wildfire would continue to threaten water quality, soil productivity, and flooding into the future (Rhoades et al., 2019; Neary et al., 2003). Given the future climate in the project area is predicted to be hotter and drier (Cayan et al., 2013), watersheds need to be able to absorb as much water as possible, so they may sustain flow during dry times. Without treatment, project area watersheds would not be able to fully perform this ecosystem service; and should a high intensity wildfire occur, would be severely impaired for many years.

While the implementation of the Proposed Action has the potential to result in short and long-term adverse impacts to watershed resources (soil, water quality, and flow regimes), they are not expected. This is largely because prescribed fire would be implemented when fuel and soil moistures are high enough to ensure a low to moderate intensity burn which preserves the soil and its vegetative ground cover (including duff; Busse et al., 2014; Robichaud, 2000; USDA, 2016). Ground cover is essential for slowing and infiltrating overland flow, preventing erosion, filtering water, and holding soil structures in place (Rhoades et al., 2011; Busse et al., 2014) . The Proposed Action has the further benefit of allowing more sunlight to reach the forest floor while releasing some nutrients from the soil to generate vegetative ground cover in areas where it was previously absent or deficient (Rhoades et al., 2011; Kane et al., 2010) Further, best management practices and numerous design criteria would guide implementation to result in only small, if any, short-term and insignificant effects on soil productivity, riparian vegetation, and stream temperatures (as well as erosion and water quality).

The proposed implementation strategy would help to avoid adverse cumulative impacts by repeat treatments within the same watershed, as well as other land uses which affect ground cover (e.g. grazing). An overall long-term beneficial effect on watershed condition is expected; proposed activities within the "properly functioning" Arroyo Hondo watershed (thinning, burning, riparian treatments, and road closure) would help to protect the components of the watershed that have integrity (e.g., water quality, aquatic habitat). Proposed activities within the other "at risk" watersheds would help to protect components that are functional while improving the condition of those that are degraded (e.g., vegetative ground cover, riparian vegetation). By implementing the Proposed Action, project area watersheds would become more resilient to climate change, a desired condition (as defined by USDA, 2011; and the forthcoming Santa Fe National Forest Land and Resource Management Plan, expected 2021). The Proposed Action is consistent with the 1987 (amended) Forest Plan, law, regulation, and policy.

References Cited

Bolin, S.B. and Ward, T.J., 1987. Recovery of a New Mexico drainage basin from a forest fire. Forest hydrology and watershed management/edited by RH Swanson, PY Bernier & PD Woodard.

Brown, G.W. and Krygier, J.T., 1970. Effects of clear-cutting on stream temperature. Water resources research, 6(4), pp.1133-1139.

Busse, M.D., Hubbert, K.R. and Moghaddas, E.E., 2014. Fuel reduction practices and their effects on soil quality. Gen. Tech. Rep. PSW-GTR-241. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station. 156 p., 241.

Cayan, D.R., Tyree, M., Kunkel, K.E., Castro, C., Gershunov, A., Barsugli, J., Ray, A.J., Overpeck, J., Anderson, M., Russell, J. and Rajagopalan, B., 2013. Future climate: projected average. In Assessment of climate change in the Southwest United States (pp. 101-125). Island Press, Washington, DC.

Certini, G., 2005. Effects of fire on properties of forest soils: a review. Oecologia, 143(1), pp.1-10.

Elliot, W.J., Hall, D.E., Scheele, D. L. 2000. WEPP Interface for Disturbed Forest and Range Runoff, Erosion and Sediment Delivery. USDA Forest Service, Rocky Mountain Research Station and San Dimas Technology and Development Center. February. https://forest.moscowfsl.wsu.edu/cgi-bin/fswepp/wd/weppdist.pl

Gottfried, G.J. and DeBano, L.F., 1990. Streamflow and water quality responses to preharvest prescribed burning in an undisturbed ponderosa pine watershed. Effects of fire management on southwestern natural resources. RMRS-GTR-191. Fort Collins, CO. USDA Forest Service. Rocky Mountain Research Station, pp.222-231.

Greacen, E.L. and Sands, R., 1980. Compaction of forest soils. A review. Soil Research, 18(2), pp.163-189.

Hatchett, B., Hogan, M.P. and Grismer, M.E., 2006. Mechanized mastication effects on soil compaction and runoff from forests in the Western Lake Tahoe Basin. California Agriculture, 60(2), pp.77-82.

HEAL. 2017. Hall Environmental Analysis Laboratory. Water Quality Sampling Results for the Lakes Project. Order No. 1708B05. For Alex Puglisi, City of Santa Fe Water Systems. September 18, 2017.

Hohner, A.K., Rhoades, C.C., Wilkerson, P. and Rosario-Ortiz, F.L., 2019. Wildfires alter forest watersheds and threaten drinking water quality. Accounts of chemical research, 52(5), pp.1234-1244.

Hook, A. 2020a. Personal Communication. Email from Alan Hook (Water Resources Analyst, Public Utilities, City of Santa Fe) regarding Manganese in water quality samples within the municipal watershed. February 3, 2020. Included HEAL, 2017 water quality sampling results.

Hook, A. 2020b. Personal Communication. Conversation with Alan Hook (Water Resources Analyst, Public Utilities, City of Santa Fe) regarding aquatic biota observations in the municipal watershed and algal blooms in the reservoirs. 2/6/2020.

Johansen, K. G. Personal Communication. City of Santa Fe Engineer (Water Engineering Department). 3-23-20.

Kane, J.M., Varner, J.M., Knapp, E.E. and Powers, R.F., 2010. Understory vegetation response to mechanical mastication and other fuels treatments in a ponderosa pine forest. Applied Vegetation Science, 13(2), pp.207-220.

Lewis, A.C., 2018. Monitoring Effects of Wildfire Mitigation Treatments on Water Budget Components: A Paired Basin Study in the Santa Fe Watershed, New Mexico. New Mexico Bureau of Geology and Mineral Resources.

Lynch, J.A., Rishel, G.B. and Corbett, E.S., 1984. Thermal alteration of streams draining clear-cut watersheds: quantification and biological implications. Hydrobiologia, 111(3), pp.161-169.

Meixner, T. and Wohlgemuth, P., 2004. Wildfire impacts on water quality. Journal of Wildland Fire, 13(1), pp.27-35.

Neary, D.G., Gottfried, G.J. and Folliott, P.F., 2003, November. Post-wildfire watershed flood responses. In Proceedings of the 2nd International Fire Ecology Conference, Orlando, Florida (pp. 16-20).

NMED. 2017. EPA Approved Total Maximum Daily Load (TMDL) for Galisteo Creek. New Mexico Environment Department. Santa Fe, NM. April 3, 2017.

Puglisi, A. 2020. Personal Communication. City of Santa Fe Environmental Compliance Specialist.

Rhoades, C.C., Entwistle, D. and Butler, D., 2011. The influence of wildfire extent and severity on stream-water chemistry, sediment and temperature following the Hayman Fire, Colorado. International Journal of Wildland Fire, 20(3), pp.430-442.

Rhoades, C.C., Chow, A.T., Covino, T.P., Fegel, T.S., Pierson, D.N. and Rhea, A.E., 2019. The legacy of a severe wildfire on stream nitrogen and carbon in headwater catchments. Ecosystems, 22(3), pp.643-657.

