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Sugarite Watershed Stewardship Plan

Prepared for **Colfax County**
Raton, New Mexico

May 30, 2008

Prepared in association with
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Acknowledgements

Daniel B. Stephens & Associates, Inc. (DBS&A) would like to acknowledge the assistance of all of the collaborators that helped to develop this stewardship plan, including Cimarron Watershed Alliance, City of Raton, Colfax County, Colfax Soil and Water Conservation District, Colorado Division of Wildlife, The Nature Conservancy, New Mexico Forest and Watershed Restoration Institute, New Mexico Game and Fish, New Mexico State Forestry, New Mexico State Parks, Silver Dollar Forest Products, and Vermejo Park Ranch. We would also like to acknowledge Melissa Savage, Amy Lewis, and Jean-Luc Cartron for their involvement in preparation of the prescription, monitoring plan, and wildlife surveys, respectively, for the Sugarite Canyon thinning project.

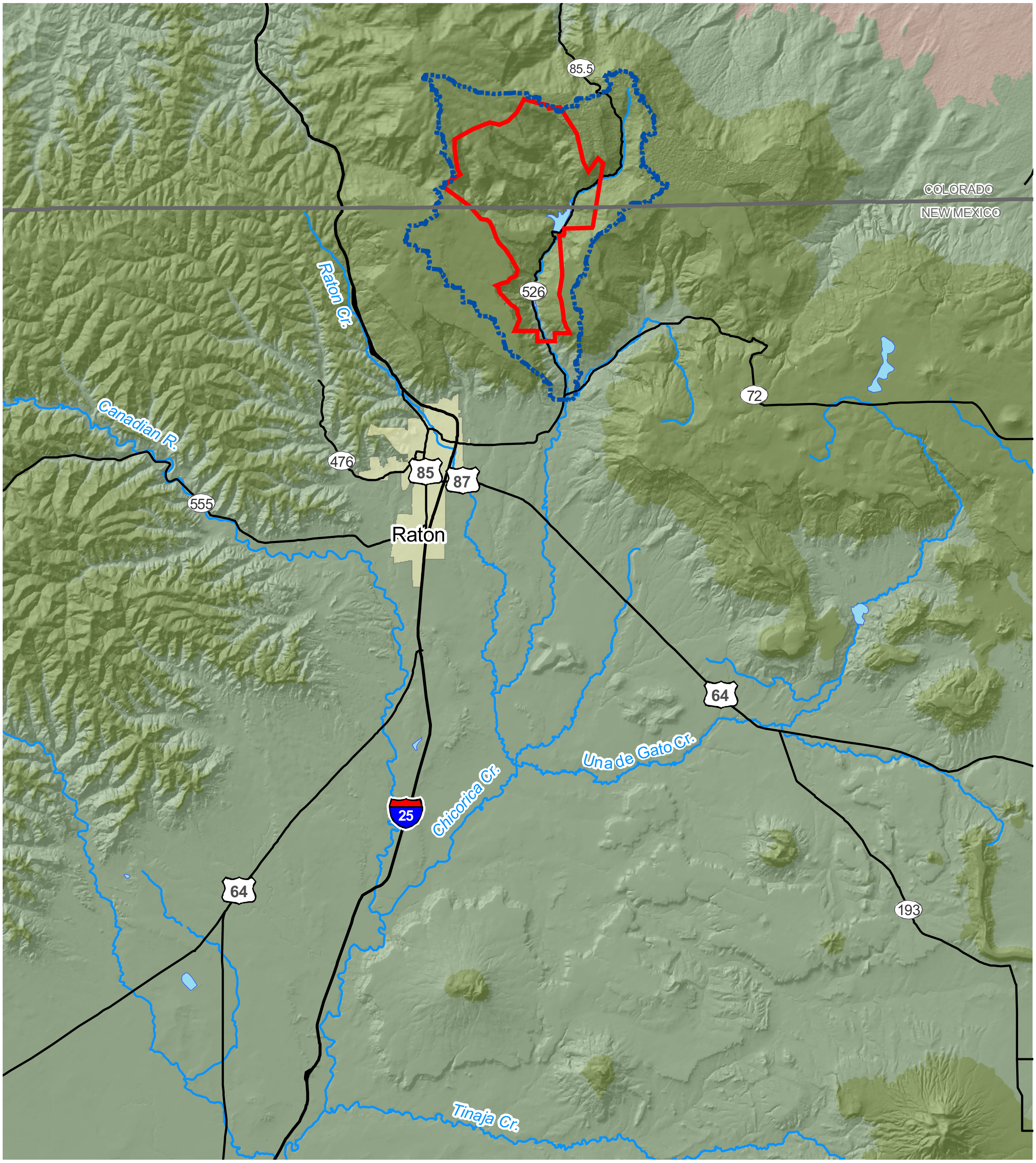
1. Introduction

Colfax County, in association with the City of Raton, and other collaborators (Section 2), is interested in reducing the risk of crown fire in the Sugarite watershed northeast of Raton, New Mexico (Figure 1-1). Lake Maloya, located in the Sugarite watershed and surrounded by dense forest, provides the majority of the water supply for the City of Raton. Colfax County applied for Collaborative Forest Restoration Program (CFRP) funding in 2006 and was awarded a grant to prepare this stewardship plan and to ensure National Environmental Policy Act (NEPA) compliance prior to initiating on-the-ground treatment activities with CFRP funding. To complete the stewardship plan, the County retained Daniel B. Stephens & Associates, Inc. (DBS&A) and Melissa Savage.

1.1 Background

Forests in the Southwest have changed dramatically in structure in recent decades because fires have been kept out of the forests. For centuries, forest density and composition were regulated by frequent low-intensity fires that burned on the surface of the forest floor, killing seedlings and tree species that were not able to survive the fires. Ponderosa pine forests, which historically experienced cool fires every 2 to 20 years on average, have become extremely dense, with understories choked with small trees. Mixed-conifer forests historically experienced fire on a longer interval, averaging around 25 years or more, and sometimes experienced small areas of crown fire. They have not only become more dense, but have also changed in composition, and many stands have understory thickets of fire-sensitive trees such as young white fir. Oak forests in the Southwest generally burned every 2 to 10 years. All three forest types now support intense fires that burn through the tree canopy and cause large-scale tree mortality.

The accumulation of a century of live and dead fuels in these forests, together with recent drought and warming temperatures, has made catastrophic wildfires increasingly common across the Southwest. In addition to causing widespread forest mortality, such nearly uncontrollable fires have caused extensive and severe hydrologic damage in many watersheds across the region. Post-crown fire flood events can be enormous and have resulted in catastrophic debris flows in a number of locations, for example, after the Vivash Fire above Las Vegas.



N

0 2 4 Miles

Explanation

- Lake
- Stream
- Highway
- City
- City of Raton land boundary
- Sugarite watershed boundary

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SUGARITE STEWARDSHIP PLAN

Site Location

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Figure 1-1

A variety of restoration approaches are being implemented throughout the regional forests to meet this threat. A review of such restored forest stands, *Wildland Fire Effects in Silviculturally Treated vs. Untreated Stands of New Mexico and Arizona* (Cram et al., 2006), concludes that the combination of mechanical thinning and prescribed fire can significantly decreased fire severity and fireline intensity.

1.2 Project Objectives

Previously completed and planned restoration work involves forest thinning in the upper headwaters of the Sugarite watershed to restore ecological integrity to the forests and reduce the risk of crown wildfire in order to protect the City of Raton water supply. The Sugarite watershed forests are typical of those described in Section 1.1; that is, most of the forest types found in the watershed were historically adapted to frequent, low-intensity fires, but decades of fire suppression have created communities of unnatural density. These forests, primarily ponderosa pine forest and mixed-conifer forests interspersed with large patches of oak shrubland (Section 4.1), are now vulnerable to crown fires.

A stand-destroying crown fire in the forests could cause an influx of ash and sediment into the lakes that provide the primary water supply for the City. The City also has some water rights from the Cimarron River that can be used to supplement supplies during short-term drought, but does not have a sufficient alternate supply to meet the longer-term needs of the City residents without the Lake Maloya/Sugarite Canyon supply. Due to the relatively small size of Lake Maloya (120 acres), the potential for sedimentation to severely impact the storage capacity is significant. Consequently, minimizing the risk of crown fire in the watershed is a very high priority for the City.

The objectives of the watershed restoration work in the Sugarite watershed are to:

- Reduce the risk of severe impairment of the City of Raton water supply due to crown fire in the municipal watershed. Additional corollary benefits include:
  - Water quality degradation will be prevented.
  - The risk of flooding, which would be higher after a catastrophic fire, will be reduced.

- Critical storage needed to provide supply during drought periods will be protected by minimizing the threat of crown fire and subsequent sedimentation of the reservoir.
- Public safety will be improved through reduction of the fire and flood risk.

- Restore the ecological health of the watershed to promote enhanced wildlife habitat.

- Provide a unique educational forum that can educate both the general public that uses Sugarite Canyon State Park and school children from Raton who are involved in ongoing educational opportunities through Sugarite Canyon State Park.

This stewardship plan is intended to advance efforts in the watershed to protect the City water supply, while integrating other goals such as protection and enhancement of wildlife habitat and protection of the natural ecology of the area. Accordingly, following a description of the collaborative process and the existing watershed conditions, this plan details the recommended prescription for forest thinning activities in the Sugarite watershed. The plan also discusses the mitigation of potential impacts from the forest thinning on wildlife, cultural resources, and hydrology. Finally the plan provides recommendations for long-term maintenance and monitoring.

2. Collaborative Process

At the onset of the project, a collaborators group was formed to help in the development of the stewardship plan and to provide input on ongoing treatment activities in the Sugarite watershed. The collaborators include:

- Cimarron Watershed Alliance
- City of Raton
- Colfax County
- Colfax Soil and Water Conservation District (SWCD)
- Colorado Division of Wildlife
- The Nature Conservancy
- New Mexico Forest and Watershed Restoration Institute
- New Mexico Game and Fish
- New Mexico State Forestry
- New Mexico State Parks
- Silver Dollar Forest Products
- Vermejo Park Ranch

Watershed restoration activities have been ongoing in the Sugarite watershed since 2002, when the Colfax SWCD initiated a pilot treatment project in the watershed. At that time a group that included most of the current collaborators reviewed a prescription for a pilot treatment program. Subsequent prescriptions for forest treatment in the watershed have built upon that pilot prescription. The collaborators listed above contributed a great deal of technical expertise regarding development of the original prescription and subsequent monitoring and planning efforts.

A number of entities have been awarded funding and have initiated treatment activities in the area subsequent to the original pilot study. In order to ensure appropriate communication and planning for future activities in the watershed by any of the collaborators, the following recommendations are made:

- The collaborators group should continue to meet quarterly or more often as needed to review monitoring plans, to provide input into treatment plans, and to integrate adaptive management. The membership of the collaborators group should be open to new parties if others are identified with an interest in the watershed.

- The collaborators group should provide an educational forum for sharing new information regarding prescriptions for treatment, prescribed fire, monitoring, or other issues and should also provide information to decision-makers who normally do not attend planning meetings.

- Entities that apply for funding for any treatment projects should inform the other collaborators of their plans.

- The State Parks Division should be informed of and allowed input on any activities within the State Park boundaries, and the Colorado Division of Wildlife should be informed of any proposed activities in the Colorado portion of the watershed.

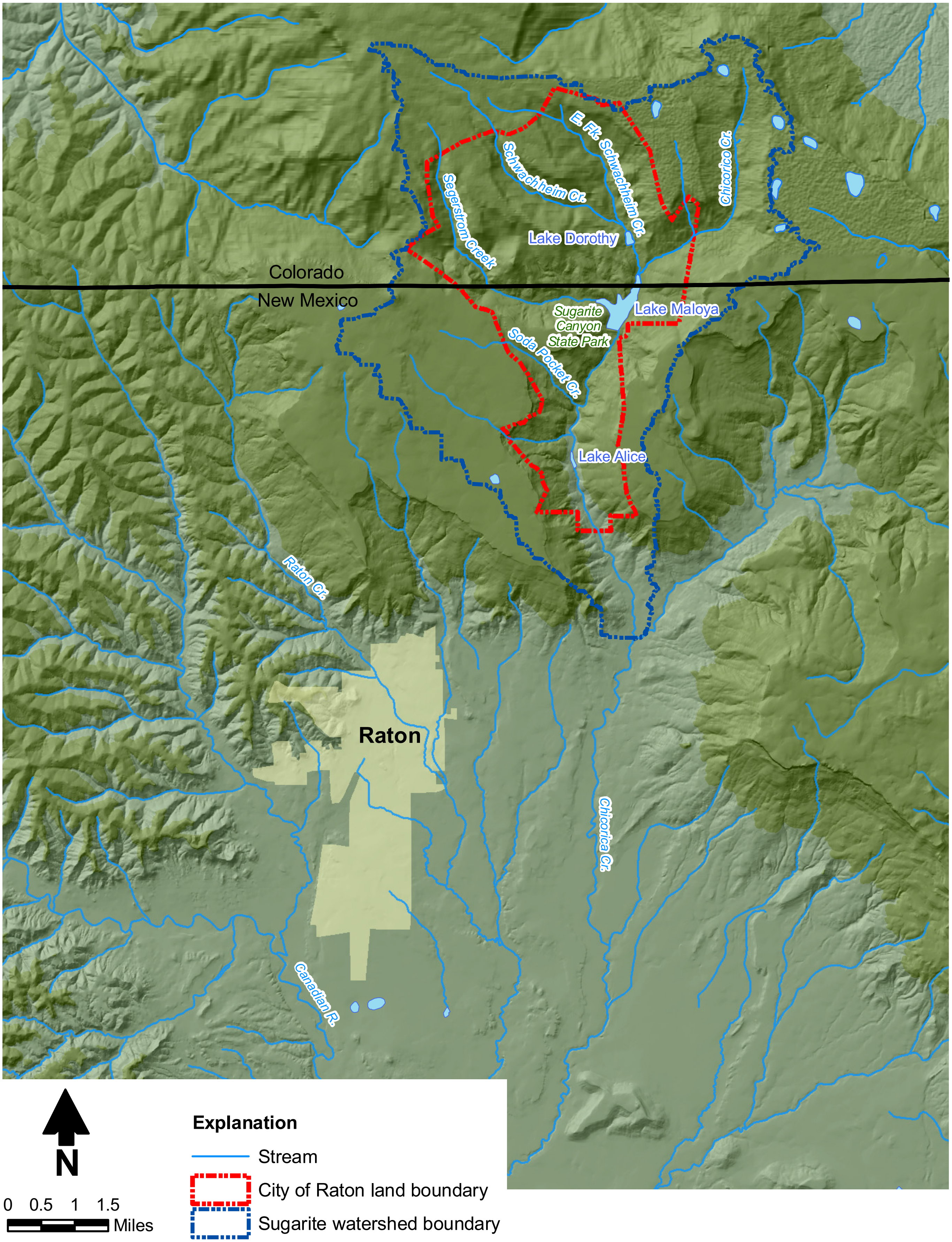
- The City of Raton should be informed of and allowed time for approval of any actions within its land boundaries. As the owner of much of the land in the watershed, the City should review any contracts for work on its land.

3. Description of Sugarite Watershed

The Sugarite watershed is located approximately 10 miles northwest of the City of Raton. The City owns most of the land in the Sugarite watershed (Figure 3-1), and part of the watershed, including some of the City's land, is managed by the New Mexico State Parks as Sugarite Canyon State Park. In the upper watershed, which lies in the state of Colorado, portions of the Chicorica Creek drainage are privately owned, while the northwestern forks of the watershed, Schwachheim and East Schwachheim Creeks (Figure 3-2), are under the management of the Colorado Division of Wildlife.

The City maintains three reservoirs in Sugarite Canyon that provide the primary water supply for the municipal system's service population, which is approximately 9,000 and growing. These reservoirs are fed by three tributaries of the Chicorica Creek that originate on Raton Mesa northeast of Raton (Figures 3-1 and 3-2). Lake Maloya is the largest of the three reservoirs, with 5,250 acre-feet of available storage. Lake Dorothey, located about 2,000 feet north of the Colorado-New Mexico state line, has 212 acre-feet of available storage, and Lake Alice has 100 acre-feet of storage. As shown on Figures 3-1 and 3-2, the Sugarite watershed extends to the confluence of Chicorica Creek and East Chicorica Creek. However, the focus of this stewardship planning effort is the watershed above Lake Maloya, as treatments in that area will have the most benefit for protecting the City of Raton water supply.

All three reservoirs have been in existence for about a century. Lake Alice was completed in Sugarite Canyon in 1892 and was connected to the city by an 8-inch steel pipeline designed to deliver 1 million gallons per day (mgd) to the city. Lake Dorothey was completed by 1904, with a 12-inch wood stave pipeline to Raton that was completed in 1905. Lake Maloya Dam was first constructed in 1907, providing 59 acre-feet of storage in the resulting reservoir. Due to lack of sufficient storage and related water quality degradation concerns, the dam was enlarged in 1949, increasing reservoir storage to 5,250 acre-feet. The water rights that define allowable storage are described in the *City of Raton 40-Year Water Plan* (DBS&A, 2007).