Robichaud, P.R., 2000. Fire effects on infiltration rates after prescribed fire in Northern Rocky Mountain forests, USA. Journal of Hydrology, 231, pp.220-229.

Sackett, Stephen S., and Sally M. Haase. 1998. Two case histories for using prescribed fire to restore ponderosa pine ecosystems in northern Arizona. Pages 380-389 in Teresa L. Pruden and Leonard A. Brennan (eds.). Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

Shephard, Z. and Cadol, D. 2018. Prescribed Fire Treatment Surface Water Quality Monitoring: Study Summary and Final Report, Santa Fe Municipal Watershed, Santa Fe NM. Final Report, Revision 1. December 27th, 2018. New Mexico Institute of Mining and Technology. Unpublished.

Smith, R.A., Alexander, R.B. and Schwarz, G.E., 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States.

Spencer, C.N., Gabel, K.O. and Hauer, F.R., 2003. Wildfire effects on stream food webs and nutrient dynamics in Glacier National Park, USA. Forest Ecology and Management, 178(1-2), pp.141-153.

Stednick, John D. "Effects of fuel management practices on water quality." In: Elliot, William J.; Miller, Ina Sue; Audin, Lisa, eds. Cumulative watershed effects of fuel management in the western United States. Gen. Tech. Rep. RMRS-GTR-231. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 149-163. 231 (2010): 149-163.

Stephens, S.L., Meixner, T., Poth, M., McGurk, B. and Payne, D., 2004. Prescribed fire, soils, and stream water chemistry in a watershed in the Lake Tahoe Basin, California. International Journal of Wildland Fire, 13(1), pp.27-35.

USDA. 2011. Watershed Condition Classification Technical Guide. United States Department of Agriculture. Forest Service. FS-978. July 2011.

USDA. 2012. National Best Management Practices for Water Quality Management on National Forest System Lands. Volume 1: National Core BMP Technical Guide. United States Department of Agriculture. Forest Service. FS-990a. April 2012.

USDA, 2015. Phos-Chek Fire Retardants for Use in Preventing and Controlling Fires in Wildland Fuels. Frequently Asked Questions. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3851594.pdf

USDA, 2016. Hydrologic Analyses of Post-Wildfire Conditions. Natural Resources Conservation Service. Title 210, Hydrology Technical Note No. 4. August 2016.

USDA, 2018. A Wetness Index Model. Unpublished. Modeled by Bill Overland. USFS Enterprise Program Hydrologist in February 2020.

USDHHS. 2012. US Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Toxilogical Profile for Manganese. Atlanta, Georgia. September. https://www.atsdr.cdc.gov/toxprofiles/tp151.pdf

USWRPC (US Water Resources Policy Commission). 1951. Ten Rivers in America's Future- The Rio Grande (No. 4). The Report of the President's Water Resources Policy Commission. Volume 2. US Government Printing Office. P. 19.

Webb, R.H., Steiger, J.W. and Wilshire, H.G., 1986. Recovery of compacted soils in Mojave Desert ghost towns. Soil Science Society of America Journal, 50(5), pp.1341-1344.

Wells, B. H. 1918. Manganese in New Mexico. Bulletin of the New Mexico State School of Mines. Bulletin No. 2. Mineral Resources Survey. Socorro, NM.

Appendix A: Best Management Practices, Design Criteria, Mitigations, and Monitoring Measures

This section contains additional information regarding how project activities would be implemented on the ground. It includes a list of Design Features, Best Management Practices, Mitigation Measures, and Monitoring Measures, as defined below:

Range-13. Best Management Practices (BMPs): guidelines or minimum standards for the proper application of management activities and operations. While specific BMPs are listed below, every *applicable* BMP located within the USDA Forest Service National Core BMP technical manual[12] (2012) is also required.

- Design Features: a list of management actions that are designed to guide implementation of on-the-ground activities to achieve desired conditions while minimizing adverse effects. Design features are integral to and considered part of the Proposed Action.

- Mitigation Measure: an activity or limitation that is implemented in conjunction with a project activity in order to avoid, minimize, or eliminate adverse impacts that could result from implementation of the Proposed Action (40 CFR 1508.20).

- Monitoring Measure: the evaluation of project activities to determine how well objectives are being met and whether impacts from the proposed action are within an acceptable range.

The analysis of effects is based on the implementation of relevant Design Features, BMPs, Mitigation Measures, and Monitoring Measures. The measures listed below are based on Forest Plan direction and policy, best available science, site-specific evaluations and other relevant policies, guidelines, standards.

All Activities

Best Management Practices

Purpose: Communicate project and policy requirements to all parties involved in implementing management activities

General-1 Implementation, layout and prep personnel, including USFS, partners, contractors and others, would be briefed on all applicable design features, resource protection measures, BMPs, and standards and guidelines from the Forest Plan, recovery plans, etc. prior to implementation, between phases and as needed, such as, as personnel changes.

Purpose: Minimize litter, waste, and other human-caused disturbances during project implementation.

General-2 Santa Fe NF employees and contractors would follow Leave No Trace practices, including packing out all trash, burying human waste properly, and respecting wildlife that may be encountered.

[12] https://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf

Purpose: Public safety and coordination.

General-3 Recreation sites, roads, trails, or other areas scheduled for treatment may be temporarily closed during treatment activities to ensure public safety. Project activities would be coordinated with potentially affected adjacent landowners, range allotment permittees, special use permittees, and any other permit holders as needed to minimize access impacts.

Botany and Invasive Species/Weeds

Best Management Practices

Purpose: Prevent the spread and establishment of noxious and invasive weeds.

Plant-1 Weed prevention educational materials would be provided to fuelwood cutters and gatherers as part of the permitting process.

Mitigation Measures

Purpose: Prevent the spread and establishment of noxious and invasive weeds.

Plant-2 All off-road equipment (e.g. masticators, OHVs) would be weed-free prior to entering the project area. Staging of equipment would be done in weed free areas. Equipment would be pressure-washed, inspected and weed-free (includes free of soil, seeds vegetative matter and other debris) before entering the project area and before moving between treatment areas.

Plant-3 Areas of noxious and invasive weeds would be avoided except for treatments that may be designed to reduce weed populations.

Plant-4 Disturbance areas such as staging areas and parking areas would be located outside of known weed areas by at least 300 feet. GIS mapping layers, Forest/District Weed specialist and the District Biologist would be consulted prior to treatments.

Plant-5 Firelines would not be constructed through or within 150 feet of invasive weed sites.

Plant-6 If project implementation calls for seed mixes, mulches or fill, they would be State-certified as weed-free. Seed mixes used for re-vegetation of disturbed sites would consist of locally adapted native plants to the extent practicable.

Monitoring Measures

Purpose: Compliance with the Endangered Species Act.

Plant-7 New occurrences of threatened, endangered, or sensitive plants species discovered before or during project activities would be evaluated for protection measures such as flag-and-avoid methods. Occurrences would also be documented and recorded in the appropriate database, such as GIS.

Purpose: Prevent the spread and establishment of noxious and invasive weeds[13].

Plant-8 New occurrences of invasive weeds discovered before or during project activities would be evaluated for protection measures such as through flag-and-avoid methods. Occurrences would also be documented and recorded in the appropriate databases, such as GIS.

[13] Weeds are defined as the species identified on the New Mexico Department of Agriculture's noxious weeds list.

Plant-9 The project area, with focus on disturbed areas, would be monitored for one to two growing seasons to observe establishment and spread of weeds. If identified, the weeds would be treated per the Invasive Plant Control Record of Decision (U.S. Forest Service 2018).

Ips Beetle

Design Features

Purpose: Prevent the establishment and spread of Ips beetle infestations.

Ips-1 Slash would be treated promptly through lop/scatter, chipping, mastication, hand pile burning, or prescribed burning. Concentrations of chipped/masticated material would not be allowed to accumulate over 4 inches in depth on more that 20% of treatment unit. Chipped/masticated materials would be distributed on slopes where they would dry quickly.

Ips-2 Activity fuels would be disposed of as soon as possible and typically would not remain for more than two years depending on burn windows.

Mitigation Measures

Purpose: Prevent the establishment and spread of Ips beetle infestations.

Ips-3 When practical, activity slash would be created only between July through December unless the potential for Ips infestation is determined to be low.

Ips-4 Creating activity slash in adjacent treatment areas would be avoided for multiple years if risk of beetle infestation is determined to be high by the Silviculturist.

Ips-5 Mechanical damage would be avoided to residual trees and their root systems to reduce risk of attracting bark beetles.

Monitoring Measures

Purpose: Prevent the establishment and spread of Ips beetle infestations.

Ips-6 Slash would be monitored during and after treatment for Ips beetle infestation. If found, the Silviculturist would be contacted.

Water and Riparian Resources

Best Management Practices

Purpose: Communicate project and policy requirements to all parties involved in implementing management activities.

Water-1. Activities in drainage bottoms (i.e., near stream channels and within swales) would be coordinated with wildlife, fisheries, and watershed personnel.

Purpose: To maintain water quality

Water-2. To prevent introducing chemical pollutants to waterbodies and soils, all equipment would be washed, clean and free of leaks prior to entering the project area. Regularly inspect equipment for leaks during use.

Water-3. Spill containment materials (e.g. impermeable containment berms, absorbent pads, etc.) would be required on site to ensure that spilled fuel would not leave the staging and fueling areas.

Water-4. Fueling and equipment staging/maintenance areas would be located outside of Riparian Management Zones (RMZ[14]) and would only be the minimum size needed for their function. Existing landings and non-system routes within RMZs may be used (given aquatic, biologic, or watershed specialist coordination) if water quality concerns can be abated through prevention measures.

Design Features

Purpose: To minimize noxious weed spread and re-establish native vegetation.

Water-5. Where livestock have access to seeps and springs, trees would be felled directionally around the RMZ of these features to protect them from livestock access.

Water-6. For riparian planting activities:

- Where possible, source plants from local, native stock.
- Plant appropriate riparian species for the ERU.
- Monitor plantings shortly after implementation; where necessary, fence plantings from herbivory (especially within active range allotments).
- Do not plant in periods of drought, during or prior to dry seasons.

Mitigation Measures

Purpose: To minimize erosion, promote soil productivity, and to maintain water quality.

Water-7. The RMZ is largely an equipment exclusion area. Vehicles, including heavy equipment (such as dozers, masticators), plows and ATV/UTVs, would be only minimally operated within RMZs when absolutely necessary. If vehicles must enter the RMZ, they would not be driven within a stream channel but would stick to designated routes and crossings as described in Water-6. Operation plans would be coordinated with watershed personnel.

Water-8. Motor vehicles (including ATV/UTVs and heavy equipment) would only cross stream channels at designated crossing areas; perennial stream crossings would be designated in consultation with a watershed or aquatic habitat specialist. Where routes cross ephemeral or intermittent channels, crossing would be done when channels are dry. Stream channels would not be crossed where equipment would cause bank breakdown. Woody debris or rock may be placed into crossings to reduce soil disturbance and compaction. Upon completion of use, the crossing would be rehabilitated to maintain a stable channel.

Water-9. New and existing landings, campsites, helipads, and drop points, would be located outside of RMZs and would only be the minimum size needed for their function.

Water-10. New and existing landings, campsites, helipads, drop points, fueling and equipment staging/maintenance areas would be evaluated post-treatment (and decommissioned when no longer needed) to facilitate soil recovery and prevent erosion.

---

[14] **Riparian Management Zones (RMZ)** *are defined by either a site-appropriate delineation of the riparian area (including one site potential tree height) or a buffer of 100 feet from the edges (e.g., each bank) of all perennial and intermittent streams, lakes, seeps, springs, and other wetlands or 15 feet from the edges of the ephemeral channels. The exact width of RMZs may vary based on ecological or geomorphic factors or by waterbody type, but includes those areas that provide riparian and aquatic ecosystem functions and connectivity. The waterbody itself is considered part of the RMZ.*

Water-11. Water-bars would be installed with the maximum spacing dependent on slope gradient (Table 6), have an open outlet, constructed lead-off, berm tied into the cut-bank, a 2-4% outslope, and a skew of 30-45 degrees (from perpendicular to the travel route), with a height (crown to trough) of 12-18 inches.

Table 6 Waterbar Construction Guidelines

Gradient	Spacing
< 5 %	200 ft.
5-10 %	150 ft.
10-20 %	100 ft.
21-40 %	50 ft.
> 40%	25 ft.

Monitoring Measures

Purpose: To minimize soil movement and sedimentation, maintain water quality.

Water-12. During implementation, periodically monitor and maintain the effectiveness of erosion control treatments (e.g., waterbars should prevent water from running down a fireline or road).

Prescribed Fire and Slash Pile Burning in Riparian Areas

Best Management Practices

Purpose: To minimize soil erosion, maintain soil productivity and maintain water quality.

Rx-1. If water drafting sites are needed for the project, they would meet BMPs[15] prior to use, during use and after final use for this project's completion.

Rx-2. Water drafting sites would only be used after coordination with a Biologist. Drafting sites would not be used where they contain whirling disease or Chytrid fungus. To avoid the inadvertent spread of these organisms, water drafting equipment would be decontaminated before use in the project area, between different water sources, and after implementation is complete. Refer to guidance found in Preventing Spread of Aquatic Invasive Organisms Common to the Southwest Region Technical Guidelines for Fire Operations, Interagency Guidance Rev. August 2009 or more recent, and the Guide to Preventing Aquatic Invasive Species Transport by Wildland Fire Operations (https://www.nwcg.gov/publications/444).

Rx-3. Screens would be used to prevent organism entrapment during water drafting.

Rx-4. Drafting would not completely dewater any water feature; enough water would remain for aquatic and wildlife species.

Design Features

Purpose: To minimize soil erosion, maintain soil productivity and maintain water quality.

[15] USDA Forest Service: FS-990a. National Best Management Practices for Water Quality Management on National Forest System Lands, Volume 1. April 2012. https://www.fs.fed.us/naturalresources/watershed/pubs/FS_National_Core_BMPs_April2012.pdf

Rx-5. To reduce fuel loads around stream channels and water bodies but maintain vegetation and duff, low-intensity prescribed fire may occur within the RMZ. Fire ignition however would not take place within the RMZ. Fire would be allowed to back down in the RMZ.