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SUGARITE STEWARDSHIP PLAN

Sugarite Canyon

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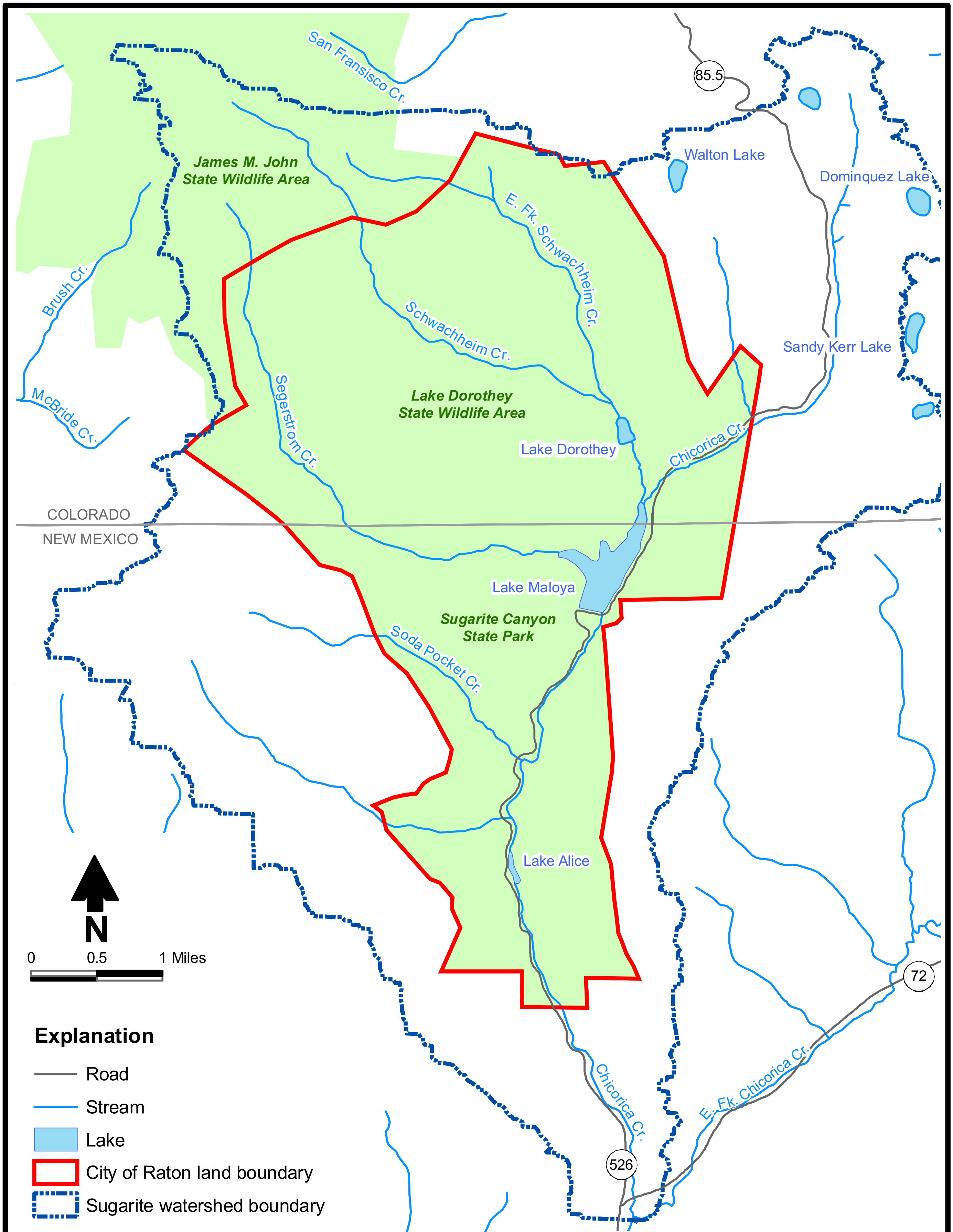
Figure 3-1



SUGARITE STEWARDSHIP PLAN

Surface Water

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Figure 3-2

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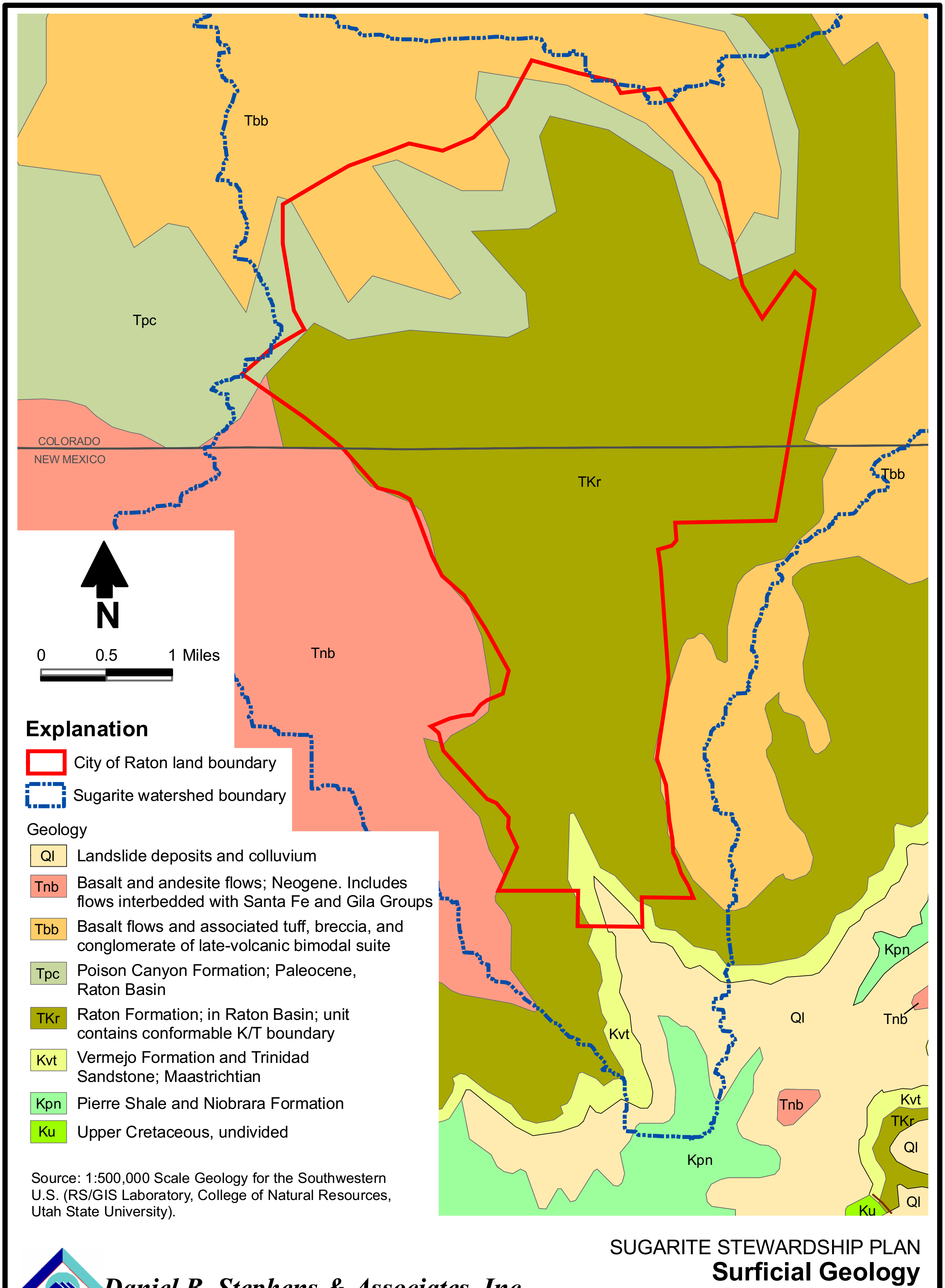
Snowmelt is the source of much of the surface water in the watershed, and most of the runoff occurs between March and June. Thunderstorm events also contribute summer runoff in the area (Bartolino et al., 1996).

The surficial geology of the watershed is shown on Figure 3-3. Most of the watershed is underlain by the Cretaceous Raton Formation. The Raton Formation is a coal-bearing formation with carbonaceous shale, brown to buff sandstone, and conglomerate (usually at the base). The Raton Formation can be classified into three divisions. The lowest division is a basal sandstone and conglomerate of quartzite, chert, and gneiss pebbles and cobbles in a coarse-grained quartzose to arkosi sandstone matrix. The middle division is fine- to coarse-grained sandstone, with some siltstone, mudstone, and coal. The upper division is coal-bearing and contains sandstone, siltstone, mudstone, shale, and mineable coal.

Vegetation in the Sugarite watershed is comprised primarily of ponderosa pine, mixed-conifer forests, and oak. Detailed descriptions of the existing vegetation conditions in the watershed are provided in Section 4.1.



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SUGARITE STEWARDSHIP PLAN
Surficial Geology

Figure 3-3

4. Existing Vegetation Conditions

The first step in developing a plan for restoration is to define existing ecological conditions, which are described in this section. Some of the Sugarite watershed has already been thinned under a variety of programs (Figure 4-1); this section focuses on the existing condition of the untreated vegetation in the watershed. Section 6 provides a restoration prescription for key vegetation community types along with recommendations on type and timing of treatments. Long-term maintenance and monitoring protocol for tracking change immediately after treatments and in future years are discussed in Sections 7 and 8, respectively.

The Sugarite watershed is a patchwork of forest and woodland types (Figures 4-2 and 4-3):

- Ponderosa pine woodlands are mainly found on the slopes near Lake Maloya (7410 feet elevation) and on the south- and west-facing slopes above tributaries to the lake.

- Ponderosa pines are also found growing together with Douglas fir, white fir, Gambel oak and scattered shrubs in mixed-conifer stands, located on the north- and east-facing slopes at lower elevations above streambeds, on steeper and higher slopes nearer the rims of the mesas, and at the headwaters of the tributaries.

- The slopes above the streams become steeper as they reach the rims of the mesas that form the upper parts of the watershed, around 9,000 feet elevation. Below the basalt rim, shale and sandstone talus slopes are partly covered with mesic mixed-conifer forest stands.

- Adjacent to lower tributary streams are large, lush meadows with diverse grass and forb communities and scattered young trees.

- Gambel shrublands and tree groves are scattered on lower slopes throughout the watershed.

- Aspen groves are primarily found adjacent to streams at higher elevations and scattered in mixed-conifer stands.

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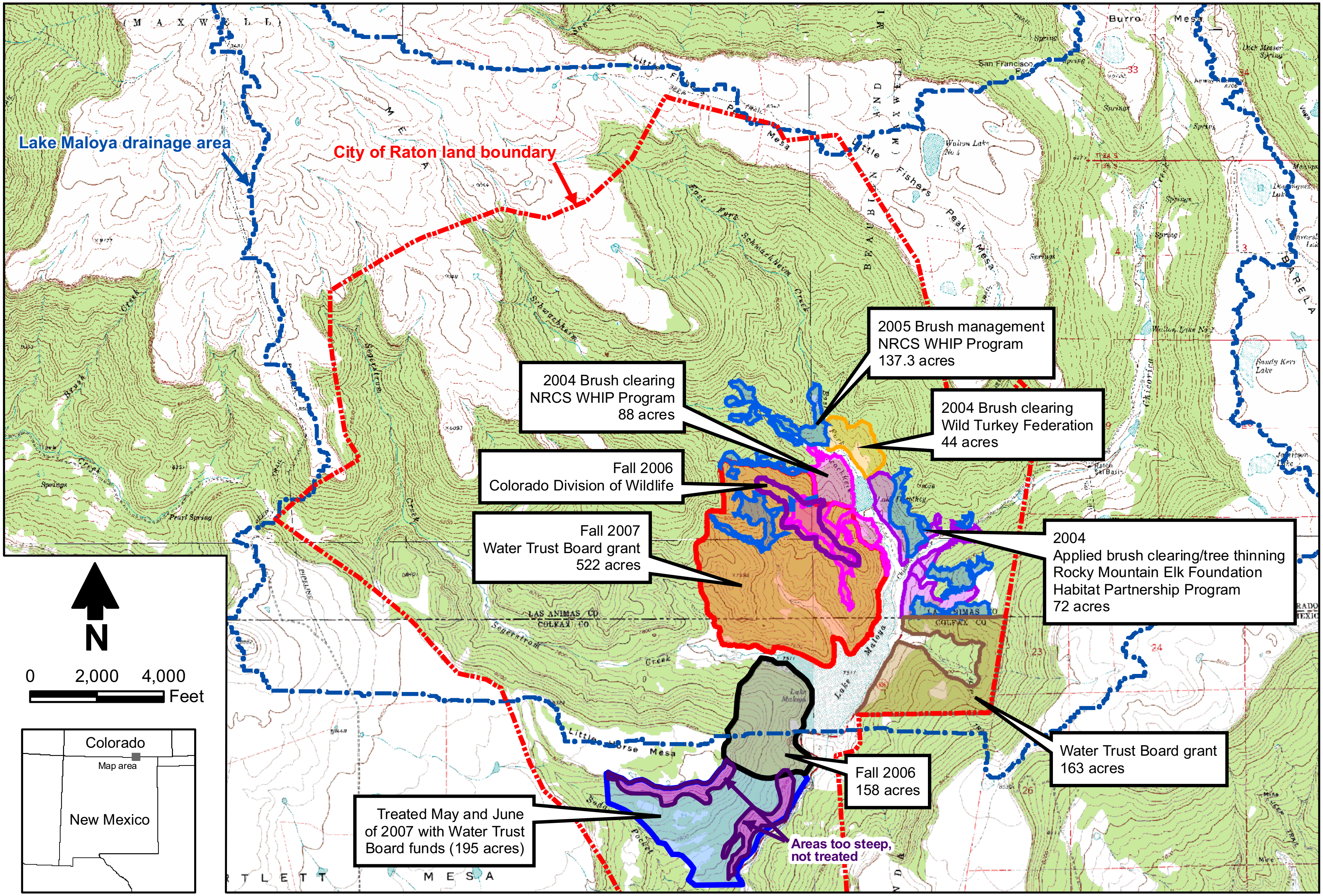

Figure 4-1

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SUGARITE STEWARDSHIP PLAN
Treated Areas

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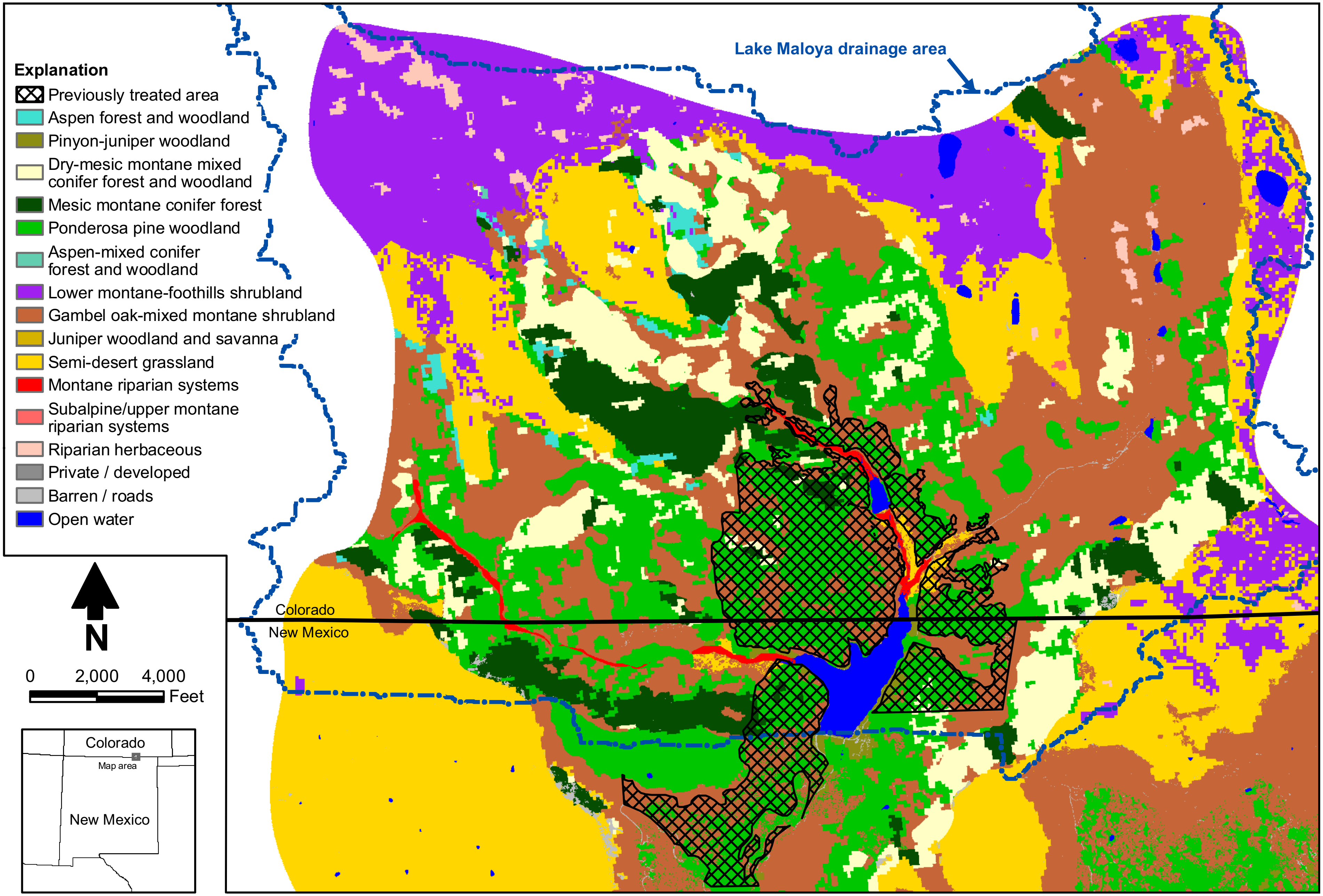

Source: The Nature Conservancy FRCC Project

SUGARITE STEWARDSHIP PLAN
Sugarite Existing Vegetation

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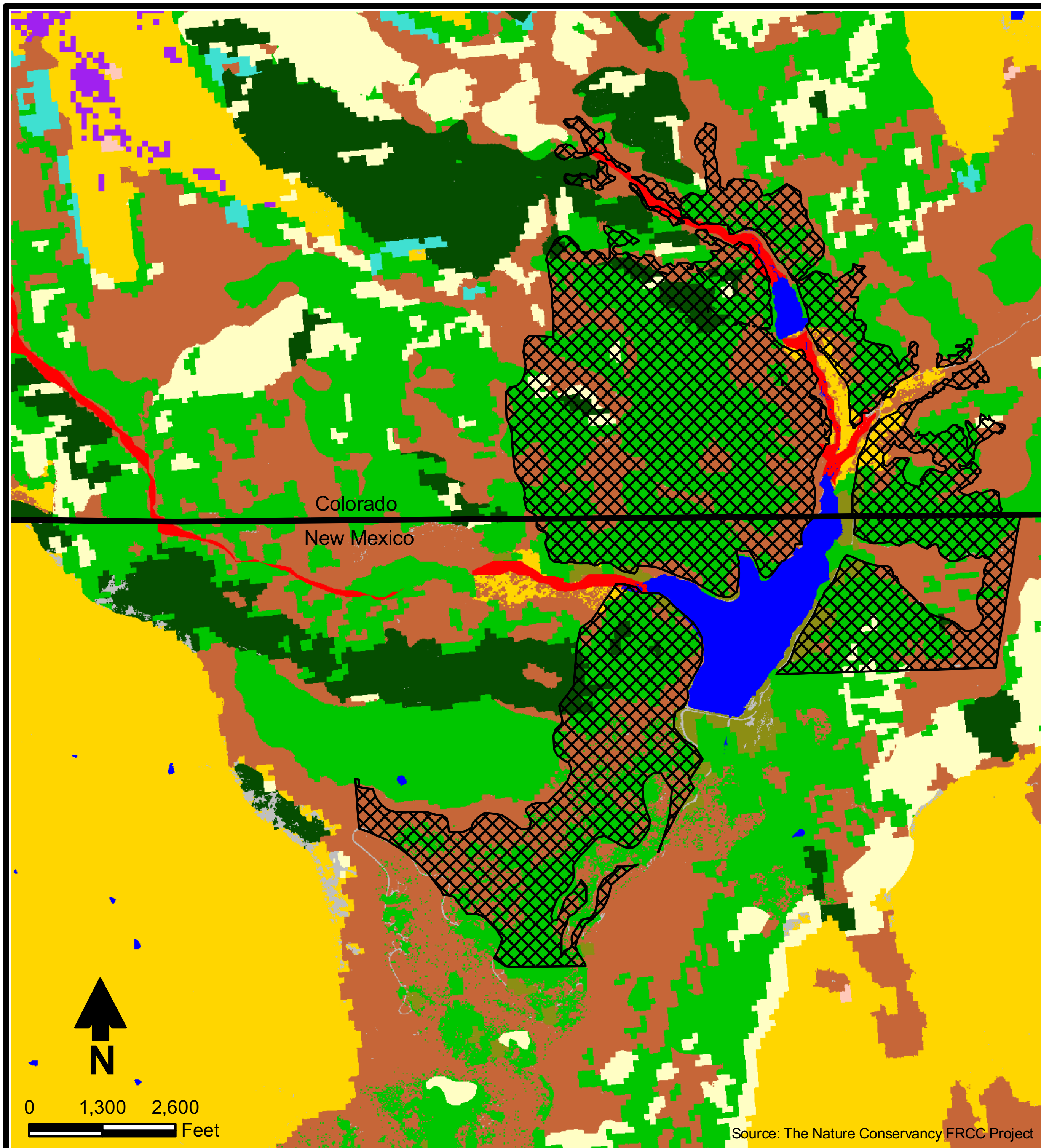
Figure 4-2



Explanation

- Previously treated area
- Aspen forest and woodland
- Pinyon-juniper woodland
- Dry-mesic montane mixed conifer forest and woodland
- Mesic montane conifer forest
- Ponderosa pine woodland
- Aspen-mixed conifer forest and woodland
- Lower montane-foothills shrubland
- Gambel oak-mixed montane shrubland
- Juniper woodland and savanna
- Semi-desert grassland
- Montane riparian systems
- Subalpine/upper montane riparian systems
- Riparian herbaceous
- Private / developed
- Barren / roads
- Open water

SUGARITE STEWARDSHIP PLAN

Existing Vegetation Near Lake Maloya

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Figure 4-3

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Nearly all the vegetation communities present in the watershed, especially oak stands, ponderosa pine stands, and the drier type of mixed-conifer stands, are adapted to a regime of frequent fires (Section 1). The exceptions are the forest stands at the highest elevations, on steep slopes near the mesa rims. In oak, ponderosa pine woodlands, and mixed-conifer communities, fire historically occurred frequently enough to remove large quantities of fuels, including small trees, seedlings and saplings, as well as dead and down surface fuels. These frequent fires were typically relatively cool fires that burned on the forest floor, leaving the canopy largely intact.