Rx-6. Pre-treat (hand thin vegetation) within the RMZ as needed to avoid moderate and high intensity fire within the RMZ.

Rx-7. Wherever possible, slash piles would be built outside of the RMZ, drainage bottoms, and swales (valley bottoms). If slash piles mush be constructed in these areas, consult a watershed specialist for best placement. If slash must remain in these areas, scattering slash is preferred to piling. If piling must occur within these areas, the following would apply:

a) Piles would be stacked as far from the channel and riparian vegetation as possible; where no riparian vegetation exists, piles would be stacked as far away from the channel as possible (at least 25 feet from the channel and outside the high-water zone).

b) Piles would be built small (<100 sq. ft. each) in order to minimize fire residence time and subsequent soil impacts.

c) Not all piles would be burned; maintain some unburned piles.

d) Piles would be burned when soil moistures are high, or when snow is on the ground.

e) If slash must be piled in windrows, rows would be along the contour and would not be in drainage bottoms.

f) Burn pile composition should contain a mixture of fuel sizes. Large woody fuels, over 8.9 inches in diameter, should be limited to less than 40 percent of the composition of the pile to prevent adverse impacts to the soil.

Mitigation Measures

Purpose: To minimize soil erosion, maintain soil productivity and maintain water quality.

Rx-8. Follow the implementation strategy for avoiding adverse cumulative watershed effects by the proposed action, as described in the *Cumulative Effects of the Proposed Action* section as well as Figures 4 and 5of this report.

Rx-9. Water sources would not be contaminated with foaming agents.

Rx-10. Fireline would not be installed parallel to stream channels, and would intersect stream channels as perpendicular as possible; fireline width would be minimal, only as large as needed.

Riparian Thinning Activities

Best Management Practices

Purpose: To maintain water quality and minimize soil erosion.

Thin-1 Operators of masticators and other heavy equipment should strive to disturb the soil as little as possible; wherever possible, machines should not execute abrupt pivot turns, but instead make as broad of an arc as the terrain will allow. Machines should not cause ruts more than 4" deep. Masticators would use low psi tracks/tires.

Design Features

Purpose: To maintain and re-establish native vegetation.

Thin-2 Outside active floodplains but within buffered riparian corridors: 1) where deciduous trees exist, remove all conifers <12"; 2) where deciduous trees do not exist remove all conifers <5"; 3) where willows and openings exist, cut, treat, and plant willows. Cut alder to stimulate growth. Pile and burn slash or lop and scatter.

Thin-3 Other riparian species (willows, cottonwood, aspen, etc.) would not be cut or removed unless for transplanting, with the exception of some, but not all, aspen could be cut to promote regeneration in areas where health and vigor are insufficient.

Purpose: To maintain streambank stability and water quality

Thin-4 To maintain natural bank protection and shade, large downed wood in stream channels would remain in place and bank stability trees (large trees >12 in dbh with roots in the bank and/or branches directly over the bank) would be left.

Thin-5 Maintain stream shade within the RMZ; consult a watershed specialist if thinning activities may substantially reduce stream shade. Where necessary or desired, plant site appropriate riparian species.

Thin-6 Galisteo Creek is not meeting state water quality standards for temperature and has an associated TMDL which recommends increasing the percentage total shade from 8 to 81. Consult a watershed specialist when developing thinning prescriptions which may affect shade over this stream. Promote stream shade.

Mitigation Measures

Purpose: To maintain water quality and minimize soil erosion.

Thin-7 So as to prevent disturbance by motor vehicles, do not promote fuelwood gathering by the public within the RMZ.

Thin-8 Machine piling of activity-generated slash would be conducted in a manner that minimizes the amount of soil displaced into burn piles. Duff and litter layers would be left as intact as possible.

Thin-9 Where it would not cause fuel loading or Ips beetle concerns, use slash to help infiltrate runoff, prevent erosion, and treat eroded areas.

Thin-10 Wherever possible, fell hillslope trees on contour; leave large sections of the boles (1000-hour fuels) in contact with the soil for the purpose of slowing overland flow as well as catching

eroded soil, seeds, and nutrients. These logs should serve to quickly re-generate vegetation and filter water. This is especially important on south and west facing slopes.

Thin-11 Depth of masticated materials should not exceed an average of 4 inches and materials should be discontinuous at the quarter-acre scale to protect the soil and allow for natural revegetation.

Thin-12 Designate skid (or other equipment) trails.

Soils

Best Management Practices

Purpose: To minimize soil erosion and maintain soil productivity.

Soil-1. UTVs and ATVs may be used for transportation around the project area during implementation. To the extent possible, travel on existing routes and trails; if off-route travel must occur, avoid travelling across side-slopes; attempt to travel on ridges.

Soil-2. To protect road infrastructure from rutting, travel to and from the project area on Forest roads and trails would be limited during periods when resource damage could occur.

Soil-3. To the extent possible, existing disturbance areas (e.g. staging areas, access trails) would be utilized rather than creating new ones.

Soil-4. Where desired for ground cover and erosion control, access routes, firelines, staging areas and other disturbed areas may be scarified and seeded, mulched, and/or covered with slash.

Design Features

Purpose: To minimize soil erosion and maintain soil productivity.

Soil-5. Machine piling operations would remove only enough activity-generated slash to accomplish surface fuel reduction needs.

Soil-6. The depth of scattered slash would be the minimum needed to limit soil erosion, so as not to impede understory growth of grasses, forbs and brush.

Mitigation Measures

Purpose: To minimize soil erosion and maintain soil productivity.

Soil-7. Prior to and during mechanical treatments, soil moisture conditions would be evaluated and monitored for operability. To prevent soil compaction and displacement, equipment (e.g., masticators, ATVs, UTVs, trucks) would only operate off of constructed roads when soil moisture is low, the ground is adequately frozen, or covered with sufficient snow.

Soil-8. For the retention of long-term soil productivity and to reduce erosion, burning would be implemented when the lower duff layer (decomposed organic matter) in contact with the soil surface is moist enough so a cool burn can be assured to avoid hydrophobic soil conditions.

Soil-9. Prior to periods of wet weather, and immediately after an area has been treated, erosion control measures (e.g. waterbars, rolling dips) would be installed on all fireline, access routes, and staging areas.

Recreation

Design Features

Purpose: To reduce visibility of treatments.

Rec-1. Create a 150 foot visual buffer around campgrounds and picnic areas where no thinning or piling would occur. Prescribed fire would be allowed to back into these areas.

Mitigation Measures

Purpose: To protect and maintain trails within the project area.

To minimize impacts on recreation users.

Rec-2. If equipment must cross trails and roads, crossing would be minimal, perpendicular to the trail, and rehabilitated after treatment of the area.

Rec-3. Use of trails as access routes for heavy equipment should be considered carefully and other routes evaluated to best protect all resources, including recreation.

Rec-4. If trails must be used as access routes, they need to be fully reclaimed with sustainable trail practices implemented such as proper cut slope, width for managed use, and drainage features including rolling grade dips, water turnouts, armoring above and below the trail at drainage crossings, water bars, and check darns. Trail reconstruction will be coordinated with the Forest Service recreation team.

Rec-5. Avoid crossing or using motorized and nonmotorized system trails where feasible. If a trail or section of trail is affected, the trail shall be restored to the original condition. All treatment slash and debris would be removed from trails. It is acceptable to make perpendicular trail crossings. Trail crossing locations would be designated and flagged with input from a qualified Forest Service recreation staff or designated representative. Crossings of existing forest system trails would be restored to pre-project condition after use.

Rec-6. Applicable signing would be placed at camping areas, trailheads and along trails to warn Forest visitors of project implementation activities such as tree thinning, or prescribed burning along trails. Information may also be provided through the Forest Service website, news releases, traffic control and signage, or other measures as appropriate.

Rec-7. Where possible, schedule work that would limit recreation access such that it does not occur around holidays and weekends. Coordination would occur with any sponsors of recreational special use events to minimize impacts to planned events occurring in the Project Area during implementation.

Rec-8. Where riparian areas are fenced, ensure that these do not block system trails. If they do, provide an easy portal through the fence.

Purpose: To reduce visibility of treatments.

Rec-9. Stumps will be cut to a maximum of 8 inches within 50 feet of National Forest System trails, and as low as possible in all other distances zones.

Rec-10. Paint and markings, such as butt marks, leave-tree and boundary markings within 150 feet of National Forest System trails, roads, and campgrounds would be applied facing away from

these areas to reduce visibility. Flagging would be used in these areas, where practical, to mark unit boundaries and should be removed upon project completion.

Rec-11. Cut trees flush with trail when they need to be cut on the edge of the trail and road.

Rec-12. Disguise route entrances to firelines with rocks, boulders, downed trees, and forest litter to prevent them from being seen, easily accessed and becoming user trails. It should be difficult to access these areas for recreational use.

Purpose: Achieve scenic integrity consistent with Forest Plan direction.

Rec-13. Activity-generated fuels created within 150 feet of National Forest System trails and roads would be piled and burned or removed within 2 years of operations and within 1 year for areas managed for a Visual Quality Objective of Retention. Piles would be located a minimum of 100 feet from trails, roads and trailheads.

Scenery Resources

Best Management Practices

Purpose: Communicate project and policy requirements to all parties involved in implementing management activities.

Scen-1 A landscape architect or forest scenery specialist would be involved with the treatment unit layout strategy in Sensitivity (Concern) Level 1 areas. The extent of viewsheds from Sensitivity Level 1 areas would be confirmed in the field.

Scen-2 When fencing is visible from Sensitivity Level 1 travelways and use-areas, consult Forest recreation staff about its design, e.g. form, color and material.

Purpose: To reduce visibility of treatments.

Scen-3 When possible, firelines would utilize existing features such as roads and trails (considering stock trails if near the area desired) and natural features (rocks and cliff-faces)

Scen-4 Fire control lines would be constructed, wherever possible, to reduce the contrast so that they are not noticeable in the middle and background views.

Scen-5 Thinning of trees should have a form and shape that simulates natural patterns and openings and edges blended to minimize visibility of unit edges (such as avoiding straight lines, sharp corners, or geometric shapes).Where feasible, the edges of such treatments should be: tied into existing meadows and openings, follow natural topographic breaks and changes in vegetation, or provide feathering that allows gradual transition into the untreated adjacent forest area (as opposed to an abrupt line).

Scen-6 When feasible, treat both sides of open system roads and trails to avoid contrast.

Scen-7 Stumps will be cut to a maximum of 8 inches within 150 feet of National Forest System roads, and as low as possible in all other distances zones.

Mitigation Measures

Purpose: To reduce visibility of treatments.

Scen-9 Mechanical and manual thinning treatments along linear features, such as roads, trails or property lines would be implemented in a manner that does not emphasize straight lines and draw attention to the linear feature.

Scen-10 No machine piles within the immediate foreground (300 feet) of sensitive viewpoints.

Scen-11 When reducing lateral fuels by limbing trees near sensitive viewpoints, make limbing cuts flush to the branch collar located at the trunk, and undulate the height of the of remaining limbs where possible. The purpose is to avoid stubs of cut branches and horizontal lines similar to animal browse.

Scen-12 Fire control line construction would only occur where necessary. Any fire control line constructed would be to minimal standard needed to complete prescribed burning.

Cultural Resources

Standard cultural resource protection measures will be implemented to protect Historic Properties (also referred to as archaeological sites or cultural sites) and to ensure No Adverse Effect to Historic Properties. These standard protection measures are identified in Appendix J and Appendix E of the Region 3 Programmatic Agreement (USDA-FS 2010). These standard protection measures have been modified for the purposes of this project. Historic Properties *Listed* on the National Register of Historic Places (NRHP), *Eligible* for the NRHP, or *Unevaluated/Undetermined* for the NRHP will be protected during all project activities. Sites determined *Not Eligible* for listing on the NRHP will be documented but not protected. If previously unidentified cultural materials are discovered during implementation, work will cease in the area until a qualified professional archaeologist is notified and has approved restarting work.

Standard Best Management Practices, Mitigation Measures, and Design Features for All Project Activities within Archaeological Sites

Best Management Practices

Purpose: Communicate project and policy requirements to all parties involved in implementing management activities.

Heritage-1 Allow project activities within site boundaries, provided a qualified professional archaeologist is present to monitor sites (those *Listed, Eligible,* or *Unevaluated/Undetermined* for the NRHP) during and following project activities.

Mitigation Measures

Purpose: Protect cultural resources and ensure No Adverse Effect to Historic Properties and Compliance with the National Historic Preservation Act (NHPA)

Heritage-2 No ground disturbance will take place within site boundaries of Listed, Eligible, or Unevaluated/Undetermined sites without SHPO consultation.

Purpose: Consistency with Appendix E of the Region 3 Programmatic Agreement (USDA-FS 2010)

Heritage-3 Rubber-tired vehicles may cross through sites only on existing roads and must remain within the existing road prism.

Heritage-4 Utility Terrain Vehicles (UTVs) and All-terrain Vehicles (ATVs) may cross through sites only on existing roads and motorized trails as long as the vehicles remain within the existing road or motorized trail prism.

Purpose: Consistency with Appendix J of the the Region 3 Programmatic Agreement (USDA-FS 2010)

Heritage-5 Do not use tracked vehicles or other heavy or mechanical equipment within site boundaries.

Heritage-6 Do not stage personnel or equipment within site boundaries.

Heritage-7 Do not pile logs, trees, and other thinned materials (slash) within site boundaries.

Heritage-8 Remove vegetation by hand from within site boundaries.

Heritage-9 Do not drag logs, trees, or thinned material (slash) across or within site boundaries.

Purpose: Consistency with Forest Plan standards.

Heritage-10 Reduce dense vegetation within site boundaries.

Heritage-11 Remove dead and down vegetation within site boundaries, especially logs in direct contact with cultural features.

Heritage-12 Qualified professional archaeologists will mark sites with white flagging tape or paint for identification during project activities.