Fire suppression and other human activities have resulted in the buildup of large amounts of ladder fuel, in the form of dense young stands of small trees and shrubs in the understory. The ladder fuel loads now present in the forests of the watershed are locally sufficient to support crown fires. Such fires would burn hot enough to kill most adult trees and leave bare soils vulnerable to erosion. Serious post-crown-fire flooding events are typical in the Southwest. An intense rainfall of even short duration could cause large amounts of ash, silt, and sediment to flow into Lake Maloya and from there into the City of Raton water supply and filtration equipment. To prevent this from occurring, existing conditions in many of the vegetation communities in the watershed, particularly those that are adapted to frequent low-intensity fires, require restoration.

The recovery of ponderosa pine and xeric mixed-conifer stands after crown fire would be very slow. These forests did not experience intense crown fires historically, and regeneration from seed sources some distance away would mean that a forest might not reoccupy burned slopes of the watershed for 40 to 60 years or more. In one potential scenario, oaks now occupying the understory of these forests would aggressively resprout and take over previously forested sites for an indeterminate period of time.

The dense oak shrublands typical of the watershed are fire-adapted communities. Oaks burned periodically in fires that removed all surface vegetation, but recovered very quickly after fire, often resprouting in almost pure thickets immediately after fires and forming a live shrub crown within a year. The oak understory beneath ponderosa pine and mixed-conifer stands has the ability to carry fires into the canopy and to serve as ladder fuels in stands that lack the small-diameter trees that typically carry fire into tree crowns.

Tree, shrub, and meadow species in the watershed are summarized in Table 4-1.

Table 4-1. Vegetation Species Present in the Sugarite Watershed

Trees	Woody Shrubs	Meadows / Understory
Ponderosa pine Piñon pine Douglas fir White fir Gambel oak Wavyleaf oak Narrowleaf cottonwood Box elder One-seed juniper Quaking aspen	New Mexico locust Mountain mahogany Skunkbush sumac Chokecherry Golden currant Wax currant Raspberry Snowberry Hawthorn Wild rose Apache plume	Numerous grasses and forbs such as: Wild iris Bluebell Larkspur Penstemons Aster Sunflower Blue flax

None of the shrub species contribute significant levels of fuels with the notable exception of the shrubby form of the oak species found in the watershed.

4.1 Existing Conditions of Primary Vegetation Communities Targeted for Restoration

Four important vegetation communities present in the watershed are (1) ponderosa pine woodland, (2) mixed-conifer forest, (3) aspen forest and woodlands, and (4) Gambel oak groves and shrublands. The existing conditions in these four communities are discussed in Sections 4.1.1 through 4.1.4 based on two sources of information: (1) initial ecological sampling in 2005 of the ponderosa pine and mixed-conifer forest type and (2) an unpublished Nature Conservancy analysis, *Multi-Scale Fire Regime Condition Class Mapping Tool Guide* (FRCC).

For the latter, the Nature Conservancy analyzed the entire Sugarite Canyon watershed using remotely sensed aerial data and developed geographical information system (GIS) map layers of existing forest types and distribution and reference forest types, expressed as a percentage departure of current conditions from natural vegetation-fuel states. These so-called reference conditions are based on biophysical factors, such as slope, elevation, and soils, that would have supported a particular forest type and seral (i.e., successional or maturity) stage. Each forest type is considered to have a low, moderate, or high departure from historical conditions, and this analysis can be used to prioritize forest types that need restoration. The FRCC analysis is discussed for each forest type in Sections 4.1.1 through 4.1.4.

Figures 4-4 and 4-5 show the distribution of two forest types in the watershed, ponderosa pine woodland and xeric mixed-conifer forest, and the general departure of these communities from reference conditions. As indicated in these figures, the departure from reference conditions is generally low for ponderosa pine woodlands and moderate for xeric mixed-conifer forest. Even though the ponderosa pine departure is in the low category on the FRCC relative scale, field mapping indicates sufficient density of ladder fuels to warrant treatment.

4.1.1 Ponderosa Pine Woodland Existing Conditions

Ponderosa pine trees are found in nearly monospecific stands, with an understory of primarily Gambel oak shrubs. Ponderosa pine woodlands and ponderosa pine-Gambel oak thickets are the dominant community types in the lower portions of the upper watershed surrounding Lake Maloya. Patches of these two vegetation types are interspersed on suitable sites on most slopes surrounding the lake. The ponderosa pine type is called woodland rather than forest because the natural or reference condition of the type is a somewhat low-density or scattered structure of all-age trees, including many large trees. Historically, ponderosa pine woodlands were described in early surveys as open and park-like in most areas. In many places there were fewer than 40 large (greater than 18 inches in diameter) trees per acre, most frequently up to 15 per acre. Other sites had denser stands, with density varying by soil type and climate—that is, drier, lower-elevation sites had fewer large trees than higher, moister sites.

Currently, however, large old trees are few and scattered. Stands are not homogeneous across the landscape, but are composed of groves of trees with different characteristics. Large ponderosa pine individuals or clumps are interspersed with patches of small adult Gambel oak trees and patches of dense small ponderosa pines. There are also fairly open areas with a low canopy of shrubby oaks. The unnaturally high-density thickets of young ponderosa pine trees will readily support a crown fire, making them a high priority for treatment.

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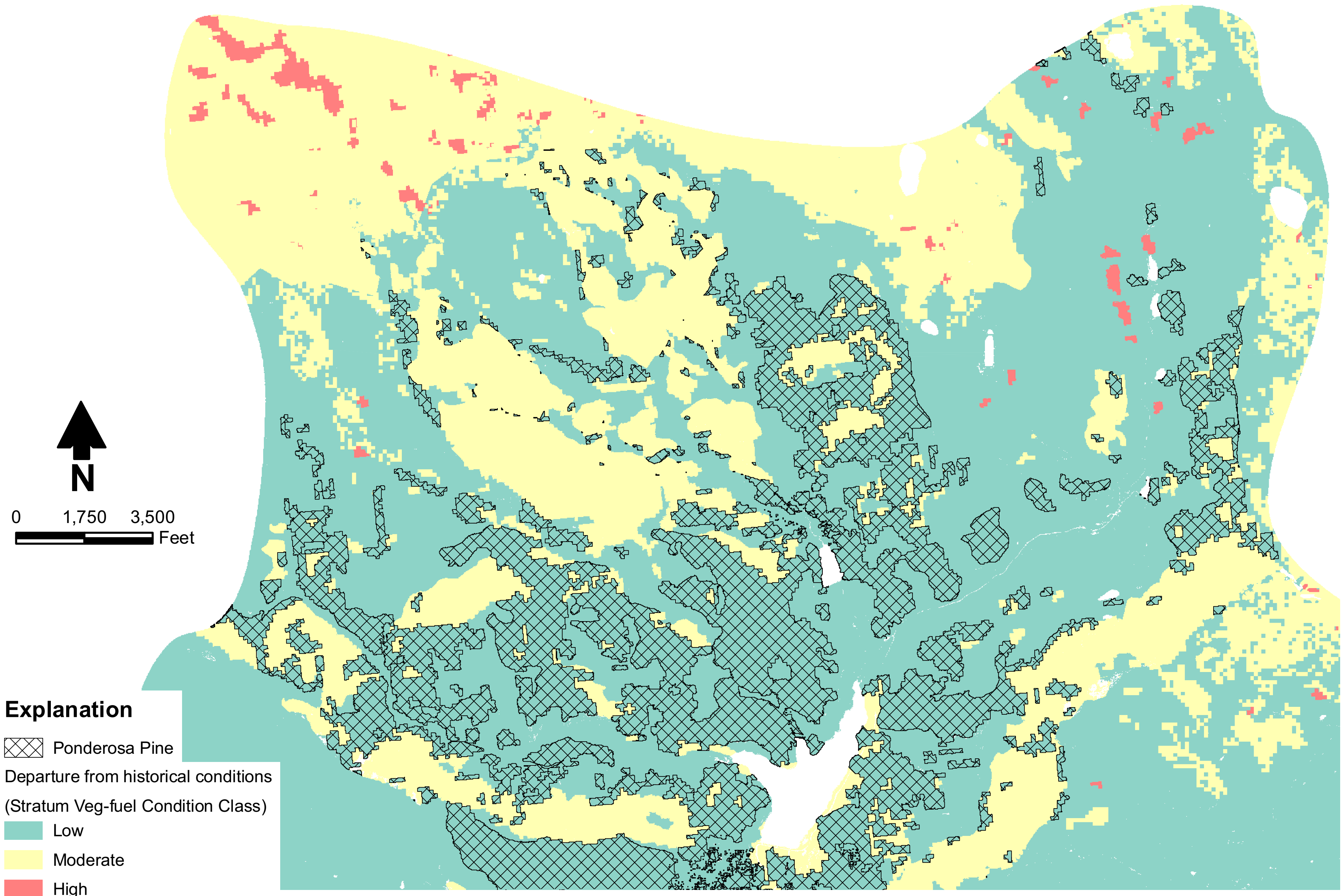

Source: The Nature Conservancy FRCC Project

Note: Ponderosa pine woodland type distribution [hatched areas] in the upper Sugarite watershed, mapped on three levels of departure from reference conditions.

SUGARITE STEWARDSHIP PLAN

Ponderosa Pine

Departure From Historical Conditions

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Figure 4-4

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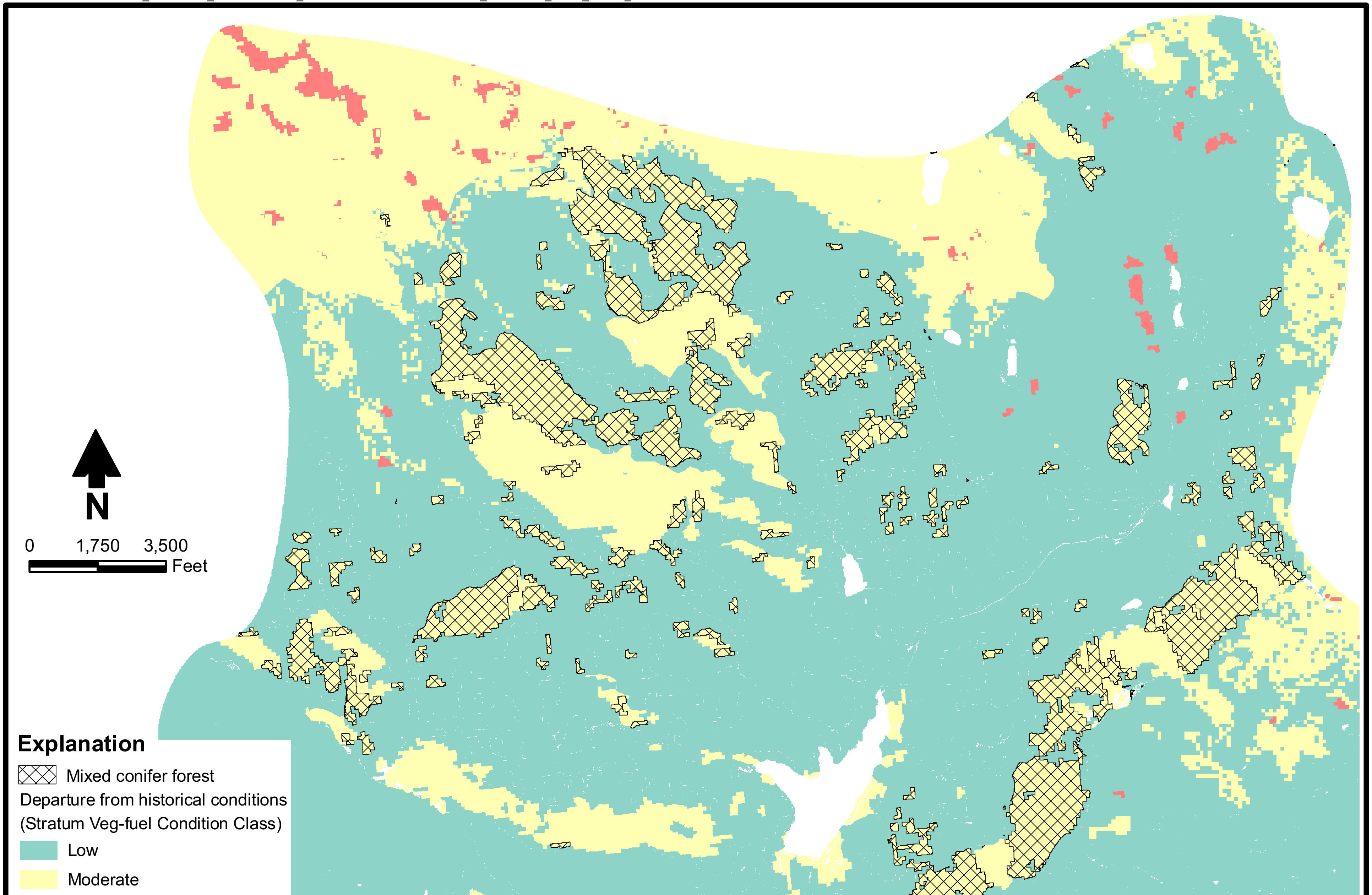

Source: The Nature Conservancy FRCC Project

Note: Mixed-conifer type distribution [hatched areas] in the upper Sugarite watershed, mapped on three levels of departure from reference conditions.

SUGARITE STEWARDSHIP PLAN

Mixed Conifer

Departure From Historical Conditions

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Figure 4-5

Based on GIS coverage (supplied by the Nature Conservancy) of existing vegetation conditions in relation to historical fire regime conditions, the most notable departure from historical conditions in ponderosa pine woodlands is the youngest stage, which occupies three times the proportion of the forest as in the reference forest. Most of the later seral stage trees (i.e., later development, or older, stages) are a lower proportion of the woodlands than they should be for optimal forest health. In other words, the current ponderosa pine woodlands consist of too many trees in early stages and too few trees in older stages. For the reference conditions to be restored, younger trees need to be removed and time allowed to replenish the older stages.

Before the initial thinning treatments began, ecological conditions were measured on south-facing slopes on the west and east sides of Lake Maloya. These two areas are drier and lower in density than many other parts of the watershed. Slopes were moderate.

In the stand to the west of the lake, only ponderosa pine trees were found, with a high density of adults: 307 trees per acre. Many ponderosa pine trees were large, up to 28 inches diameter at breast height (dbh), and these large trees were mixed with clumps of small trees. Ponderosa pine snags, at a mean dbh of 2.5 inches, were very small. Abundant regeneration was evident by the presence of 73 ponderosa pine seedlings per acre and 32 saplings per acre. Gambel oaks formed groves of adults interspersed in patches between ponderosa pine stands, with means of 186 trees per acre and 81 oak snags per acre. There were also dense thickets of oak shrubs, including 895 oak saplings per acre and 2,315 shrub individual stems per acre. Gambel oak shrub thickets, dead standing adult oaks, stands of small ponderosa pine trees, and a moderately large surface fuel component (16.2 tons per acre) constitute a wildfire threat in this area.

The ponderosa pine woodland site to the east of the lake was a mix of primarily ponderosa pine and Gambel oak and was very dense: 266 adult ponderosa pines per acre and 242 Gambel oak trees per acre. A few small white fir (8 trees per acre) were present in the stand. Most trees were small, with an average diameter of 10.7 inches for ponderosa pine, 4.4 inches for oaks, and 5.1 inches for white fir. Ponderosa pine is not regenerating well under these dense canopies, with only 40 seedlings per acre and 8 saplings per acre. White fir, a fire-sensitive tree that tends to invade when fire is absent, is regenerating at the rate of 24 seedlings per acre and

8 saplings per acre. There were 64 Gambel oak saplings per acre and an extremely large number (5,057 per acre) of shrubby form small oak stems. Fuels in this stand were mostly small, live tree ladder fuels. Ponderosa pine, oak trees, and shrubby oaks of small size, together with abundant dead standing oaks, were at dangerously high levels. Dead and down surface fuels were relatively low by comparison, at 4 tons per acre.

4.1.2 Mixed-Conifer Forest Existing Conditions

Mixed-conifer forests extend from low-elevations near Lake Maloya up the slopes of the watershed to the rim of the canyon, as shown on Figure 4-2. These forests grow along a moisture gradient that strongly determines tree species mix as well as vulnerability to fire:

- The lowest-elevation mixed-conifer forest type, called dry or xeric mixed-conifer, is a mix of ponderosa pine, Douglas fir, and white fir, with patches of Gambel oak shrub and small groves of adult Gambel oak. These forests historically burned with some frequency in mostly low-intensity fires, with occasional blowups of severe fire in patches.

- At the highest elevation in the watershed, mixed-conifer is a much moister type, with a longer fire return. These high-elevation stands of moist, or mesic, mixed-conifer stands are dominated by white fir and Douglas fir. The stands are probably little changed from historical structural conditions, when they experienced, as now, a much longer fire interval than the lower and drier communities.

The mesic mixed-conifer stands are less likely to have unnaturally dense thickets of small trees and, therefore, are less likely to need restoration intervention. However, the xeric mixed-conifer stands on the lower slopes near the lake, although moister than ponderosa pine stands, currently have far higher tree density than historically due to fire suppression. Under existing conditions, such forest stands will support intense wildfire in hot and dry weather conditions. Oak is present under the tree overstory and also as pure patches with forest stands. The grass-forb understory, which can anchor soils and reduce erosion, is sparse under existing mixed-conifer stand conditions. The relatively dense shade produced by overly dense mixed-conifer stands has discouraged this understory.

The FRCC analysis described the existing vegetation/fuel conditions and the departure from historical conditions for two kinds of mixed-conifer stands distributed along the dry to wet spectrum, including Rocky Mountain dry to mesic montane mixed-conifer forest and woodland and Southern Rocky Mountain mesic montane conifer forest.

About twice the proportion of early seral, or younger, stage trees currently exist in dry to mesic montane mixed-conifer forest and woodland, compared to reference conditions. There is also a significant deficit in the open late-seral or oldest stage, indicating that the youngest trees need substantial thinning. This forest type is one of the few in the watershed noted as having moderate, as opposed to low, departure from reference conditions.