Vegetation Thinning Treatments

When manual or mechanical vegetation thinning activities will occur, the following mitigations or combination of mitigations will be followed in addition to those listed above in the *Standard Design Features for all Project Activities within Archaeological Sites* section:

Design Feature

Purpose: Protect cultural resources and ensure No Adverse Effect to Historic Properties

Consistency with Appendix J of the Region 3 Programmatic Agreement (USDA-FS 2010)

Heritage-13 Allow treatments within site boundaries, provided:

a. Cutting is accomplished using hand tools only (chainsaws or cross-cut saws)
b. Trees are felled away from all features

Mitigation Measure

Purpose: Protect cultural resources and ensure No Adverse Effect to Historic Properties

Consistency with Appendix J of the Region 3 Programmatic Agreement (USDA-FS 2010)

Heritage-14 Allow construction of landing zones, skid trails, and staging areas in 100% surveyed areas, with archaeological monitoring as appropriate to ensure sites are avoided by ground-disturbing activities.

Heritage-15 In areas of less than 100% survey, cultural resources survey and clearance is required prior to construction of landing zones, skid trails, and staging areas.

Prescribed Fire Treatments

Where prescribed burning activities will occur, the following mitigations or combination of mitigations will be followed, in addition to those listed above in the *Standard Design Features for all Project Activities within Archaeological Sites* section:

Mitigation Measure

Purpose: Protect cultural resources and ensure No Adverse Effect to Historic Properties

Consistency with Appendix J of the Region 3 Programmatic Agreement (USDA-FS 2010)

Heritage-16 No ignition points within site boundaries

Heritage-17 Allow construction of safety zones, helicopter landing and sling sites, staging areas, and additional fire line in 100% surveyed areas, with archaeological monitoring as appropriate to assure sites are avoided.

Heritage-18 In areas of less than 100% survey, cultural resources survey and clearance is required prior to construction of safety zones, helicopter landing and sling sites, staging areas, and additional fire line.

Heritage-19 Site protection measures and fuel reduction treatments will occur prior to implementing prescribed burns.

Heritage-20 Site protection measures and fuel reduction treatments will be monitored by a qualified professional archaeologist.

Heritage-21 Allow prescribed fire to burn through sites with low or moderate fire sensitivity, provided that heavy fuels are removed prior to burning.

Heritage-22 Protect fire-sensitive sites (i.e. sites with combustible features, rock art, rock or cave shelters, or structures comprised of friable stone). Protection measures may include the following:

a. Exclude from project area, OR

b. Use hand line, black line or wet line to prevent the spread of fire into sites

c. Use foam retardant or structural fire shelter directly on fire-sensitive resources to prevent their consumption

d. Ensure that heavy fuels that cannot be removed from within site boundaries are not ignited

e. Implement same protective measures for all future maintenance burns

f. When using aerial ignition, provide pilot with GPS site locations to avoid the sites

g. A qualified professional archaeologist will monitor fire-sensitive sites during prescribed burning.

Road Closure

Where forest road closure will occur, the following mitigations, or combination of mitigations, will be followed, in addition to those listed above in the *Standard Design Features for all Project Activities within Archaeological Sites* section:

Mitigation Measure

Purpose: Protect cultural resources and ensure No Adverse Effect to Historic Properties and Consistency with Appendix E of the Region 3 Programmatic Agreement (USDA-FS 2010)

Heritage-23 Sites adjacent to a proposed road closure will be flagged for avoidance.

Heritage-24 Earth-disturbing closure activities (i.e., earthen berm construction, ripping road tread) may take place within site boundaries only if the Forest and the SHPO agree that there will be No Effect or No Adverse Effect to sites.

Heritage-25 Vehicles and equipment using USFS roads must stay on the road prism in areas that bisect heritage sites.

Heritage-26 No new road construction, reconstruction, or modification of the existing road prism within site boundaries.

Range Resources

Grazing Management Activities & Protection of Allotment Improvements:

Best Management Practices

Purpose: Maintain existing rangeland monitoring sites.

Range-14. Existing rangeland monitoring sites would be located prior to treatments. Monitoring sites would not be excluded from treatments; however, sites would not be used for landing areas, skid trails and slash piles.

Purpose: Coordinate management activities with range staff to minimize impacts to rangeland resources.

Range-15. Before treatments occur, consult with district range staff to coordinate pasture use.

Range-16. All water infrastructure (earthen dams, trick tanks, storage tanks, pipelines, drinkers, etc.) should not be removed or excluded from treatments. Any damage to infrastructure due to project implementation activities would be reported to the District and repairs coordinated with relevant District staff.

Range-17. Damage to range infrastructure would be avoided to the extent possible. If there is damage to infrastructure from treatments, it would be restored before the project is completed.

Range-18. Managers of vegetation treatment projects would consult with District range managers to ensure alteration of natural barriers does not allow livestock to circumvent fences and lose the integrity of the pasture or allotment.

Range-19. All pasture gates would be kept closed during the grazing season (May through November).

Range-20. Fence openings created to facilitate any management actions should be closed each day in active grazing areas during the grazing season. (May through November)

Prescribed Burning

Best Management Practices

Purpose: Minimize impacts to range infrastructure.

Range-21. Fire and timber personnel would coordinate with district range staff on prescribed burn operations and thinning prior to implementation.

Range-22. Avoid damaging fire-sensitive range infrastructure (corrals, pipelines, water storage tanks, water troughs, fences, and cattleguards) to the extent possible. Methods may include pre-burn fuel removal, fire containment lines around structures, strategic ignition patterns, or other methods. Any damage to infrastructure due to project implementation activities would be reported to the District and repairs coordinated with relevant District staff.

Range-23. Fencelines would be used as burn area boundaries when possible.

Range-24. When and where possible, take advantage of natural barriers and existing roads to limit soil disturbance and construction of new fires lines.

Design Features

Purpose: Minimize impacts to rangeland resources.

Range-25. Livestock would be managed to allow for habitat response after project implementation. Allotment pastures would be rested from grazing for a minimum of one year following broadcast burning of that pasture. Prior to livestock being authorized to graze an area that was treated with prescribed burning, interdisciplinary vegetation monitoring would be conducted to determine if plant health and groundcover has recovered sufficiently to support grazing and protect soil.

Range-26. No single pasture within a grazing allotment would be treated with prescribed fire within two consecutive years.

Wildlife Resources

Best Management Practices

Purpose: Communicate project and policy requirements to all parties involved in implementing management activities.

Wild-1 A Forest Service (FS) Biologist would be consulted prior to treatment unit preparation as well as during implementation as necessary to assure these wildlife measures are considered.

Wild-2 If treatments that might disturb nests are planned to occur during nesting season, nests and dens would be located during project preparations before implementation occurs. Procedures for locating the nests and dens would be coordinated with an FS Biologist.

Purpose: Compliance with the Endangered Species Act.

Wild-3 If any Forest Service Sensitive Species, or Threatened or Endangered species is observed within or near the project area before or during implementation, sufficient protection would be provided in accordance with recovery plans and specific forest, regional and national guidance. Implementation would cease until an FS biologist has been notified, has investigated and has made recommendations. Occurrences would also be documented and recorded in the appropriate databases, such as GIS.

Purpose: Meet the project's desired conditions

Create and maintain diversity in structure, composition, and age classes across the landscape.