Pretreatment sampling was conducted in xeric mixed-conifer forests on north-facing slopes above Segerstrom Creek, at the drier end of the moisture gradient for mixed-conifer forest. Slopes were moderate, around 30 percent for the most part, but grading into steeper slopes around 40 percent, which is at the upper edge of treatability. The stand was closed canopy almost throughout the site, with an unnaturally high density of small trees; ponderosa pines (194 trees per acre) and Douglas fir (178 trees per acre) were interspersed with Gambel oak trees (395 trees per acre). A few adult white fir were mixed into the stand (8 trees per acre). Consistent with a regeneration pulse after fire suppression, trees sizes were mainly small: the mean dbh of ponderosa pine was 10.3 inches, of Douglas fir, 3.4 inches, and of oak, 4.3 inches. The sampled site on the north-facing slope above Segerstrom Creek appears to be typical of mixed-conifer stands throughout the watershed. This stand has extremely high densities, at 516 adult trees per acre with an additional 242 dead standing trees per acre, reflecting a serious risk of crown fire for standing fuels.

Increased tree density due to fire suppression has shifted species composition. Ponderosa pine seedlings and saplings were entirely absent due to the dense overstory canopy. Species adapted to the closed canopy and a lack of fire were regenerating: Douglas fir had a per acre mean of 169 seedlings and 226 saplings, and white fir, a fire-sensitive tree that tends to invade when fire is absent, had a per acre mean of 24 seedlings and 8 saplings. Gambel oak regeneration formed a large component of the stand, with a mean of 121 saplings per acre, 129 dead saplings per acre, and a stunning 8,913 individual small stems per acre. Dead standing tree density was also high, with 8 ponderosa pine snags per acre and 194 Gambel oak snags per acre. This large amount of ladder fuels, combined with high adult tree densities, creates high flammability, even on moister north-facing slopes.

4.1.3 Aspen Community Existing Conditions

Aspen stands have a more limited distribution in the watershed (Figure 4-2). Some trees form nearly pure overstory stands, particularly in the wetter areas adjacent to the streams (e.g., in the higher elevations of East Schwachheim Creek). Other stands are interspersed with higher-elevation mesic mixed-conifer forests. Existing aspen stands are most likely the result of past fires, usually fairly intense fires that removed mixed-conifer stands. Regeneration of aspen stands is most often dependent on these fires, as they recover rapidly after fires by sprouting from underground roots. The apparent age of the Sugarite watershed aspen stands indicates that the last fire was probably about a century ago. In the absence of future fire, these stands will probably transition to mixed-conifer forest.

The FRCC analysis described the existing vegetation/fuel conditions and the departure from historical conditions for two kinds of aspen stands.

- *Aspen mixed-conifer forest and woodland:* This type has a moderate departure from reference conditions, with a very significant surplus of small, young trees and deficits in older trees.

- *Aspen forest and woodland:* This type has a low departure from reference conditions, with a small surplus of young trees and deficits in older trees.

Because aspen stands are generally moist and the deciduous leaves relatively non-flammable, they offer little threat of crown fire. But dead and down trees are often very abundant, piled one on top of another in heaps of fuel that could burn during severely dry conditions. Aside from this potentiality, aspen stands are currently a low priority for treatment.

4.1.4 Gambel Oak Community Existing Conditions

Oak communities are an extensive and important vegetation community in the Sugarite watershed and are comprised primarily of Gambel oak. To simplify a complex community, this stewardship plan describes the oaks of the watershed as three subtypes:

- Nearly pure oak shrub thickets, or shrublands, often containing widely scattered and isolated ponderosa pine trees
- Scattered or continuous shrub thickets beneath forest stands
- Scattered groves of moderate-sized adults interspersed as patches among ponderosa pine and mixed-conifer forests

Oaks are a valuable component of watershed forests, providing an important food source for many animals; oak thickets provide cover, and oak snags and fallen logs are persistent and form key habitat for birds, bats, and small mammals.

The large thickets of oak in the watershed may be a product of the severe human impacts on the forests during the period of mining in the first half of the 20th century. Even so, oaks would have been a natural component in regional forests in the past. The current extensive thickets of oak throughout the watershed are a significant fire threat, because oaks, especially in shrub thickets, carry fire continuously through the forest and into conifer tree crowns.

Gambel oak can produce a large number of small stems that never grow taller than shrub form. Many of these stems are sprouts of the same individual. Nevertheless, each stem has a fuel value, and small oaks contribute a large fuel component in forest understories. Oaks have a robust capacity for resprouting and can vigorously resprout in the same season following burning, crushing, or cutting. This is less true of older oak trees than of the shrubby form.

Like other vegetation communities in the watershed, the oak community, termed Rocky Mountain Gambel oak-mixed montane shrublands on the FRCC map, has an overabundance of the earliest seral stage and a lack of later seral stages. However, the last seral stage for oak, the open late-seral stage, is also overrepresented, perhaps reflecting the lack of fire in a fire-adapted species.

4.1.4.1 Oak Shrublands

The dense oak shrub thickets typical of the watershed are especially adapted to fire. They recover extremely well after fire, often resprouting in almost pure thickets immediately after fires and forming a live shrub crown within a year. Oak thickets increase in size and biomass with time, as do all shrublands that burn periodically.

4.1.4.2 Understory Oaks

Oak shrubs beneath forest and woodland canopies represent a threat in terms of becoming ladder fuels in stands that lack small-diameter trees to carry fire into tree crowns. Ponderosa pine stands are particularly vulnerable to crown fires in areas where oak grows densely and tall beneath the pine overstory. The closed mixed-conifer stands tend to have fewer oak growing densely enough to form extensive ladder fuels, but given the density of the small tree understory in these stands, the additional contribution of an oak shrub understory is a concern in these stands as well.

4.1.4.3 Oak Groves

Clumps of mid-sized tree-form Gambel oak are present throughout the lower slopes above Lake Maloya, in ponderosa pine and mixed-conifer stands. Beneath these groves of small and mid-sized adult Gambel oak trees, the grass-forb understory is dense and rich. The deciduous nature of oak enables the development of a ground cover that allows good infiltration of rainfall and prevents soil erosion. The oak clumps also offer significant resources for wildlife. Many of these stands are found growing at the lower margins of the forest, near the meadows found on either side of streams.

4.2 Other Restoration Considerations in the Sugarite Watershed

4.2.1 Understory Grass/Forb Communities

The grass and forb understory beneath dense young ponderosa pine forests are an important part of the forest ecosystem. Understory plants provide a crucial contribution to forest restoration by serving as fuel to carry low-intensity fire. When grasses and forbs are dry, they burn readily and enable surface fires to spread across the forest floor. Without a good understory, low-intensity fires that thin overabundant tree seedlings and saplings will not occur, and dense young tree thickets will establish, creating a crown fire threat. In addition, much of the biodiversity of the forest is contained in the understory plant community: understory plants provide food and cover for small mammals and other wildlife, protect the soil surface from erosion, and provide foraging for native herbivores. Restoring these functions is an important part of a healthy forest.

The extreme density and closed canopy of most watershed forests means that the understory plant cover is greatly reduced. Under ponderosa pine forests, a thick layer of dry pine needles has excluded most understory plants. Where the canopy is very closed, as in many xeric mixed-conifer stands, understory plants are few and scattered. In the Sugarite watershed, a healthy understory plant cover is found only beneath oak groves, which allow sunlight onto the forest floor (due to a leafless phase) in early spring and patchy sunlight during summer.

4.2.2 Riparian Communities

Riparian vegetation systems are located directly adjacent to streams at all elevations in the Sugarite watershed. The FRCC analyzed three kinds of riparian vegetation types: (1) montane riparian system, (2) subalpine/upper montane riparian systems, and (3) riparian herbaceous systems. Only for the riparian herbaceous system is there a high departure from reference conditions. Since these communities are both very restricted geographically and are usually very moist, the threat of fire spreading into the watershed from these systems is low, and they are therefore a low priority for restoration treatment. Additionally, due to the sensitive habitat in the riparian areas, as well as potential water quality concerns, treatment or physical disturbance of riparian areas has been avoided in the watershed.

4.2.3 Meadows

Meadows that occupy sites adjacent to some of the riparian systems of tributaries near Lake Maloya appear to have a dense cover and to be in healthy condition. However, trees from nearby forests have invaded the meadows, and in some meadows, fairly significant numbers of small and even mid-sized trees, especially ponderosa pines, are now found scattered in meadows. These trees should be removed, together with seedlings and saplings, up to the margin of the forest, usually at the toe of the slope. All trees, regardless of size, should be removed from natural meadows.

4.2.4 Mesa Communities

Above the rim of the canyon, the mesas are relatively flat and are covered primarily with grass communities interspersed with ponderosa pine woodlands. The risk of crown fire in these woodlands would be reduced by thinning, but there appears to be little risk of a significant contribution of ash to the fluvial systems in the watershed in case of fire on the mesas, and little risk of fire moving from the mesa communities down into the canyon. The mesa tops are therefore a low priority for treatment at present, but may be considered for restoration treatments later.

4.2.5 Surface Fuels

Down and dead woody fuels are not excessively high in the Sugarite watershed forests compared to some southwestern forests. The level of surface fuels that should be considered a fire threat depends on levels of living tree density, topography, ground moisture, and other factors. If values of 10 to 15 tons per acre are considered relatively safe, then surface fuel values in the sampled stands are not excessive in most of the vegetation communities in the watershed. The sampled value of 4 tons per acre in the ponderosa pine woodland on west-facing slopes is certainly not a concern. The north- and south-facing slopes, with sampled values of 17.5 and 16.2 tons per acre, respectively, need some fuel reduction.

An exception to this relatively moderate level of surface fuel is found in mixed aspen/mixed-conifer forest and aspen woodlands at high elevations in the watershed. Although no ecological sampling was done to quantify the surface fuel load in these areas, they contain large numbers of piled large dead and down aspen. These dead and down aspen boles are for the most part moist enough and lacking in volatile compounds that they do not currently present a serious threat. However, if a prolonged severe drought occurred in the watershed, the level of surface fuel loading from dead aspen trees should be reevaluated.

5. Other Stewardship Considerations

An integrated approach for stewardship planning includes considering a variety of factors in the design of treatments for the watershed. This section discusses wildlife, cultural resource, and hydrologic considerations. Additional information on wildlife monitoring is provided in Section 8.

5.1 Wildlife Considerations

In addition to numerous wildlife surveys that have been conducted in the Sugarite watershed over the years, field surveys were conducted and wildlife considerations reviewed as part of the pre-treatment planning process for areas that have already been restored. Additional surveys will be conducted prior to treatment of new areas on the watershed.

Bird species recorded during the surveys near Lake Maloya prior to field treatment are listed in Table 5-1.

Table 5-1. Bird Species Detected in Field Surveys near Lake Maloya

Family	Common name	Scientific name
Phasianidae	Wild turkey [a]	*Meleagris gallopavo*
Accipitridae	Bald eagle	*Haliaeetus leucocephalus*
	Northern goshawk [b]	*Accipiter gentilis*
Picidae	Hairy woodpecker	*Picoides villosus*
Corvidae	Steller's jay	*Cyanocitta stelleri*
	Common raven	*Corvus corax*
Paridae	Black-capped chickadee	*Poecile atricapillus*
	Mountain chickadee	*Poecile gambeli*
Sittidae	White-breasted nuthatch	*Sitta carolinensis*
	Pygmy nuthatch	*Sitta pygmaea*
Certhiidae	Brown creeper	*Certhia Americana*
Emberizidae	Dark-eyed junco	*Junco hyemalis*

[a] Not seen or heard, but feathers found on the ground
[b] Identification only tentative (observed from a great distance)

Additional species encountered near the project area on Lake Maloya and along its banks included the Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), ring-necked duck (*Aythya collaris*), and western bluebird (*Sialia mexicana*). American coots (*Fulica Americana*) and a belted kingfisher (*Ceryle alcyon*) were recorded at the mouth of Segerstrom Creek in Lake Maloya, just outside the project area. A red-tailed Hawk (*Buteo jamaicensis*) was also heard during a November 2007 survey.

Among mammals, red squirrels (*Tamiasciurus hudsonicus*) were seen in the ponderosa pine and mixed-conifer forest along the north-facing slopes of the project area, and red squirrel middens were seen in a variety of locations. Mule deer (*Odocoileus hemionus*) are common year-round throughout Sugarite Canyon State Park and were seen in the project area. Signs of underground activity by pocket gophers (*Thomomys*) were observed along the lower slopes. Abert's squirrel (*Sciurus aberti*) and pocket gopher (*Geomydae*) activity were also observed. Other mammals not seen during the survey but known to occur in the general area include elk (*Cervus elaphus*), coyote (*Canis latrans*), and black bear (*Ursus americanus*). Finally, common muskrats (*Ondatra zibethicus*) and signs of American beaver (*Castor Canadensis*) activity were seen at the mouth of Segerstrom Creek and along a creek just above Lake Dorothy.

5.1.1 Biologically Sensitive Features

Biologically sensitive features detected during surveys in the project area consisted of the following:

- Numerous red squirrel middens
- A bald eagle
- A raptor tentatively identified as a northern goshawk
- Potential meadow jumping mouse habitat in small drainage areas between slopes
- A beaver lodge and a beaver dam just upstream from Lake Dorothey, along the northeastern boundary of the project area

All red squirrel middens were mapped and flagged. As ongoing treatment proceeds, red squirrel middens should continue to be flagged prior to movement of mechanized equipment into the area. Other features such as aspen stands, the beaver territory, and the meadows representing potential jumping mouse habitat have been mapped and should continue to be mapped shortly before initiating treatment in new areas.

The bald eagle is currently listed by the U.S. Fish and Wildlife Service as Threatened, although it has been proposed for delisting from the Endangered Species Act (ESA). Once delisted, bald eagles will continue to be protected by the Bald and Golden Eagle Protection Act (BGEPA) and the Migratory Bird Treaty Act (MBTA). Both acts protect bald eagles by prohibiting killing, selling, or otherwise harming eagles, their nests, or eggs. The BGEPA also protects eagles from disturbance. When observed on December 5, 2006, the bald eagle at Lake Maloya perched in a tree almost directly below the ridge where thinning and mulching were in progress. It seems highly unlikely that noise from thinning operations along a small portion of the lake shoreline constitutes a disturbance to any wintering bald eagle.

While the northern goshawk is not listed under the ESA, it is generally considered conservation-sensitive. It was listed in January 1992 as a candidate species (Category 2) for possible future listing under the ESA throughout its range in the United States. Later it was petitioned for listing as Threatened or Endangered under the ESA. Goshawks are resident in mountains of New Mexico, and nesting remains a possibility, if not in the project area, at least along surrounding slopes.

The New Mexico jumping mouse (*Zapus hudsonius luteus*) is considered sensitive by both the Bureau of Land Management and the Forest Service Region 3 and has recently been listed as a candidate species under the ESA. It also has the Natural Heritage conservation status of critically imperiled in New Mexico. Its main habitat consists of tall, dense herbaceous vegetation typically dominated by sedges and growing in moist or wet soils along shallow, slow-moving, perennial water. Surveys conducted in New Mexico in 2005 revealed substantial, widespread declines during the last 15 years. According to Dr. Jennifer Frey, the main threat to the New Mexico jumping mouse is the alteration or loss of its habitat, in particular through livestock grazing or through erosion and downcutting of streams.

As revealed by a study published in 1999, Sugarite Canyon State Park harbors a population of New Mexico jumping mice. In 2006, Dr. Frey and Zachary Schwenke captured 22 of the mice at five locations inside the park: Segerstrom Creek, Upper Chicorica Creek, Soda Pocket Creek, Soda Pocket Campground, and Lake Alice. All five locations had optimal or near-optimal jumping mouse habitat. The mouse was not captured at two locations along lower Chicorica Creek, where perennial water is not continuous and tall, dense herbaceous cover is reduced. In their final report to New Mexico State Parks, Frey and Schwenke (2006) concluded that the New Mexico jumping mouse is "relatively abundant" in suitable habitat at Sugarite Canyon State Park. In fact, the rate of capture at Sugarite Canyon State Park was twice the average found at other New Mexico locations where the jumping mouse was found.

The ongoing work in the watershed is not altering streams or riparian habitat. As long as there is not impact to these areas, the beaver habitat is not expected to be a concern.

5.1.2 Recommendations for Mitigation of Wildlife Concerns

As discussed above, a key consideration for minimizing disturbance to wildlife that could occur due to thinning activities is to conduct field surveys and to flag sensitive areas prior to initiating on-the-ground treatment activities and to then avoid using mechanized equipment in the flagged areas. In order to avoid damage to wildlife habitat, the field contractors should be provided with a map and explanation of the flagging.

Specific recommendations include the following:

- Avoid passage of heavy equipment across grassy meadows between slopes.
- Conduct goshawk surveys in the project area and along adjacent slopes prior to treatment. Any nest found during those surveys should lead to the establishment of a buffer zone and/or time restrictions for thinning activities.
- Establish a buffer zone with a 100-foot radius around flagged red squirrel middens.
- Map and avoid sensitive jumping mouse habitat.

- Avoid disturbance of riparian areas and stream crossing. Access to all treatment areas has been through existing bridges or bypassing any stream crossings. If riparian areas are to be disturbed at any time, careful site-specific planning and mitigation will be required.

- Leave wildlife travel corridors and hiding habitat untreated along riparian zones and other difficult-to-treat areas.

- Leave one to two small patches per acre of untreated forest for temporary wildlife refuge.

- Preserve large snags and large downed logs; if possible, protect them from prescribed burns by lining or raking debris and needles from immediate surroundings.

- Leave a few piles of slash per acre in open areas.

5.2 Cultural Resource Considerations

Field surveys were conducted to ensure that all projects in New Mexico are in compliance with the New Mexico Cultural Resources Properties Protection Act, which requires that professional surveys be conducted to ensure that cultural properties are not inadvertently damaged or destroyed if project areas are within New Mexico (New Mexico Statutes Annotated [NMSA] 1978 §18-6A-5) (MAI, 2005). Surveys were submitted to the New Mexico State Historic Preservation Office (SHPO) for review and concurrence. Similar field surveys should be conducted prior to all future field activities.

Cultural resources are to be evaluated in consultation with the state historic preservation officer at the New Mexico Historic Preservation Division. A Class III 100 percent pedestrian survey recording archaeological and historic sites is required to comply with the requirements of the New Mexico Cultural Resources Properties Protection Act, and a cultural report is required to be submitted to the SHPO, to determine whether any sites meet the criteria for listing on the National Register of Historic Places or State Register of Cultural Properties. The cultural reports state how impacts to cultural resource sites will be avoided and/or, for sites that cannot be avoided, include recommendations for further investigation and/or mitigation measures (MAI, 2005). The SHPO review process takes 30 days.

Though field cultural resource surveys are not required in Colorado, they have been conducted for the City of Raton projects to ensure continuity in the protection of cultural resources. Similar surveys are recommended for future Colorado projects.

Based on the surveys conducted to date, SHPO has concurred on all projects that treatment could proceed without impact. Cultural resource and mitigation techniques that have been identified include:

- A number of very large "culturally modified" trees have been identified. These are trees that are scarred from cultural use of bark. Since the prescription calls for preservation of these large trees, they would not be thinned in any case. As an added precaution they have been flagged and their locations determined with a global positioning system (GPS).

- Some historic properties, such as an old homestead and mining prospecting site, have been identified; these have been flagged for avoidance.

- Minimal cultural sites, including artifact scatter, have been identified; these were flagged for avoidance.

5.3 Hydrologic Considerations

As discussed in Section 3, the Sugarite watershed provides the primary drinking water supply for approximately 9,000 people in the City of Raton and vicinity. The primary objective of this project is to protect Lake Maloya, Lake Dorothey, and Lake Alice from sediment encroachment and/or flooding following a severe fire in the watershed. Due to its much larger size, Lake Maloya is the highest priority for protection of the City reservoirs.

A crown fire in the watershed of sufficient size could potentially create two serious hydrologic issues:

- Ash and debris flows are typical following crown fires and have the potential to both affect the water quality in the City reservoirs and accumulate in the reservoirs, creating diminished storage capacity. Plant roots stabilize the soil and plants slow rainfall, giving it time to percolate into the soil. A crown fire that kills most or all of the vegetation creates easily erodible surface soils, and debris flows frequently occur during post-crown fire storm events. For example, following the 1994 South Canyon fire in central Colorado, a rain event triggered debris flows that inundated a 3-mile stretch of Interstate 70, engulfing 30 cars. In 1996, a high-intensity storm following the Buffalo Creek fire resulted in severe and costly sedimentation of the Strontia Springs Reservoir, a major water storage and distribution facility for Denver (Colorado Division of Forestry, 2004).

- In addition to post-fire water quality concerns, there is a significant risk of post-fire flooding. In general, the denser the pre-fire vegetation and the longer it burns on a site, the more severe will be the effects on the soil and its ability to absorb and process water (Colorado State Forest Service, 2008). A severe wildfire may also cause certain types of soil to become hydrophobic by forming a waxy, water-repellent layer that keeps water from penetrating the soil and dramatically amplifies the rate of runoff. When the hydrophobic layer is deposited beneath the soil surface, a perched water table develops that may cause thin (1- to 2-centimeter) hillslope failures. Evidence of these failures was observed after a fire near Santa Barbara, California (Gabet, 2003). This condition could contribute to a severe post-fire flooding risk. After the 2002 Missionary Ridge fire near Durango, Colorado, local officials observed that the fire effects had altered stormwater runoff to the point that homes that had never experienced flooding were now in high-risk debris and flood zone areas (Colorado Division of Forestry, 2004).

In the event that there is a fire in the watershed, a quick response after the fire will be critical to minimizing post-fire sedimentation. Techniques that can be used to prevent post-fire sedimentation include check dams within drainages, sediment traps, contour logging, and placement of straw bales. Where hydrophobic soils are present, rehabilitation often includes mechanical breaking of the hardened layer followed by reseeding (Colorado State Forest Service, 2008).

The high risk of potential post-fire impacts greatly outweighs potential short-term consequences of mechanized thinning. Nonetheless, thinning should proceed using best management practices to reduce the risk of sedimentation following treatment. To minimize the risk of erosion and sedimentation from treatment, the following precautions are recommended:

- Avoid use of mechanized equipment for stream crossings unless stable bridges are in place, even if access through other routes is longer.

- Avoid repeated use of the same pathways by equipment, particularly during wet periods, to minimize the risk of developing ruts. Existing treatments have involved setting up a staging area and building temporary gas tanks to avoid repeated use of the access paths.

- Mitigate any temporary road damage by placing logs or slash material over disturbed areas immediately following treatment

- If temporary roads are constructed for any purpose, design road placement and draining (including culverts) to minimize the potential for head-cutting and erosion. All plans for temporary roads must be approved by the City of Raton.

6. Prescriptions for Restoration

Restoration by reducing tree density involves thinning small and young trees in several vegetation communities in the Sugarite watershed. Tree thinning increases sunlight on the forest floor and fosters the recovery of a grassy understory that can increase infiltration of rainfall, protect the soil from erosion, and support the kind of low-intensity fires that will thin new trees that establish over time. A restoration program for the watershed should be integrated with a long-term maintenance plan that maintains the benefits of restoration.

A portion of the Sugarite watershed has already been restored, as illustrated on Figure 4-1. As shown on this figure, a variety of entities have conducted various treatments in the area. A prescription for treatment was developed in conjunction with the collaborators group during the pilot treatment project conducted by the Colfax SWCD in 2002. This section provides updated prescriptions for treatment, by vegetation type.

Implementing restoration on the entire watershed is expensive; consequently, the watershed restoration has been and will continue to be implemented incrementally. Priorities for treatment are based primarily on:

- Proximity to Lake Maloya or drainages feeding Lake Maloya. Because the objective of the treatment is to protect the City reservoirs, particularly Lake Maloya, from the results of a catastrophic crown fire, the portions of the watershed nearest the lake and its tributaries are the highest priority for treatment. Since Lake Dorothey could potentially serve as a sediment buffer to the larger Lake Maloya, the Schwachheim Creek drainage is a slightly lower priority than Segerstrom and Chicorica Creeks.

- Vegetation types that are currently at risk for crown fire and are accessible to treatment.

Using these criteria, the relative sequence for treatment is illustrated on Figure 6-1.

Two forest types have the highest priority for restoration treatment: ponderosa pine woodlands and the xeric mixed-conifer forest. Both occur on the slopes directly above Lake Maloya. Other vegetation communities tend to be resistant to treatment (i.e., the extensive oak communities),

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PRELIMINARY SUBJECT TO REVISION

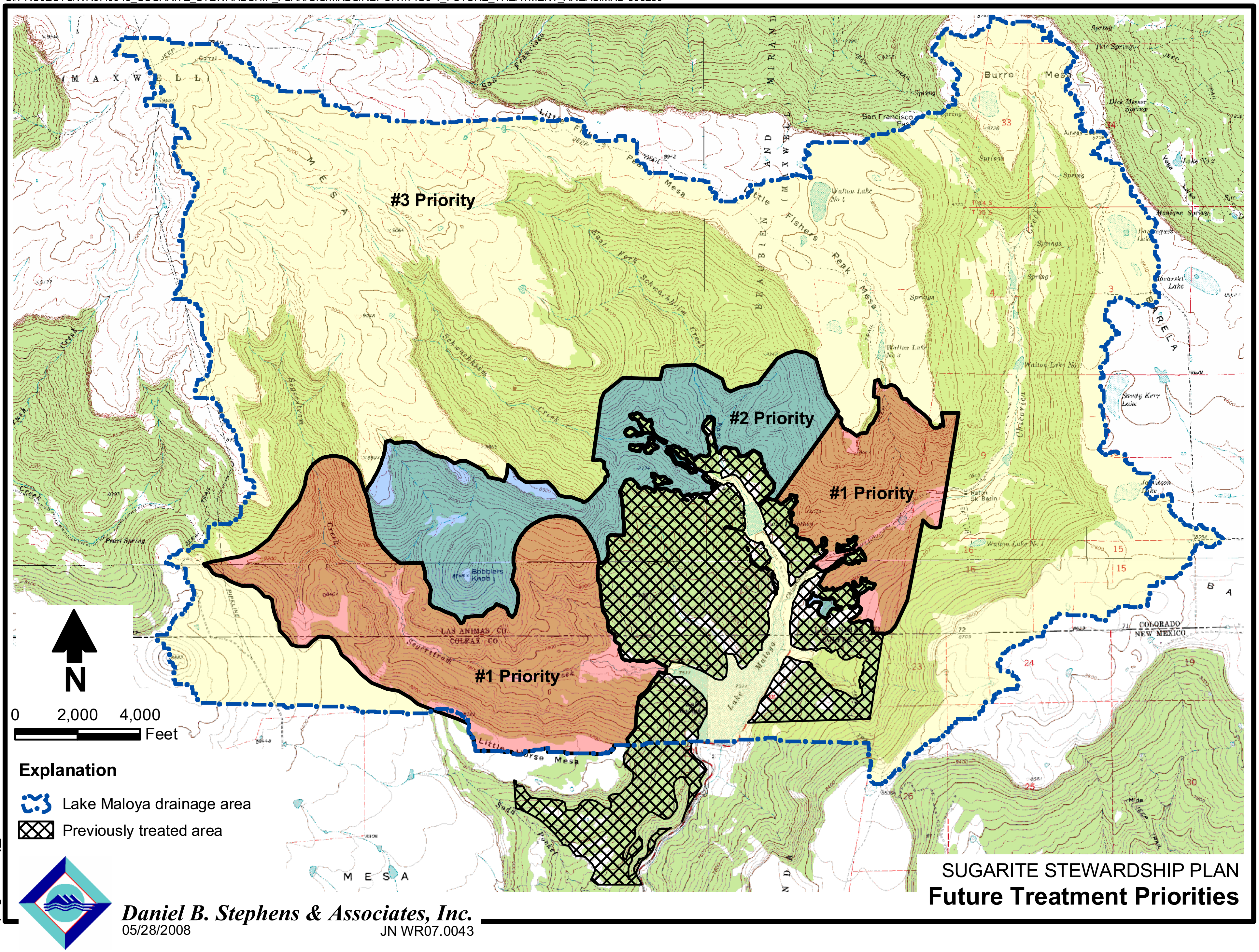

Figure 6-1

occupy higher elevations with moister conditions, or grow on steep slopes. Although these have a lower treatment priority, some restoration in these other communities is needed as well.

The remainder of this section presents prescription recommendations for a series of forest traits that can be directly treated: density, size, and heterogeneity. Other recommendations are made for traits that are, in general, indirect results of direct treatments, such as canopy cover, basal area, and understory cover. Although these are not directly addressed by treatment, these traits must be monitored in order to fine tune prescriptions and ensure that restoration objectives are actually being met.

Tree density is used as a controlling aspect of prescriptions. Fire suppression over the past century has allowed many more trees to establish, often in thickets of suppressed small trees that can convey fire into the forest canopy. Removing these small trees changes the vertical potential for fire sweeping through the forest. Thinning is essentially a replacement for a century of low-intensity fires.

Forest traits that result from changing tree density, such as canopy cover and basal area, will vary depending on the kinds of trees that are cut. For example, the degree of change in the continuity of forest canopy cover will differ depending on the size of the trees removed. Trees removed at one site may have occupied a significant part of the overstory canopy, and canopy cover will be significantly reduced, whereas trees removed at another site may be short, in which case canopy cover will change minimally. In the first instance, lower density values would reduce the risk of horizontal spread of crown fire in the canopy; in the second instance, it would not.

Overstory tree canopy cover is an important factor in the horizontal movement of fire through the forest. Thinning disrupts the continuity of tree crowns, thereby lowering the ability of trees to conduct crown fire. Historical canopy cover was variable in the region, from around 20 percent in the most open stands of ponderosa pine woodland, to up to 50 or 60 percent or more. Aside from fire concerns, there are wildlife considerations, since some wildlife need denser patches of cover. For example, prescriptions for canopy cover in portions of the forest where northern goshawk habitat may be found recommend 60 percent canopy cover or more for limited patches. Canopy cover in mixed-conifer forests was historically greater than in ponderosa pine woodlands, but the typical extent of the coverage is unclear.

In general, canopy cover values will be determined by prescribed density values. However, canopy cover should be varied across the watershed. This should be accomplished when trees are thinned into a pattern of clumps and small openings. Canopy cover should range from approximately 30 percent to 50 percent, with some areas of higher cover values (up to 80 percent) for wildlife. Ponderosa pine woodlands canopy cover should fall at the lower end of the range and mixed-conifer forest at the higher end of the range.

Historically, ponderosa pine and xeric mixed-conifer forests were all-age forests. In many ponderosa pine forests today, the balance of small and tall trees is skewed, with many small trees and few large trees. Thinning young and small trees should even out that balance. In contrast, higher elevation forests, such as aspen, mesic mixed-conifer, and spruce fir, often regenerate after fire, producing a more even-age structure.

In addition to creating clumps of trees, small areas of the landscape should be left unthinned, to offer structural heterogeneity, an assured area of regeneration classes, temporary dense habitat for wildlife, a seed source for native grasses and forbs, and visual variability.

General recommendations for ponderosa pine woodlands and xeric mixed-conifer forests are:

- On-the-ground thinning choices should take advantage of existing forest structures, such as large trees, group structures, and canopies.

- While on-the-ground thinning choices should follow average density prescriptions across the landscape, some variation in forest structure—that is, a range of densities and clumpiness over the landscape—is desirable.

- In general, all large trees over 16 inches dbh should be protected.

- Small trees growing under forest and woodland canopies should be aggressively thinned.

6.1 Ponderosa Pine Woodlands Prescription

Thinning to a residual density range of 50 to 70, or more rarely 80, adult trees per acre is recommended for ponderosa pine woodlands. Removing all trees smaller than 12 inches dbh will usually accomplish this target density. Visible clumps of trees and small openings can be created if there is a flexible approach to thinning. It is recommended that some small clumps of seedlings or saplings, several clumps per acre when available, be left in order to retain some variability in age structure. The mortality rate for these seedlings and sapling clumps will be high from a prescribed burn, so it is important that some survive the thinning effort.

Specific prescription recommendations for ponderosa pine woodlands are:

- In predominantly ponderosa pine overstory stands, mainly on west- and south-facing slopes, between 50 and 70, or more rarely 80, adult trees per acre should be left uncut.

- In many areas of ponderosa pine, the vast majority of the trees are so small that thinning to 50 to 70 of the largest trees per acre would leave only small and widely spaced trees standing. In areas where the vast majority of trees are less than 6 inches dbh, another 20 of these small trees should be preserved per acre, in small groups of around 10 trees.

- Trees in forest and woodland stands larger than 16 inches dbh should not be cut.

- Trees with old-growth features (e.g., yellow bark, large drooping limbs, twisted trunks, flattened tops) should be left uncut regardless of size.

- Basal area values should generally be no lower than 50 square feet per acre.

- Thinning treatments should strive to create a mosaic of clumps of denser groups of trees surrounded by sparser areas. Thinning should not result in a homogeneous, evenly spaced tree pattern.

- The thinning should not only lower the density of small trees, but also raise the canopy height of the remaining trees; this will be achieved by removing small trees, not by removing limbs from remaining trees.

- Thinning treatments may be conducted both by machinery and hand cutting crews, depending on topography, density, and vegetation type.

- A small proportion of the woodland should be left unthinned, in small areas. In a 100-acre area four areas of around 1 to 2 acres each may be left unthinned.

- Stands of ponderosa pine trees growing in meadows adjacent to streams should be cut, including all those larger than 12 inches dbh.

- Two to four of the largest ponderosa pine snags per acre should be left uncut. Ideally these snags would be large, greater than 18 inches dbh and greater than 20 feet tall. Snags should not be created, however, when snag density is low, as mortality of large trees from burns or insect infestations is relatively high in restored forests.

- The use of a masticating machine is recommended because of its low impact on soils and the disposition of fuels into chunks of varying size.

- In general, slash remaining after treatment by a masticating machine should be left scattered where it lies to rot or be burned in a prescribed fire. If for any reason slash is piled, it should be left to decompose for wildlife use.

6.2 Mixed-Conifer Forest Prescription

Mixed-conifer forests in the watershed vary in stand condition across a moisture gradient. For the purposes of developing a prescription, mixed-conifer forest is treated as two forest types, reflecting the FRCC description: (1) the mesic (or moist) mixed-conifer forest occupying the uppermost canyon slopes and high tributary valleys and (2) the xeric (or dry) to mesic mixed-conifer forests occupying the north- and east-facing lower slopes and protected valleys near Lake Maloya.

Mesic mixed-conifer forest growing on the uppermost slopes and valleys should not be thinned. These moist stands presumably experienced fires on a longer return interval and currently present a lower crown fire risk than forests on the lower slopes. Only in the case of a severe and persistent drought should they be considered for treatment. However, the extreme slope that many of these stands occupy would likely prohibit treatment even then.

Fire burned in xeric mixed-conifer forest historically, but not as often as in drier, warmer ponderosa pine woodlands. Studies of the historical fire return interval in the Santa Fe watershed xeric mixed-conifer forests, for example, show a return interval of around every 30 to 40 years. This interval would reflect a low-intensity kind of fire, since more time is required to produce the fuels that would support a crown fire. Residual densities can remain higher than in ponderosa pine woodlands, but a somewhat open stand, without completely continuous canopy, is recommended. Higher-elevation mixed-conifer forests have longer fire intervals, and densities increase and patchiness decreases with elevation for these mixed-conifer forests.

Some xeric mixed-conifer stands in the Sugarite watershed were observed on sites that exhibit slope slumping where soils are saturated. Thinning these areas is not recommended, since the removal of trees, with their stabilizing roots, may intensify the tendency for soils to slump. These areas should not be thinned in any part of the watershed, but may be treated as groups of denser trees isolated by sparser stands.

Mixed-conifer forests historically had mixed fire intensities, that is, a combination of low-intensity fire with some patches of high-intensity fire. Because of this variability of fire intensity, mixed-conifer stands should have considerable heterogeneity in density and species composition across the landscape.

Specific prescription recommendations for the xeric mixed-conifer stands on the lower slopes near Lake Maloya are:

- In mixed-conifer stands of ponderosa pine, Douglas fir, and white fir, mainly on north- and east-facing slopes and directly above ponderosa pine-dominated stands, approximately 70 to 90 trees per acre should be left uncut.

- Trees larger than 16 inches dbh should not be cut.

- In many ponderosa pine and mixed-conifer stands, the vast majority of the trees are so small that leaving 70 to 90 of the largest trees per acre would leave only small and widely spaced trees standing. In areas where the vast majority of trees are less than 6 inches in diameter, another 20 of these small trees per acre should be preserved, in small clumps of 8 to 15 trees.

- In many stands of dry mixed-conifer forest, fire suppression has allowed an overabundance of fire-sensitive trees such as white fir or spruce to dominate as young trees in the understory; these young trees should be cut.

- Thinning treatment should strive to create a mosaic of clumps of denser groups of trees surrounded by sparser areas. Thinning should not result in a homogeneous, evenly spaced tree pattern.

- Mixed-conifer stands on saturated slopes should not be thinned with machinery due to the impact on wet soils. In the wettest places on such slopes, for example, near springs or seeps, no trees should be removed.

- Three to five of the largest ponderosa pine, white fir, or Douglas fir snags per acre will be left uncut. Ideally these snags would be large, greater than 18 inches dbh and greater than 20 feet tall. Snags should not be created, however, even when snag density is low.

- A small proportion of the forest may be left unthinned, in small areas. Four areas of around 1 to 2 acres each may be left unthinned in a 100-acre area.

6.3 Aspen Stand Prescription

Aspen trees do not offer a significant fire danger in the watershed because they are deciduous and lack the potent set of chemicals that make conifer trees so flammable. Moreover, the aspen groves in the watershed tend to occupy the wettest sites, on or adjacent to the banks of streams and at higher elevations. These stands offer low fire threat and do not generally need treatment. They typically occur along streams or in patches amidst similarly low-fire-threat mesic mixed-conifer stands.

Specific prescription recommendations for aspen stands are:

- During prolonged drought, in aspen stands with very high dead and down fuel loads, pile and burn logs under wet and cool conditions.

- If there is a desire to encourage regeneration in fully mature aspen stands, pile aspen logs in a fence around a stand to create an exclosure that allows aspen regeneration to be protected from wildlife browsing. If elk are common in the area, the fence should be piled to a height of 10 feet.

6.4 Gambel Oak Community Prescriptions

Each of the three oak communities described in Section 4.1.4 contribute to a flammable community, and each requires its own prescription, as described in Sections 6.4.1 through 6.4.3.