Wild-4 Crushing or displacement, of large down logs with machinery would be avoided.

Wild-5 Prescribed burning treatments would be implemented to attain low-to-moderate fire severity across the burn area. Implementors would strive to limit high burn severity areas to <10% of each burn unit. Such efforts are expected to create a mosaic burn pattern, with a diversity of fuel consumption and fire intensity.

Wild-6 If present, Gambel oaks would be retained and protected from thinning activities. To the extent feasible, native shrubs such as wild rose (Rosa spp.), mountain mahogany (Cercocarpus montanus), Rocky mountain maple (Acer glabrum), currants (Ribes spp.) raspberry (Rubus spp.), would be retained during thinning activities. Prescribed fire implementation would not target these species for ignition, but would be allowed to consume some in a mosaic manner; burning some while leaving others unburned.

Wild-7 Where available, at least 3 trees per acre with unique branching, broke-off top, spike-top or multiple tops would be retained, with additional emphasis within 200 feet along cliffs, major ridges and openings. Preferred species for retention would be large pines and firs.

Design Features

Purpose: Consistency with Forest Plan direction for vegetation management.

Meet the project's desired conditions

Create and maintain diversity in structure, composition, and age classes across the landscape.

Create and maintain diverse habitat types across the landscape.

Wild-8 Leave-islands (thickets or clumps) and openings would be distributed throughout each treatment unit to provide for cover and foraging areas for wildlife species as well as to retain younger age classes. Leave islands would be approximately ¼ to ½ acre in size and approximately 10% of the treatment unit.

Wild-9 An average of 3 slash piles (approximately 3 feet high and 10 feet in diameter) per acre would be retained (not burned) except within a quarter mile of privately-owned structures, where at least 1 slash pile (at least 3'h x 10'd) per acre would be retained. To provide cover and nesting habitat, location preference would be near (within ¼ mile) water sources and away from infrastructure such as roads, campgrounds, buildings, private land, etc.

Wild-10 The retention and release of aspen, oaks, Scouler's willow and the release of the largest ponderosa pines and largest Douglas fir would be facilitated by focused thinning immediately surrounding these species. Focused thinning would remove the conifers under and over the canopy of these species and ideally/approximately an additional 30 feet beyond. This would be done in coordination with an FS Biologist.

Wild-11 Trees selected for retention in project-created openings would be suited for open stand conditions, such as pines. Firs would not be selected for retention in openings, as they are more susceptible to sun-scorch and wind-throw in open conditions.

Wild-12 Cover would be maintained to provide connectivity corridors for big game as well as furbearers. This would include leave-islands and stringers that would generally connect across the landscape. Screening (areas that have not been thinned with sufficient vegetation cover to block viewing long-distances) would be used, especially along roads. Screening would be designated beyond the primary road corridor to allow for fire management.

Wild-13 In pinyon-juniper (PJ) woodlands, depending on the habitat type (PJ persistent, PJ savanna, PJ grassland, etc.), treatments would be implemented to promote pinyon jay habitat (mast-producing trees, nesting cover and recruitment) and connectivity. At least 15% of mature and over-mature mast-producing stands of pinon-juniper and oak zones within each treatment area would be maintained.

Mitigation Measures

Purpose: Consistency with Forest Plan direction for vegetation management.

Meet the project's desired conditions

Create and maintain diversity in vegetative structure, composition and age classes across the landscape

Create and maintain diverse habitat types across the landscape.

Wild-14 Tree felling would be directed away from trees designated to be retained. Machinery would avoid contact with trees designated to be retained. Smaller diameter trees (<12 in DBH) that are designated to be retained would be the most vigorous/healthy of the site.

Wild-15 The largest coarse woody debris (downed logs) would be retained. Emphasis would be on the retention of wood in the largest size classes and in decay classes 1, 2, and 3, but also representing a range of decomposition classes if available.

a) At least 5 logs per acre would be retained where available, according to Forest Plan guidelines.
b) The largest diameter logs available would be retained; at least 12 inches diameter, with preference for logs over 15 feet in length, but at least 8 feet long.
c) If these standards cannot be met with current downed logs, additional down logs would be supplemented by felling trees that meet the above standards and leaving them on site.
d) Where fuelwood gathering would be planned, downed logs retained to meet this standard would be painted (side away from roads and trails) along length.
e) Fuelwood permits would specify that trees and logs with paint would not be cut or removed.

Wild-16 During thinning and prescribed fire prep, snags would not be cut unless they pose a safety hazard; for example, within falling/striking distance of high human residency time areas such as staging areas.

Wild-17 If the desired number of snags per acre is not available for retention, snag creation would be considered. If determined as necessary to meet the desired conditions, snags would be created through methods such as girdling .

Wild-18 Snags that are cut for this project (e.g. safety) would be left after felling to contribute to downed log habitat.

Wild-19 Prescribed fire ignition would not target large down logs and ignition would not occur at the base of snags, however, these features may ignite if fire creeps to them while burning occurs.

Wild-20 Burn piles would be located a sufficient distance from large snags and large down logs (where deficient) to minimize the risk of ignition to these habitat features during pile burning operations.

Wild-21 Piles would be placed away from healthy, mature aspen (which have thin bark) to minimize negative impacts to them. An exception would be in cases where mature aspen are unhealthy to an extent that the stand is unlikely to remain sustainable without management, therefore, fire could be used to encourage the stand to re-sprout.

Wild-22 Leaners (trees/snags that have fallen at an angle of approximately 15 to 45 degrees from the ground, often held up by surrounding trees or rocks) would be retained and avoided, where available, and/or could be created, which provide plucking posts (goshawks) and subnivean (under snow) access.

Purpose: Consistency with the Migratory Bird Treaty Act.

Create and maintain diverse habitat types across the landscape.

Wild-23 When possible, treatments (such as thinning, burning, mastication, road work, etc.) would be implemented outside of nesting season to minimize impacts to migratory birds, especially in brush/shrub areas, riparian areas, along cliff faces, and rock features. Typically, breeding season is from April 15 through August 15. If treatments have to occur during the breeding season, they would not occur on more than 1/3 of the National Forest Land in each sub-watershed (HUC 12) during that specific breeding season, and a 150-foot buffer would be established around observed active songbird nests, which would have not treatments.

Wild-24 Trees would be inspected for nests and cavities prior to cutting/removal. Trees with an observed nest (bird, squirrel, etc.) or cavity would be retained during thinning and not targeted during burning, along with the trees immediately surrounding (interlocking crowns, provides shade or cover to nest) the nest tree to maintain the existing cover and shade. If a den is known or discovered, vegetation that provides cover surrounding the den and cover corridors from the den leading out of the project area would be retained during thinning and not targeted during burning. Prescribed fire implementation would not target these trees for ignition, but some may be burned.

Wild-25 An FS biologist would be notified upon discovery of a large stick-type nest. From February through September, noise-producing project activities within ¼ mile of the nest would be temporarily paused, at least until the nest is investigated by an FS biologist who can provide recommendation for proceeding.

Wild-26 There would be no intentional killing, harassment, removal or handling of animals, nests, eggs, dens, etc.

Monitoring Measures

Purpose: Utilize an adaptive management approach when implementing treatments to assess treatment effectiveness and adjust future management actions as needed.