6.4.1 Oak Shrublands

Under natural conditions oak chaparral communities burn regularly, when enough biomass is on the ground and weather conditions are conducive. Oak shrublands in the watershed present the most difficult challenge for treatment, because of the large homogeneous swaths of oak shrubland and because of the speed of their recovery, particularly Gambel oak, from disturbance such as crushing or burning. The management of oak shrublands for the reduction of fire risk is therefore a difficult case.

One option for long-term treatment is the creation of a mosaic of oak thickets of different ages, and thus different densities and biomass. This could be accomplished by “black-lining” patches of oak thicket, that is, by creating a 5- to 10-foot burned strip around an area of, for example, 10 to 30 acres. This allows a safer prescribed burn of the patch of oak thicket within the black-line during cool and wet conditions. Younger thickets of oak have lower levels of biomass, particularly of dead biomass, and are therefore less flammable. The creation of a patchwork area, or mosaic, of different age and densities would mean that a wildfire burning across the entire landscape would be slowed at patches of lower biomass, allowing fire control efforts to gain some advantage.

Prescribed burning in oak shrubland has clear risks. Crushing would achieve a similar effect to prescribed burns, but machinery generally cannot operate on slopes greater than 40 percent and many oak thickets are on slopes steeper than this.

Another option is the creation of linear fire breaks through oak shrubland, either by burning or preferably crushing using a masticating machine, to slow the movement of a fire across the landscape. For example, linear fuel breaks could be created through the oak thickets that parallel the road at intervals up the slopes on either side of the Canyon.

Both black-lining and patch burning would need to be done under very safe climate conditions, that is, cool and moist or snowy conditions. Both approaches to treating dense oak thickets are expensive and must be done on an ongoing basis if fuel loads are to be reduced. Depending on the climate patterns and the rate of recovery of the oak, retreatments would most likely be required on more than a 5-year cycle. Repeated treatments over time would be required to reduce the vigor of the oak recovery response.

This kind of ephemeral treatment requires a commitment to repeated crushing or black-lining in order to make it worthwhile. Without frequent, repeated treatment, the shrubs may rebound more robustly than before. Careful consideration of the cost-benefit value of this treatment is thus advisable. One strategy may be to conduct oak shrub treatment strategically, in places where treatments will be of easy access and high value, for example, around campgrounds.

Specific prescription recommendations for oak shrublands are:

- Oak shrublands may be treated by creating patches or linear fuel breaks to produce zones of lower density or younger plants. The use of prescribed burn to accomplish this must be done with great care.

- Burning or crushing treatments should be conducted on a periodic cycle of 3 to 5 years.

6.4.2 Oaks in Forest and Woodland Understory

Shrubby oaks growing beneath both ponderosa pine woodlands and mixed-conifer forests are capable of carrying fire into the forest canopies. Treatment of these communities should sufficiently disrupt shrub continuity. It is expected that where machines are operating, much of this material will be crushed by the movements of the machine. While intentional crushing of oaks to check fire spread may not be efficient, since oaks can rapidly resprout and replace their flammable biomass, crushing tall oak shrubs directly beneath large, old canopy trees may be one instance where oak crushing is worthwhile.

6.4.3 Oak Groves

Oak groves should generally be protected rather than cut or thinned. Such groves help stabilize soils near the streams and maintain understory richness. Patches of larger oak trees are often around 30 to 50 feet across and should be left intact.

Specific prescription recommendations for oak groves are:

- Groves of adult oak trees should be left untreated. Current densities of oak trees should be maintained in watershed forests during restoration.

- Tall oak groves growing immediately under large conifers should be removed.

- A buffer of between 12 to 15 feet should be left between these oak islands and other woody vegetation.

6.5 Understory Grass/Forb Communities Prescription

Understory plant communities usually respond very well to overstory thinning treatments. Removal of trees causes increased sun and available moisture on the forest floor, allowing understory plants to increase in abundance, cover, and species numbers. Seeding, if done, should use locally collected native seeds. Seeding the restoration site with commercial seed mixes is not recommended because of the high likelihood of contamination with non-native invasive grass and forb species. Cheatgrass seeds, in particular, are commonly found in such mixes. There are generally sufficient native grass and forb seeds in adjacent untreated forest to repopulate the restored site.

Specific prescription recommendations for grass and forb understory communities are:

- The use of commercial seed mixes to reseed restored communities is not recommended.

- If seeding is deemed necessary, for example, on areas with severe impacts from use of machinery or on access roads created by treatment, seed should be collected from untreated areas within the watershed.

- If possible, and when seeded areas are small, seeds should be raked in lightly, which will double the germination rate.

- Small amounts of slash should be left scattered on the ground to provide safe sites for native plant germination and establishment.

6.6 Landscape Considerations

6.6.1 Prescription for Fuel Breaks

Fuel breaks, strategically located throughout the forest, can increase the ability of a fire-suppression effort to manage a high-intensity wildfire. Fuel breaks are strips of forest thinned to a lower density than surrounding treated forest stands. Under extreme weather conditions, such as the very hot, dry, and windy conditions that can prevail (albeit rarely) in New Mexico in spring, high-intensity fire can move through tree crowns even in treated forest stands. Fuel breaks are invaluable tools for lowering the risk of the spread of crown fire within treated stands, and even more so, between treated and untreated stands. Locations of fuel breaks should thus be developed as the various treatment projects are completed. The most effective placement of fuel breaks can be adaptively chosen as the relationship between project areas becomes clear. Specific prescription recommendations for fuel breaks include:

- Fuels break widths should range from 50 to 150 feet depending on the perceived degree of danger from rapidly moving high-intensity fire; for example, a wider fuel break may be required above steep slopes than on flat terrain.

- Trees should be thinned to a density approximately half that recommended for the forest type. For example, density of fuel breaks in ponderosa pine stands should range from around 25 to 30 trees per acre. Density of fuel breaks in mixed-conifer stands should range from around 30 to 45 trees per acre.

- Fuel breaks should be strategically placed in the landscape to slow the spread of high-intensity fire. High priority locations for fuel breaks include ridges, boundaries between projects, and boundaries -between treated and untreated forest stands.

- Fuel breaks should be cleared of ground fuels, such as slash piles.

6.6.2 Timing of Treatments

The season of treatment should be carefully chosen to not conflict with high-ignition periods, high rainfall periods, or migratory bird breeding season. Autumn or early winter is an optimal time to conduct thinning treatments. The long spring season is unsuitable for two reasons: (1) melting snow keeps soils saturated and elevates the risk of damage to soils, and (2) treatments should not be timed to take place during migratory bird breeding season, from March 1 to July 15. Early summer is the pre-monsoonal dry season in northern New Mexico, when there is an elevated risk of treatment activities igniting a fire accidentally. Later in the summer, the monsoon rains wet the soil and increase the potential for damage to soils and understories.

Autumn, beginning around the first of September, and early winter, before the snows are deep, are good seasons for treatment because the soils and understories are least likely to be damaged. Even better conditions are in place when soils are frozen. Treatments should continue in winter as long as possible. If there is not a sufficient amount of time in autumn that does not conflict with hunting seasons, or if hunting cannot be restricted during treatment times on treatment sites, then early summer appears to be another option. For a short period of time in June, prior to the monsoon season, soils are relatively dry, but extreme care must be taken at this time of year to avoid ignition of dry fuels.

6.6.3 Landscape Heterogeneity Prescription

Natural ecosystems display a great deal of variation across the landscape, and on-the-ground treatment efforts should remain sensitive to and adapt to such natural variation. For example, groves of mid-sized adult oaks vary in size but form recognizable patches in the forest. The dense grove can be preserved if adjacent areas are slightly lower in density. Incorporating variable thinning rates across a site can reduce the risk of crown-fire by breaking up fuel continuity. Implementation of prescriptions should be flexible enough to consider treatment objectives—for example the need for heterogeneity, preservation of large trees, reduction of ladder fuels, protection of soils and riparian communities, and so forth—as much as quantity recommendations.

Forest and woodland prescriptions mainly address adult tree densities. However, site heterogeneity is also served by leaving some younger trees—seedlings and saplings—after treatments. Southwestern conifer regeneration historically occurred in episodic pulses linked to favorable climate conditions. Restoration efforts should retain a proportion of the youngest cohorts to help jump-start an all-age structure. These youngest trees may be left in small patches in the understory.

6.6.4 Snag Prescription

Dead standing trees, or snags, are part of a functioning forest. In particular, large snags provide nest, roost, and den sites, as well as important food resources for birds, bats, and small mammals. Both birds and bats play a crucial role in keeping insect populations in check. The slowly decomposing wood of snags also returns nutrients to the soil. U.S. Forest Service standards for the Southwest call for retaining a minimum of two snags per acre of at least 18 inches dbh and at least 20 feet tall in ponderosa pine forests, and a minimum of three snags per acre of this size in mixed-conifer forests. In practice, many of the snags currently found in forests are much smaller and thus decay and fall more rapidly than larger snags. Recommendations for minimum sizes of snags can be made, but may not be currently possible considering the sizes of snags currently existing on the ground.

Dead boles (downed logs) lying on the ground are particularly vulnerable to prescribed fires, which can reduce snags by 20 percent land boles by 50 percent. Care should be taken to direct prescribed fire flames away from snags and large boles. Specific prescription recommendations for snags include:

- Large snags last longer and provide greater resources to wildlife and so are a priority for protection.

- Snags with broken tops are especially useful to wildlife and should be protected.

- In ponderosa pine woodlands, ponderosa pine and Gambel oak snags are a protection priority.

- In mixed-conifer forests, white fir, ponderosa pine, and Gambel oak snags are a protection priority.

- Snags are susceptible to prescribed burns, and if possible, care should be taken to protect snags during burns; one labor-intensive approach is to rake duff and branches away from the bases of large snags.

6.6.5 Invasive Herbaceous Species Prescription

While disturbed mid- and high-elevation western forests are not vulnerable to invading non-native tree species, they are vulnerable to invasive grass and forb species. Understory invasives can change soil chemistry in ways that damage the ability of native understory plants to recover and thrive. For example, some invasive non-native plants can absorb soil nutrients at a higher rate than native plants and come to dominate the understory. Some invasive plants also contain lower levels of nutrients for native grazing animals. Most importantly, invasive understory species can change the fire regime in ways that intensify the severity of fires and alter their periodicity.

Cheatgrass (*Bromus tectorum*) is an example of a non-native grass species that causes serious problems in Southwestern forests. The grass has strong dispersal and establishment abilities. While more common in lower-elevation forests, cheatgrass does spread to as much as 13,000 feet elevation. It is successful in establishing itself in disturbed communities, such as thinned and prescribed-burn sites. Cheatgrass is a fire-adapted species and not only survives and expands its populations when burned, but it burns hot, thereby supporting hotter and more frequent fires. In addition, cheatgrass generally out-competes other native grasses and forbs, reducing understory diversity and causing cascading negative consequences through insect and bird communities.

There are concerns that cheatgrass populations will expand significantly with forest restoration treatments. Despite a variety of methods used experimentally to reduce cheatgrass populations, only a few can be reliably recommended. Preventing the spread of cheatgrass and other non-native invasive plants is challenging.

Cheatgrass has often been introduced to post-burn sites as a contaminant in a reseeding mix. Collecting seeds from native species on adjacent untreated forest stands is safer and often more economical than using commercial native seed mixes. Removing small groups of invasive plant populations soon after fires can help native plants compete. Since the watershed provides a community water supply, the use of herbicides to control invasive non-native plants is inappropriate. Moreover, no herbicide is specific to invasive grasses. Pulling small populations of invasive non-native plants, however, has proven effective in reducing their spread. Prescribed burns in any season seem to be capable of stimulating the spread of cheatgrass, but a two- to five-year or so lag after a burn before cheatgrass gets strongly established provides some time to reduce populations. Specific prescription recommendations include:

- If possible, determine the locations of stands of invasive plants before a prescribed burn and reduce their populations before burning. A pretreatment inventory can help locate existing populations of cheatgrass.

- Take care to avoid the introduction of invasive non-native plants brought in on machinery; if possible, hose down equipment off-site before treatments.

- Conduct prescribed burns in wetter years to minimize the spread of invasive non-natives, which tend to be more competitive in drought conditions.

- Larger prescribed burns have a smaller perimeter to volume ratio than smaller burns and therefore minimize the spread of invasive species.

- Burn with cooler fires that tend to favor native understory species over cheatgrass, which responds better to hotter fires.

- Do not use herbicides to reduce invasive non-native plant species populations.

- Reseed with native grass species only if there are seed mixes that are free of contaminant weed seeds; an excellent source of seeds are those collected from adjacent forests, and even a small amount of seed can help reestablish the understory.

6.6.6 Wildlife Issues

The sudden reduction of tree density that results from restoration treatments can dramatically change the habitat for wildlife in relatively large areas. This impact can be mitigated by strategically leaving portions of the site untreated and otherwise protecting wildlife resources. Specific prescription recommendations include:

- Leave wildlife travel corridors and hiding habitat untreated along riparian zones and other difficult-to-treat areas.

- Leave one to two small patches per acre of untreated forest for temporary wildlife refuge.

- Preserve large snags and large downed logs; if possible, protect them from prescribed burns by lining or raking debris and needles from immediate surroundings.

- Leave a few piles of slash per acre in open areas.

Other recommendations for mitigating impacts to wildlife are discussed in Section 5.1.2.

6.6.7 Roads

Roads in the area serve three access functions: (1) for recreation access, (2) for fire suppression, and (3) for fuels reduction treatments. The number of roads in the watershed appears to be sufficient to serve these needs. Expanded public access via new roads would increase the potential for human ignition of wildfire. Should any access roads be created for treatment implementation, they should adhere to the following prescription recommendations:

- No new permanent roads should be constructed above Lake Maloya.

- Following treatment, access roads should be rehabilitated by spreading branches or chunks of wood on them.

- Because access roads located in steep places will be subject to erosion, along the steepest gradients logs should be placed on the slope contour in several places.

- If temporary roads are constructed for any purpose, road placement and draining (including culverts) must be designed to minimize the potential for head-cutting and erosion. All plans for temporary roads must be approved by the City of Raton.

6.6.8 Topography

Forest structure in southwestern forests is sensitive to local conditions, particularly to moisture conditions. Aspect, or the orientation of slopes to sun exposure, can also be a key factor in determining vegetation structure and forest type, especially at sites with hilly topography such as the Sugarite watershed. On the lower slopes around Lake Maloya, mixed-conifer forests may occur on north-facing slopes and ponderosa pine woodlands on south-facing slopes. Slopes that are moist or wet from springs and seeps are likely to support denser stands of any forest type. If possible, lower-density prescriptions should be implemented on more exposed aspects, and higher-density prescriptions on less exposed aspects, such as north- and east-facing slopes.

6.6.9 Upper Watershed Tributaries

The three main tributaries north of Lake Maloya—Schwachheim Creek, East Schwachheim Creek, and Chicorica Creek—form a large part of the forested watershed. Portions of these tributaries are privately owned. The forested slopes of these tributaries present an urgent fire risk and therefore, in the case of a crown fire, a danger to the water supply of Raton. To the extent possible, the land owners of these tributaries should be encouraged to develop and implement a similar fuels reduction program of thinning treatments and long-term management for a safe forest structure. Efforts will be most successful if all partners become involved in a collaborative process to protect the watershed.

6.6.10 Treatment Options

Machines that chunk trees into large and variable pieces rather than chipping trees into small and uniform pieces are commonly used in forest restoration and are recommended for the Sugarite Canyon restoration for a variety of reasons. Small chips, especially the thick layers resulting from chipping a large amount of biomass, tend to discourage the recovery of the grass-forb understory. In addition to creating the more desirable large, variable pieces, masticating machinery treats acreage rapidly and with a minimum of soil disturbance. However, machinery should be kept out of wet areas, especially meadows near streams, and smaller tributaries and wetlands. Meadows can be thinned when the soils are firm, either when frozen or dry.

In areas where machines cannot be used, forest patches can remain untreated if isolated by adjacent areas of low density. If there are compelling reasons to thin trees in areas that are difficult to access by machines, crews may use chainsaws to thin by hand. Slash can be piled into small slash piles and left to disintegrate. Areas near riparian zones, on slopes where soils are saturated, or on slopes greater than 40 percent can benefit from hand-cutting of trees. Slash from hand-thinning should be lopped and scattered, or if deeper than 2 feet, piled and burned in the coolest, wettest conditions possible. Specific prescription recommendations include:

- Preferably use masticating machines for treatments.
- If a prolonged drought intensifies threat of crown fire, consider using chain saws in certain situations, for example, in aspen stands or on slopes steeper than 40 percent.
- Implement thinning treatments on sensitive areas when soils are cold or frozen in order to minimize soil disturbance.

6.6.11 Prescription Flexibility to Climate Shifts

Climate shifts in the coming decades may bring important changes to southwestern forests and woodlands. The current drought, together with climate warming changes that appear to be already underway, will likely result in an increased incidence of fires, intensification of fire severity, increased insect outbreaks and tree mortality, and direct dieback along elevational gradients. These changes are not hypothetical, and the impacts can already be seen across the forest landscapes in the Southwest. For this reason, restoring historical or reference structural conditions to watershed forests may not be sufficient to bring back historical fire levels.

It is recommended that managers of the Sugarite Canyon watershed use ongoing monitoring information to observe changes in overall climate conditions and forest density, particularly crown continuity, to ensure that the forests and woodlands remain safe for low-intensity fire. If the severe drought is prolonged or the overall climate trends toward drier conditions, the prescribed tree densities in all forest types should be revisited and revised if necessary to protect the watershed from crown fire.

7. Long-Term Maintenance

The key to creating a fire-safe forest and protecting the water supply over the long term is to maintain low fuel levels. Without excessive fuels—especially ladder fuels comprised of thickets of young trees—crown fires will not be supported in ponderosa pine and mixed-conifer forests. The main challenge to management of the wildfire risk in Sugarite Canyon, therefore, is the continual regrowth of vegetation in the absence of periodic fires. Oak, in particular, will recover from thinning and crushing with great rapidity. Without long-term management, the densities of young oak, ponderosa pine, and other tree species will rebound on the order of a decade, and the threat of crown fires will rebound with them.

Thinning, either by masticating machinery or by hand, alters the fuel structure of the forest by changing live vertical fuels into dead horizontal fuels. And trees regenerate rapidly in these conifer forests. Unless there is a plan to maintain the watershed, regrowth on previously treated areas will eventually lead to a return to conditions similar to current ones.

Reducing dead and down fuels and keeping regenerating biomass low can be accomplished in two ways. Fuels can continue to be removed from the forest by thinning treatments, or the low-intensity fires that shaped the natural forest structure can be reestablished at intervals over time. While it is possible to do some maintenance of previously thinned areas through additional mechanical thinning, treatment of the Sugarite watershed is proceeding in an incremental manner, due to both funding and timing (i.e., treatments being primarily limited to the fall [Section 6.6.1]) constraints, and costs for retreating previously cleared areas need to be weighed against the relative benefit of treating new areas. A more cost-effective and ecologically beneficial method of maintaining conditions in the watershed is through prescribed fire.

The role of prescribed fire in the watershed is discussed in Section 7.1. Because the watershed provides the drinking water supply for the City of Raton, considerable caution must be used regarding any fire in the watershed; accordingly, Section 7.2 discusses precautions necessary to protect the watershed prior to introducing prescribed fire.

7.1 Post-Thinning Prescribed Burning in Sugarite Watershed

Maintenance burning can prevent the re-accumulation of biomass in treated forest stands to maintain the reduced risk of high intensity fire. Prescribed burning is less expensive than continued mechanical treatment, but more importantly, it restores the natural processes that made forests safe for fire in the past.

Nearly all the vegetation communities present on the lower slopes of the watershed above Lake Maloya, especially ponderosa pine stands, mixed-conifer stands, and oak stands, are adapted to a regime of frequent fires. In all three communities, fire has occurred frequently enough to remove large quantities of fuels on a regular basis, including small trees, seedlings and saplings, and dead and down surface fuels. In the Southwest, fires generally burned about every 2 to 20 years in ponderosa pine forests, every 20 to 40 years in mixed-conifer stands, and every 2 to 10 years in oak communities. Such frequent fires were generally relatively cool fires that burned on the forest floor. The single best indicator of restoration success in the watershed would be the return of periodic low-intensity fires, and the return of such “safe” fires is the only way to avoid the need for continuous mechanical treatment. Reestablishing natural fire intensity and frequency would therefore protect both the Sugarite watershed water supply and the integrity of the whole forest ecosystem.

The most important objective for any prescribed burn plan is that fuel loads, both live and dead, be maintained at levels that are appropriate to the forest type. Post-thinning fuels should be reduced in a timely way and with consideration of the spatial pattern of fuels on the landscape, in order to minimize the risk of a woody debris-fueled high-intensity fire. Regeneration of young trees begins immediately after thinning treatments, encouraged by the sunnier and less competitive conditions created by more open canopies.

To prevent a return to the kind of stand conditions that support a crown fire, prescribed fire should be reintroduced into thinned forests early and often. A study by Finney et al. (2005) found that while thinning treatments significantly reduced fire severity in ponderosa pine forests when the treatments occurred between 3 and 9 years before a wildfire, fire severity increased with time since the thinning treatment. The study also makes the case that it may take repeated prescribed burns before wildland fire use can play its desired role.

Prescribed burning needs to be introduced to a thinned forest in stages, to safely move stand conditions toward those that will allow naturally ignited, low-intensity fires to burn. A first step in reestablishing low-intensity fire to thinned stands would be the burning of piled dead and down woody fuels, if any are created during thinning treatments. Subsequent efforts may be able to use broadcast burning. For example, the second and third steps can be made using backing (moving against the wind) fires, after which heading (moving with the wind) fires can be used. Backing fire is used first to maximize fire control in what may be moderate to heavy horizontal surface fuels and ladder fuels. After this, fuels may be sufficiently reduced so that subsequent fire efforts can be heading fires, which are faster and cheaper than back-burns.

7.1.1 Prescribed Burning Intervals

Ideally, the long-term prescribed burn periodicity in the Sugarite watershed should be similar to the historical fire regime return interval. No reconstruction of fire frequency history in the various forest types have been conducted in Sugarite Canyon. However, a fire interval history has been reconstructed for the nearby Santa Fe watershed, where Balmat et al. (2005) found a mean fire interval in ponderosa pine forests of 8 years (from 1600 to 1850), with a maximum fire interval of 18 years and a minimum of 1 year. (The clock on the period of burn interval begins as soon as thinning treatments are complete in any particular area.)

Prescribed burning must be implemented when weather and fuel conditions are conducive to safe fires: dry enough to adequately burn the fuels, yet wet enough to prevent an escaped wildfire, and during suitable wind direction and smoke dispersal conditions. Burn-season weather conditions will affect the pace at which the burn schedule is accomplished. Individual dry years or a prolonged drought, when prescribed fires must be deferred, may significantly hamper the pace of burning. A specific burn schedule, therefore, must be flexible enough to allow more acres to be burned in suitable weather to make up for the lack of burning in unsuitably dry periods.

In order to accomplish a prescribed burn plan that mimics historical intervals, enough of the watershed must be burned each year on average so that all of the area is burned within that interval. For example, a maintenance burn plan may choose to burn every 6 years in ponderosa pine forest in order to keep fuels from getting to levels that would support a crown fire. That means that, on average, one-seventh of the area must be burned every year. This value is said to be “on average” because some years will not offer climate conditions that are suitable for burning (e.g., extremely dry and windy years). More than the apportioned acreage, then, must be burned in weather-appropriate years.

One concern of burning many acres in any one year is the issue of increasing runoff and sedimentation to Lake Maloya. Research results from elsewhere, however, show no large increases in sedimentation or ash-laden runoff after mechanical thinning, pile burning, or broadcast burning. A hydrologic analysis used for the Los Alamos watershed and the Cerro Grande fire has provided a useful methodology for assessing the potential impacts of fire treatments and for estimating the risk to water supplies if the treatments are not maintained over time (Kuyumjian, 2007). Loomis et al. (2003) suggest that the length of the prescribed fire burn interval corresponds to the amount of sediment produced; that is, shorter burn intervals produce less sediment. Based on predictions of sedimentation from this model, no standard is set for the maximum number of acres that can be burned if suitable conditions exist.

The long-term goal for restoring fire to the watershed would be to conduct prescribed burns for the entire treated area in the watershed at an interval that will prevent fuel accumulation, especially the establishment of thickets of young trees that increase the risk of crown fire. Eventually, natural fires that burn within acceptable intensity levels (i.e., low-intensity surface fires that do not rise into the canopy) can share the burden of fuel reduction together with prescribed burning.

7.1.2 Burn Seasonality

Choosing the best season is key in successful prescribed burning. It is crucial for safety to avoid burning during the natural fire season, that is, the late spring/early summer drought period. Burns in both spring and fall reduce fuels, kill small trees, and lower fuel loads, but fall burns are more effective, especially in reducing dead and down fuels. On the other hand, fall burns may cause a higher leave tree mortality.

Given these considerations, prescribed burning is probably best accomplished at three times of year: fall, winter, and during the monsoon season (Isakson, 2006) (although because of the drinking water supply in the watershed, monsoon season burns, when ash flow may be highest, may not be appropriate). Still, conditions vary depending on the climate, and burning can take place only when environmental conditions allow safe burning. Climate conditions are unstable in the spring, with the potential for sudden, high winds followed by a predictably dry and warm early summer period. There also tends to be an abrupt transition in spring from very snowy conditions, preventing an efficient burn, to risky dry conditions with unpredictable winds.

Understory plants in forests adapted to low-intensity fire recover quickly after prescribed fire. There is some evidence that the response of understory plants varies by burn season, but not enough information on post-prescribed fire understory recovery is yet available to clearly assess optimal burn seasons. However, evidence shows that fall burns can encourage the growth of exotic species, such as Dalmatian toadflax and cheatgrass (Abella and Covington, 2004). Cheatgrass, in particular, may alter the fire regime in ways that are damaging to native understory plants and shrubs. Monitoring to detect changes in the abundance of non-native invasive species could be focused on areas burned in the fall.

7.1.3 Prescription for Restoration of Low-Intensity Fire

Prescribed fire has been used extensively throughout the Southwest by the Forest Service, BLM, and others to maintain conditions that are not conducive to intense crown fires. Because the vegetation communities in the Sugarite watershed are adapted to low-intensity surface fires, prescribed burning offers advantages in terms of ecological health and affordability. It does present risks, however. The recent design for and implementation of a fuel reduction project in the large municipal watershed of the City of Santa Fe offers an example of the successful reintroduction of prescribed burning, both slash pile burning and broadcast burning, after thinning treatments by both hand crews and machinery.

Specific prescription recommendations for reintroducing low-intensity fire include:

- Introduce prescribed fire at a frequency that resembles the historical fire interval, in order to keep fuels low and prevent a crown fire.

- Conduct prescribed burns during the dormant season, to increase old tree survival.

- To increase survival of old trees, rake thick duff layers and branches away from the bases of large and old trees before prescribed burns if possible.

- Conduct prescribed burning when fuels moisture is high, to keep fire intensities low. Cool fires are particularly important for protecting adult oak trees.

- Reduce fuel load sufficiently to prevent prescribed fires from entering tree canopies.

- Avoid damage to the soil by keeping prescribed fire intensity low; avoid burning large slash piles.

- Do not burn slash within 15 feet of perennial streams.

- Place fuel breaks, when needed, on ridgetops above unthinned steep slopes or between large treated and untreated sites. Fuel breaks tend to make wildfires more manageable. Fuel breaks should have about 20 to 30 trees per acre, a canopy cover of 10 to 20 percent, and a width of about 100 feet.

- Prescribed burns should be conducted in specified units surrounded by fire lines; units of manageable size (e.g., 100 to 1,000 acres) should be burned at a time, depending on topography and conditions.

7.2 Prescribed Fire Precautions and Procedures

Fire is an uncertain tool, as has been seen in recent years when land managers have lost control of prescribed fires. Many of these events, including the Cerro Grande fire, have occurred when prescribed fires were implemented in dangerous seasons, such as late spring, when dry conditions and high winds are common. Prescribed fires in cool and wet conditions, such as late fall and winter, have proven to be safer, although more difficult to keep burning. However, no prescription can guarantee a perfectly safe burn.

Due to the sensitive nature of the City of Raton drinking water supply and the damage that could be done if prescribed fire is not contained, extra caution must be used in considering any use of fire in the Sugarite watershed. Precautions and procedures that are necessary prior to introducing prescribed fire in the watershed are as follows:

- Fire of any form (e.g., broadcast burning or burning of slash piles) can only be introduced with the full approval of the City of Raton Fire Marshall and City of Raton Commission.

- Prior to broadcast burning, sufficient treatment of the watershed needs to occur to ensure that the fire will not become a crown fire; of particular concern is making sure that the fire does not jump from treated to non-treated areas.

- Fire should only be introduced by land management agencies that are experienced in working with prescribed fires.

- Weather conditions must be ideal for burning to occur; the City of Raton Fire Marshall will have authority to make last-minute cancellations of burning if weather conditions change.

- Initial broadcast burning should be small-scale. Sediment traps should be installed immediately after the fire, and monitoring should be conducted to assess sediment movement and the potential impacts on Lake Maloya prior to initiating a larger-scale burn.

- A written plan must be submitted to the City that details the individuals that will oversee the fire, the location and timing of the fire, and precautions that are in place to ensure that the fire does not cause damage.

Ongoing discussions through the collaborators group can be used to provide educational material regarding prescribed fire and for determining when and how it can best be introduced into the watershed.

8. Monitoring and Adaptive Management

Restoration monitoring is the repeated measurement of ecological variables over time to determine how treatments have changed the forest system and how the forest changes over time after treatments are completed. Projects need monitoring to ensure that the two primary goals of the work are being met: (1) restoring forest ecosystem integrity and (2) lowering the likelihood of destructive crown fire and keeping it low over time. Monitoring also provides data relevant to other watershed goals, such as improvements to ecological integrity and wildlife habitat.

Monitoring is thus a critical component of a forest restoration program. It allows for evaluation to determine if forest restoration is proceeding as planned and it provides data needed to revise prescriptions (adaptive management) if early indicators suggest that a change is warranted. Monitoring and adaptive management considerations are discussed in Sections 8.1 and 8.2, respectively.

8.1 Monitoring

The partners involved in the collaborative process have begun monitoring many aspects of the watershed in an effort to assess the impacts that the thinning may have on the ecological health, water quality, and erosion. Ongoing monitoring studies include:

- Permanent vegetation plots (1/5 acre) established by State Forestry to monitor revegetation (by measuring density and species)
- Bird monitoring conducted by the Rocky Mountain Bird Observatory
- Bat survey conducted by Jennifer Frey of Frey Biological Research
- Small mammal survey conducted by Jennifer Frey and Zachary Schwenke of Frey Biological Research
- Red squirrel and Abert's squirrel survey conducted by students

- Butterfly survey conducted by Steve Cary, State Parks

- Pre-treatment wildlife surveys conducted by Jean-Luc Cartron

- Water quality measurements conducted on Segerstrom Creek by students under the supervision of Karen Orderman of Sugarite Canyon State Park

- Aquatic insect survey conducted by Jacob Jacobi, biologist for Sugarite Canyon State Park

- Weed survey conducted by George Cox, ecologist and botanist consultant for Sugarite Canyon State Park

- Water quality sampling conducted by DBS&A on three streams that feed Lake Maloya

A long-term post-treatment monitoring plan is essential for evaluating the success of forest restoration efforts in the upper Sugarite watershed. Vegetation communities are adapted to recover after disturbances, and the woody species in Sugarite Canyon, particularly oaks, are quick to recover. When conditions become open and sunny and competition is reduced, tree species will regenerate readily. Studies suggest that even ponderosa pine woodlands recover sufficiently to support a hot fire in 7 to 10 years. Long-range monitoring of vegetation communities is thus essential to track changes in forest density and structure that may reflect the return of dangerous levels of ladder and surface fuels. Monitoring of ecological parameters at permanent points on a regular schedule tracks the rate and abundance of regeneration so that an effective schedule of maintenance can be designed.

Monitoring can be greatly strengthened by sampling control sites in forest stands where no treatments are planned. Control data allow comparison between treated and untreated areas in order to determine if influences other than restoration are altering vegetation parameters. Climate trends, in particular, may be influential in driving change, such as regeneration and understory plant recovery. Using controls isolates the effect of the treatment and separates out local climate. Parameters should be sampled in an identical monitoring design in control plots.

The data from treated and control sites can then be analyzed separately and the values statistically compared to measure the impact of treatments.

The following core monitoring activities are proposed for the project:

- Use monitoring results to assess the effectiveness of restoration treatments and to adjust prescriptions in order to maximize treatment impact.

- Establish control plots to statistically compare pre- and post-treatment monitoring values.

- Conduct repeat monitoring at permanent locations marked with numbered stakes and identified using GPS.

- Plan for long-term monitoring at longer intervals.

Eight monitoring parameters are recommended for measuring the response of forests to restoration treatments in the watershed:

- Photo points
- Live tree, seedling, and sapling density
- Tree size
- Basal area
- Snag density
- Understory plant composition and cover
- Tree canopy and cover
- Dead and down surface fuels

Monitoring recommendations for these and other parameters are summarized on Table 8-1. Specific monitoring protocol is provided in Appendix A.

Table 8-1. Summary of Forest Restoration Monitoring

Resource or Issue	Parameter	Location of Measurement	Method and Sampling Techniques	Timing / Frequency	Responsible Group	Indication of Possible Need to Change	Observations/Anecdotes
Fuels and forest vegetation							
Question/Issue: Are treatments effective in meeting the fuel reduction objectives by breaking up fuel continuity in the overstory and reducing the density of understory ladder fuels?							
Response of forest to treatments	Photo points	Treated and untreated areas in Ponderosa pine Mixed conifer Oak shrublands Aspen stands	16 points per forest type	Before and after treatments and every three years afterward, in July or August	New Mexico State Forestry	Visual lack of improvement in stand conditions	State Parks has established photo points
	Live tree, seedlings and sapling density	Treated and untreated areas in Ponderosa pine Mixed conifer Aspen stands	48 plots (30- by 30-foot square) per site, spaced 6 plots every 50 feet on 8 parallel 300-foot transects	Before and after treatments and every 5 years afterward, in July or August	New Mexico State Forestry	Values fall outside of range for forest type	Permanent vegetation plots have been established to monitor revegetation by State Forestry (1/5 of an acre in size where density and species are measured)
	Tree size structure	Treated and untreated areas in Ponderosa pine Mixed conifer	Measure diameter at breast height (dbh) of trees in 30- by 30-foot plots	Before and after treatments and every 5 years afterward in July or August	New Mexico State Forestry	Qualitative assessment, less similar to reference curve	
	Basal area	Treated and untreated areas in Ponderosa pine Mixed conifer	Measure base of each adult tree at 10 inches above ground in 30- by 30-foot plots	Before and after treatments and every 5 years afterward in July or August	New Mexico State Forestry	Value falls outside of range	
	Snag density	Treated and untreated areas in Ponderosa pine Mixed conifer Aspen stands	48 plots (30- by 30-foot square) per site, spaced 6 plots every 50 feet on 8 parallel 300-foot transects	Before and after treatments and every 5 years afterward in July or August	New Mexico State Forestry	Value falls outside of range	

Table 8-1. Summary of Forest Restoration Monitoring

Resource or Issue	Parameter	Location of Measurement	Method and Sampling Techniques	Timing / Frequency	Responsible Group	Indication of Possible Need to Change	Observations/Anecdotes
Fuels and forest vegetation (cont.)							
Question/Issue: Are treatments effective in meeting the fuel reduction objectives by breaking up fuel continuity in the overstory and reducing the density of understory ladder fuels? (cont.)							
Response of forest to treatments (cont.)	Understory composition and cover	Treated and untreated areas in Ponderosa pine Mixed conifer	Measure in 3- by 3-foot micro-plots located every 30 feet along each line transect.	Before and after treatments and every 3 years afterward in July or August	New Mexico State Forestry	No increase in species number or cover	
	Tree canopy and cover	Treated and untreated areas in Ponderosa pine Mixed conifer	Measure canopy values every 10 feet along the eight established 300-foot line transects using a densiometer	Before and after treatments and every 5 years afterward in July or August	New Mexico State Forestry	Percent cover falls outside prescription range	
	Dead and down surface fuel loading	Treated and untreated areas in Aspen stands	Measure on two short transects pivoting randomly off either end of 300-foot transects	Before and after treatments and every 5 years afterward in July or August	New Mexico State Forestry	Falls outside prescription range	
Wildlife habitat and diversity							
Question/Issue: Are treatments resulting in a loss of key habitat features such as large snags, down logs or riparian hardwood species, or reducing vegetative cover too much in the drainage bottoms/corridors? Are treatments resulting in an increase or decrease of existing aquatic insects, fish, beavers, birds or small mammals, which may indicate an improvement or decline in biological diversity?							
Key wildlife habitat features	Large snags	Each treated area	Count number of snags (>3-inch dbh) in 30- by 30-foot plots	Post-treatment	City of Raton	Fewer than 3 to 5 snags per acre in ponderosa pine forests	

Table 8-1. Summary of Forest Restoration Monitoring
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Resource or Issue	Parameter	Location of Measurement	Method and Sampling Techniques	Timing / Frequency	Responsible Group	Indication of Possible Need to Change	Observations/Anecdotes
Wildlife habitat and diversity (cont.)							
Question/Issue: Are treatments resulting in a loss of key habitat features such as large snags, down logs or riparian hardwood species, or reducing vegetative cover too much in the drainage bottoms/corridors? Are treatments resulting in an increase or decrease of existing aquatic insects, fish, beavers, birds or small mammals, which may indicate an improvement or decline in biological diversity? (cont.)							
Wildlife populations; biological diversity, species/ habitats of concern	Abundance and species richness of breeding birds, small mammals, elk, and deer	Each treated area	Survey by field biologist	Prior to treating new areas; repeat surveys in target areas from spring through summer	City of Raton	No indicators. Document change in wildlife in treated and untreated areas for database and knowledge.	• Bird monitoring by the Rocky Mountain Bird Observatory • Bat survey conducted by Jennifer Fry • Small mammal survey by Jennifer Fry • Red squirrel and Abert's squirrel survey conducted by students • Butterfly survey by Steve Cary, State Parks • Wildlife surveys by Jean-Luc Cartron
Heritage resources							
Question/Issue: Are treatments adversely affecting heritage resources such that we are not in compliance with Forest Plan standards and National Historic Preservation Act regulations?							
Site preservation	Heritage resource sites	Sites identified in pre-treatment archaeological surveys	Sampling 20% of known sites, identified during pre-treatment surveys; observations made by archaeologists	One time after thinning	City of Raton	Evidence of damage from thinning	

Table 8-1. Summary of Forest Restoration Monitoring
Page 4 of 4

Resource or Issue	Parameter	Location of Measurement	Method and Sampling Techniques	Timing / Frequency	Responsible Group	Indication of Possible Need to Change	Observations/Anecdotes
Water							
Question/Issue: Establish baseline data for use in future watershed preservation							
Water quality	Turbidity Total suspended solids	Segerstrom Creek Chicorica Creek Schwachheim Creek	Turbidity meter with automatic recording device	Record at 15-minute intervals, collect data every 3 months	City of Raton	Increase in turbidity to double the range observed in historical Lake Maloya data	Water quality samples collected in November 2007 and May 2008 at Segerstrom, Chicorica and Schwachheim Creeks
	Water chemistry (pH, temperature, dissolved oxygen Metals (ammonia, nitrate, nitrite, nitrogen, phosphorus Suspended and dissolved solids Major cations and anions Total organic carbon	Segerstrom Creek Chicorico Creek Schwachheim Creek	Water sample collection and laboratory analysis	Three times annually: spring, summer, fall	City of Raton	Increase above state standards	• Water quality measurements conducted on Segerstrom by 8th graders • Water quality samples collected in November 2007 and May 2008 at Segerstrom, Chicorica and Schwachheim Creeks
Peak stream-flows in side drainages	Streamflow	Gages on: Segerstrom Creek East side tributary Schwachheim Creek	Automatic recording equipment to measure and record streamflows.	15-minute intervals March through October	City of Raton	Peak in hydrograph increasing and causing severe erosion	Streamflow measured in November 2007 and May 2008 at Segerstrom, Chicorica and Schwachheim Creeks
	Precipitation	Lake Maloya Dam Raton filter plant	Precipitation gage	Daily	City of Raton		

Parameters that change more slowly (e.g., tree size) should be sampled at longer intervals; those that change rapidly (e.g., understory plant cover) or warrant greater attention (e.g., shrubs) should be monitored more frequently. Parameters should be sampled at approximately the same time of year. A suggested monitoring frequency is provided in Table 8-1.