Wild-27 Project implementation would be monitored during and after completion of each phase (thinning, piling, burning, etc.) to allow for adaptive management. During treatments, the first portions of each block/unit would be monitored, then as necessary, subsequent portions, units and blocks would be adjusted to meet prescriptions, achieve desired conditions and adhere to requirements such as these IDFs. Monitoring would be done by qualified individuals, such as a certified-silviculturalist, hydrologist and/or biologist as applicable, and reviewed by an interdisciplinary team of specialists, including those just listed.

Mexican Spotted Owl

Mitigation Measures

Purpose: Consistency with the 2012 Mexican Spotted Owl Recovery Plan

MSO-1 The 2012 Mexican Spotted Owl Recovery Plan would be implemented. Implementation of IDFs from the Aquatics, Watershed (Hydrology and Soils) and Botany IDF sections also provide for the requirements listed in the MSO Recovery Plan.

Within MSO Protected Activity Centers (PACs)

MSO-2 Coordination with USFWS would occur when planning and implementing site-specific thinning within MSO PACs.

MSO-3 No treatments would occur in the PACs during the breeding season.

MSO-4 Trees less than 9 inches in diameter would be cut in PACs if objectives can be met with this restriction and by focusing work in areas outside of the PACs. Trees up to 16 inches in diameter may be cut if needed to meet objectives.

MSO-5 Slash would not be piled within PACs, where possible.

MSO-6 A 100-acre Core Areas would be designated in each PAC, burning would be allowed to creep into Core Areas only if they are expected to burn at low intensity with low severity effects.

MSO-7 A fire management burn plan would be prepared for broadcast burning applications within PACs, employing low intensity fire.

MSO-8 Timing and type of burning would be coordinated with wind direction, topography, time of year, and distance to PACs to reduce smoke impacts.

MSO-9 Hardwoods, downed woody debris, snags and other key habitat variables would be retained, unless when their removal would be compatible with MSO habitat management objectives, documented through reasoned analysis.

MSO-10 Fuelwood gathering units for the public would not be designated in PAC boundaries. Fuelwood gathering by the public would not be promoted in PAC boundaries.

Within MSO Recovery Habitats

MSO-11 All trees greater than 24 inches dbh, as well as hardwoods, large down logs, large trees and snags would be retained. If snags must be removed due to hazards, cutting should be avoided from March through September. Cut snags would remain on site to contribute to large downed wood debris habitat.

MSO-12 Hardwoods, downed woody debris, snags and other key habitat variables would be retained, with an emphasis in managing for large hardwoods.

MSO-13 Before implementing management activities in areas that have been identified as draft recovery nest/roost habitat (per the most recent GIS shapefiles) USFS staff will review site

conditions and project activities for compliance with MSO management direction, including amended forest plan standard S06 and guidelines G01, G02 and G03.

Northern Goshawk

Mitigation Measures

Purpose: Consistency with Northern Goshawk management guidance in the current Forest Plan

NOGO-1 Guidance from the SFNF Forest Plan would be reviewed and followed which includes the Northern Goshawk Management Guidelines. Implementation of mitigations from the Aquatics, Watershed (Hydrology and Soils) and Botany mitigation sections also provide for the requirements listed in the Forest Plan for Northern Goshawk.

NOGO-2 Suitable habitat within the project area, including ½ mile beyond the project boundary, would be surveyed to R3 Survey Protocol prior to project implementation of thinning and burning treatments that could impact the species.

NOGO-3 A Goshawk Post-Fledging Area (GPFA) of approximately 600 acres and a Goshawk Home Range (GHR) of at least 6,000 acres would be designated around active northern goshawk nests and territorial goshawks. A Goshawk Nest Area (GNA) of at least 30 acres would be designated around active northern goshawk nests and each GPFA would have at least three nest areas and three nest replacement areas within it, for a minimum total of 180 acres of nest areas in each GPFA. These designated areas would be delineated by a FS District Biologist to include the best available habitat within the immediate area.

NOGO-4 A Limited Operating Period (LOP) would be in effect from March 1 through September 30 within ¼ mile of active GNA and GPFA boundaries. If the nest site cannot be determined, but territorial adult northern goshawks are present, the LOP would be within ¼ mile of an averaged activity center or the PFA. This LOP would not exclude work from occurring, but would restrict what types of work could occur and would consider noise level, human presence, duration, proximity to known species occurrence, topography, etc. to remain within the current effect determinations. Project activities proposed to be implemented during the LOP would be reviewed and agreed to by the Forest Service (FS) District Biologist.

NOGO-5 Vegetation Management guidelines for goshawk habitats described in the Forest Plan would be followed. Emphasis would be to maintain or create uneven-age stand conditions and retain live reserve trees, snags, downed logs, and woody debris levels throughout woodland, ponderosa pine, mixed conifer and spruce-fir forest cover types. Old age trees would be managed so as much old forest structure as possible is sustained over time across the landscape. A mosaic of vegetation densities (overstory and understory), age classes and species composition would be maintained or created across the landscape. Non-uniform spacing of trees and clumpiness would be promoted.

NOGO-6 At least two groups of trees per acre with a minimum diameter of 12 inches would be retained, with a minimum of 3 trees per group (USDA 1992).

NOGO-7 Within goshawk habitat in the ponderosa pine vegetation type, an average of 5-7 tons/acre of woody debris larger than 3 inches in diameter would be retained. Within goshawk habitat in the spruce-fir and mixed conifer type, an average of 10-15 tons/acre of woody debris larger than 3 inches in diameter would be retained.

NOGO-8 Prescribed burning would be implemented to ensure that the entire 6,000-acre home range would not be burned in one year. Human presence while implementing prescribed burning will

be minimized within 100 yards of known active nest areas. A burn plan would be prepared for broadcast burning applications within GPFA boundaries to employing low intensity fire. Timing and type of burning would be coordinated with wind direction, topography, time of year, and distance to GNA boundaries to reduce smoke impacts, risk of crown fire, consumption of nest trees and displacement of adult goshawks.

NOGO-9 The ground surface layer would be maintained in satisfactory condition to minimize soil compaction and maintain hydrologic and nutrient cycles.

NOGO-10 Riparian vegetation would be managed to maintain or achieve good condition. Riparian vegetation, stream banks and channels would be protected.

NOGO-12 Emphasis would be to maintain snags that are 18" or larger DBH and 30 feet or larger in height, downed logs that are 12 inches in diameter and at least 8 feet long, and woody debris is 3 inches or larger on the forest floor.

NOGO-13 Canopy cover would be maintained according to goshawk area designation and stand type, and would consist of 40-60% or more canopy cover in landscapes outside GPFA, and 50-70% or more canopy cover within GPFA and GNAs.

NOGO-14 Piling of debris (slash) would be avoided in goshawk designated areas, where possible. If needed, within GNAs piling would be by hand and would not utilize grapple or dozer piling, while outside of GNAs, piling would be done by hand or grapple to minimize soil compaction, and forest floor and herbaceous layer disturbance.

NOGO-15 Fuelwood gathering units for the public would not be designated in PFA boundaries. Fuel-wood gathering by the public would not be promoted in PFA boundaries.