Other monitoring to be conducted in the area includes wildlife and water quality monitoring.

- Initial wildlife monitoring has been conducted in the project area as part of the NEPA process. Ongoing wildlife monitoring efforts will include small mammal surveys, bird surveys, and large mammal surveys.

- Water quality monitoring will include collection of samples from Segerstrom Creek in the project area.

Target values for measured parameters can be a useful approach to assessing restoration success and for developing an adaptive management plan. The City of Boulder's Forest Ecosystem Management Plan (http://www.ci.boulder.co.us/openspace/xForest/forestmain.htm) discusses the development of specific restoration targets and statistical assessment of how well targets are being met. Target values for parameters such as density, canopy cover, and surface fuel loads are easier to develop for some forest types than for others, depending on the amount of historical information currently available for various forest types. Table 8-2 provides examples of general trends or values that can be modified for parameter target values.

8.2 Adaptive Management

Every restoration objective should be linked to a management response if monitoring results indicate that the goals of the objective were not met. In a process called adaptive management prescriptions and treatments can be altered if necessary. Adaptive management for long-term forest stability is needed so that the effort and funds originally expended are not wasted.

Adaptive management is a structured process of optimal decision-making in the face of uncertainty, with a goal of reducing the uncertainty through monitoring. Adaptive management allows for improvements in the prescriptions and plans for future forest restoration based on observed conditions or new data. For watershed restoration treatment that is being implemented incrementally, such as the Sugarite restoration, adaptive management allows for early treatments to provide data for improvements in subsequent treatments.

Table 8-2. Target Values for Monitoring Parameters

Variable	Desired Condition	Range or Acceptable Rate of Change
Photo points	Visual improvements in stand conditions	Qualitative analysis only
Live tree, seedling, and sapling density	Number of trees per acre Number of saplings per acre Number of seedlings per acre	Value falls within prescription range for forest type (e.g., 70 to 90 per acre for mixed-conifer)
Tree size	Graph of trees by stem size	Qualitative assessment, more similar to reference curve
Basal area	Minimum square feet (ft^2) per acre	Value falls within prescription range (e.g., 50 ft^2 per acre)
Density and average size of snags	Specified number of large snags per acre	Value falls within prescription range (e.g., 3 to 5 per acre for ponderosa pine woodland)
Understory composition and cover	Maintenance of or increase in number of native species Increased cover	No more than a specific percentage decrease from pre-treatment is acceptable. Any percentage increase in species number or cover is acceptable.
Tree canopy and cover	A range of cover	Percent cover falls within prescription range (e.g., 30 to 50%)
Non-native invasive plant species composition and cover	Minimized presence of non-native understory plants	Example metric could be no more than 20% increase over baseline. Decrease in number of species and density after 2 years.

Adaptive management will help evaluate and adjust future treatments based on future weather conditions. If the future weather pattern brings much dryer conditions, reduced tree densities may be required to protect the watershed.

The key components of adaptive management for the Sugarite watershed project are (1) defining thresholds for the monitoring parameters that indicate a need for change and (2) defining the process for addressing the need for change. The Sugarite collaborators group will meet annually to review the monitoring data collected by the responsible parties outlined in

Table 8-1 and assess the need for changes to treatment prescriptions, as described in Section 2.

Ideally, each party will actively review monitoring data throughout the year to identify any concerns that arise in a timely basis. More frequent meetings may be necessary should unforeseen issues occur (fire, beetle infestation, problems with water treatment, etc.). It shall be the responsibility of each collaborator to notify the group of such concerns.

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Appendix A

Monitoring Methods

Monitoring Methods

by Melissa Savage

1. Landscape photo points

1.1 Restoration objective

A series of repeated photographs taken from permanent points can provide general but valuable information about many responses of forest components to treatments. Photographs form a permanent visual record of the past and changing conditions over time. Features that can be broadly assessed from repeat photos include changing density of trees, invasive non-native plant species abundance, condition of grass and forb understory, tree mortality, rates of soil erosion, and the rate of snag fall. Although the assessment is visual, the results are sometimes arresting, and especially useful in communicating forest changes to the public.

1.2 Method

Photo points should be taken systematically, together with other sampling methods, at the end of line transects. At least 16 photo points should be photographed per forest type. For each point, permanently place a painted stake at the point, locate the point with a GPS device, and mark the location of each photo point on a topographic map. An identification card that states the site name, photo point number, and date should be taped to the stake during photography. Rephotographs should capture the identical view, from the same height, and in the same compass direction, at approximately the same season and time of day. Record the location of each photograph by number.

1.3 Analysis

Simple visual comparison of repeat photographs before and after treatment, and over years thereafter, is most useful. Descriptions of the field conditions seen in the photographs should be noted and stored with each photo in a notebook. Notable changes observed from one date to another can include tree density, new seedling establishment, understory plant recovery, soil erosion and invasive non-native plants.

2. Live adult tree, seedling and sapling density

2.1 Restoration objective

Restoration treatments should reduce the number of trees on average to a point where naturally occurring or prescribed fire can burn through a stand without ascending into the tree canopy. Target density depends not only on forest type, but also on site conditions such as elevation and available moisture. This monitoring parameter tracks the change in mean densities per acre of seedlings, saplings, and adult trees by species over time. A restoration objective would be adult densities similar to reference conditions. The objective for seedlings and saplings should be small numbers of each remaining in the forest after treatment. Potential tree density restoration targets could include: ponderosa pine woodland: 50 to 80 adult trees per acre; xeric mixed-conifer forest: 70 to 100 adult trees per acre. A target value for seedlings and saplings should be a low abundance per acre of each.

2.2 Method

Sample in 30 by 30 foot square plots on a total of 48 plots per site, spacing 6 plots every 50 feet on 8 parallel 300-foot transects. To measure tree density within the plot, count every adult tree, seedling, and sapling in the plot. Seedlings are woody trees of any diameter at breast height [dbh] that are less than 4.5 feet high. Saplings are woody trees taller than 4.5 feet high, but less than 3 inches dbh. Adult trees are woody trees taller than 4.5 feet high and greater than 3 inches dbh. Use a dbh tape to record the diameter of each adult tree.

2.3 Analysis

Calculate mean density values for adult trees, seedlings, and saplings per acre separately, as well as by species, and a total density value for all species together. Calculate the mean size per acre of adult trees by species, and a total density value for all species together.

3. Tree size structure

3.1 Restoration objective

The restoration objective for some forest types is to help nudge the forest toward an all-age structure by reducing an overabundance of small trees. Plotting the number of trees in all-age forest types in different size categories gives a reverse-J curve, with more small trees and fewer large trees. In many ponderosa pine forests today, the curve is skewed to the left, with an overabundance of small trees. Thinning should return this curve closer to a more moderate reverse-J shape, and in years to come, more trees will grow into the larger classes, balancing the curve.

A potential tree size restoration target will depend on existing sizes of trees on the site. Mean tree size would be expected to rise significantly, but may be constrained by the number of large trees currently on the site. If a bar graph of size classes is made, tree size distribution with fewer trees in smaller categories relative to larger trees indicates a favorable trend.

3.2 Method

Data on tree size can be collected at the same time that data on the density of living trees are collected in square plots. When using a dbh tape to measure adult trees, also record the diameter of each adult tree by species. The measurement should be taken at breast height, on the uphill side of the tree if there is a slope. Record measurements to the nearest half inch. If a tree has multiple stems, measure the largest stem.

3.3 Analysis

Calculate a mean size of adult trees for each species, and for all trees summed together.

Using the data for seedlings, saplings, and tree size, tally the numbers of individuals that fall within the following categories and size classes: seedlings, saplings, 3-6", 6-9", 9-12", 12-15", 15-18", 18-21" and greater than 21" dbh. Each value will need to be in the same units: the number of trees in a size class per acre. If there are many larger trees, the range of size categories can be wider, or there can be more classes.

Size can also be used to compare an existing tree size distribution with hypothetical reference tree size distribution. Put trees of a similar size range in categories: 3-6", 6-9", 9-12", 12-15", and so on. Make a bar graph of size classes, including seedlings and saplings in categories to the far left of the graph. Under reference conditions, a size-class distribution would look like an inverse-J curve, with more trees in the younger categories, but with trees in many size categories, including larger trees. Under current conditions, this inverse-J is very exaggerated, with far too many trees in the smallest [and youngest] classes. Visual comparison of these two graphs conveys most information, although it is possible to statistically analyze the difference. Graphs can be made of all tree species combined and for each species separately.

4. Tree basal area

4.1 Restoration objective

Tree basal area should be reduced to a value for each forest type that, when considered together with density values, represents a fire-safe stand structure. This monitoring parameter tracks the change in the size structure distribution over time.

4.2 Method

Sample in 30 by 30 foot square plots; data on tree basal area can be collected at the same time that data on tree density are collected. Basal area is measured by putting a dbh tape around the base of each adult tree at 10 inches above the ground surface. The measurement should be taken on the uphill side of the tree if there is a slope. Record measurements to the nearest half inch.

4.3 Analysis

Tree basal area is expressed in square feet per acre.

1. Convert the diameter of each tree to basal area. Use the formula πR^2 = basal area, that is 3.14 multiplied by the radius squared.

2. Add the basal area values of all trees of one species together; a total basal area per acre can be calculated as well by adding basal area values for all species together.
3. Convert the basal area from square inches to square feet (144 in^2 = 1 ft^2). Convert the basal area in the area sampled to basal area per acre.

5. Density and size of snags

5.1 Restoration objective

The restoration objective should be to maintain the number of snags, especially large diameter snags, to densities appropriate to a forest type. A potential restoration target for snag density depends on current conditions; restoration treatments cannot increase the number of snags, but should aim to avoid decreasing the number of snags, especially large snags. Current Forest Service minimum standards are 2 to 4 snags in ponderosa pine woodlands and 3 to 5 snags in mixed-conifer forests. Similarly, post-treatment snag size depends on current conditions, but average size should rise if snags are abundant enough on the ground to allow thinning of smaller snags.

5.2 Method

Sample in 30 by 30 foot square plots; data on tree snags can be collected at the same time that data on tree density are collected. In each plot, count all snags (standing dead trees >3” dbh) and record dbh using a dbh tape. The measurement of size should be taken on the uphill side of the tree on a slope.

5.3 Analysis

Density is a representation of the number of individuals per area. To calculate density of snags, follow directions for tree density above. Snags are not likely to be identifiable by species, so there will be only a single density number for snags. To calculate the average size of snags, add together all diameter measures and divide by the total number of snags.

6. Understory plant species composition and cover

6.1 Restoration objective

The restoration objective should be an increase the number of native species and the total percent cover of native grasses and forbs on the forest floor over time. It is difficult to quantify reference conditions for the grass/forb understory in most forest types. But, for example, it has been suggested that ponderosa pine woodlands can support between 300 to 1,200 pounds of understory biomass per acre. This monitoring parameter tracks the change in the number of grass and forb species present, and the relative amount of ground cover they provide. Reference cover ranged widely, from lows around 10% in closed canopy forest to over 75% in open canopy woodlands in some locations.

A potential understory composition restoration target is an increase or stable number of native species of grasses and forbs, and no increase in the number or proportion of non-native invasive species. A potential understory cover restoration target is an increased ground cover of grasses and forbs of as great a percentage as possible.

6.2 Method

Measure both plant species and cover in microplots located along each line transect. Each microplot is a 3 x 3 feet square; locate 10 microplots every 30 feet along one side of each transect line.

A complete list of native and non-native species found in microplots can be recorded; record native and non-native species separately; record grass and forb species separately. Alternatively, a limited plant species composition list can be made: select plant species of interest can be identified and the presence or absence of those species recorded. This works especially well for invasive non-native species. Recording the number of individuals of each species also allows an assessment of relative abundance of species.

For species composition and abundance, record each grass or forb species encountered by species name, and mark a tally for each individual counted after the species name.

Cover is an estimate of the amount of ground surface that is covered by live and dead plant foliage, and is closely related to the amount of production. Because of this, cover varies from season to season, so it is important to measure cover at the same time or times of year at each resampling.

In each microplot, the cover of all plants is estimated. Percent cover is defined as the percent of ground shaded by foliage of all understory plant parts considered together. Precise percent cover is not estimated in each plot. Instead, a rough estimate of percent of the ground covered by understory plants is estimated by cover categories. Use the following percent cover categories: 0 to 5%, 5 to 25%, 25 to 50%, 50 to 75%, 75 to 95% and 95 to 100%. Estimating cover is somewhat subjective, and there are several ways to minimize subjectivity. Cardboard cutouts of the various % categories can be cut out, and an observer can practice with these. To the extent possible, the same observer should collect data in subsequent resampling.

6.3 Analysis

Understory plant cover is expressed as a percent of ground covered.

1. Use the midpoint value for each percent cover category: 2.5, 15.0, 37.5, 62.5, 85.0 and 97.5. There will be one value for each microplot.
2. Add the midpoint values for all microplots together.
3. Divide the total sum of all the midpoint values by the number of microplots. This is the percent cover. Because it is a percent, there is no need to convert it to coverage per acre.

7. Tree canopy cover

7.1 Restoration objective

Restoration treatments should reduce the tree canopy cover to a point where naturally occurring or prescribed fire can burn through a stand has a low risk of spreading through continuous tree canopy. Target canopy cover depends not only on forest type, but also on site conditions such as elevation and available moisture. This monitoring parameter tracks the change in percent tree canopy cover over time.

7.2 Method

Estimation of percent canopy closure can be defined as the percent of ground shaded by overhead foliage, and measured using a densiometer. Sample canopy values every 10 feet along the eight established 300-foot line transects using a densiometer. This tool has a round concave or convex mirror with a grid marked on it. The grid divides the mirror into small squares. To measure canopy cover, stand at the beginning of a transect and hold the densiometer level in your hand at elbow height in front of you. The dark areas of canopy and the bright areas of sky reflect in the mirror. Imagine a box of four dots in each grid square, and count the number of times each of those dots is covered by canopy. A total of 96 values are possible at each point, 4 within each box. The method requires two people, one to hold the mirror and count out the values, and another to record them. Direction for the use of a densiometer and analysis of results are included with each instrument.

7.3 Analysis

Canopy cover is expressed as a percent of ground covered.

1. For each sample point, you will have a number between 0 and 96 which represents the number of "dots" that reflect canopy rather than open sky. To convert this into a number between 0% and 100%, multiply by 1.04. This number represents percent canopy for that sample point.
2. To find the average canopy cover for a site, add up the percent canopy figures for all the sampled points, and divide by the number of sampled points.

8. Shrub biomass

8.1 Restoration objective

Gambel oak shrublands are highly flammable, and ideally should be treated to reduce biomass. The recovery time of oak from treatments necessitates tracking the speed of replacement of oak biomass. This monitoring method is labor-intensive and should be used only in an area of experimental reduction biomass in Gambel oak shrublands by burning or crushing. Resampling should be on a frequent basis, for example, a one-year basis, to gauge whether treatments have a favorable cost-benefit ratio. A potential restoration target is the long-term reduction in shrub biomass by 50 to 80% or more.

8.2 Method

The method is widely used by the Forest Service, and therefore, yields values that can be compared with information from other shrub monitoring efforts.

1. Establish two plots at 16 sample points in the oak shrubland, one at each end of a 10-foot line transect. The transects should be located parallel t one another 200 feet apart.
2. Use a 1.86 foot rod to describe a circular plot [this is a 1/4-milacre subplot]. Sample shrub fuel loading by recording the species of the shrub, the percent shrub cover for all species live and dead, the percent cover of dead shrubs for all species, and the height from forest floor to the average shrub top. Cover should be estimated in percent cover ranges as follows: 0-5%, 6-20%, 21-40%, 41-60%, 61- 80%, 81-95%, and 96-100% cover. This estimation of cover is similar to the subjective estimation of understory plan cover. In general, there will be only Gambel oak shrubs sampled in plots. Both live and dead shrub should be included.
3. Estimate the percentage of shrubs that are dead, in the same cover classes as for percent cover.
4. Measure the height of the shrub layer in the plot, to as estimated average height.
5. Count the number of shrub stems in the plot, and tally according to species in the following size classes: 0-0.2 inch, 0.2-0.4 inch, 0.4-0.6 inch, 0.6-0.8 inch, 0.8-1.2 inch, 1.2-2.0 inches, over 2.0 inches. Stem diameter measurements should be made at the base of the stem but above the swelling of the root collar. A gauge with cutouts of the size classes can be used to facilitate this measurement.

8.3 Analysis

Estimate shrub fuel loading by calculating shrub weight using this formula:

1 Live shrub weight = 8.8185 Σ from i,j,k to N,2,7 respectively of ci $(s_k w_k)_{ij}$ / (2N).
2. Dead shrub weight = 8.8185 Σ from i,j,k to N,2,7 respectively of c_i D_{ij} $(s_k w_k)_{ij}$ / (2N)
3. Use these values:
   s = number of stems per diameter class
   w = weight per stem of foliage
   i = index for sample plots
   j = index for shrub subplots
   k = index for diameter size classes
   D = fraction of dead shrubs per subplot
   N = number of sample plots

For further explanation and assistance with analysis, see Brown, J.K., R.D. Oberheu, and C. M. Johnston. 1982. Handbook for inventorying surface fuels and biomass in the Interior West.

USDA Forest Service Intermountain Forest and Range Experimental Station, General Technical Report INT-129, Ogden, UT. Use weight per stem combined values for weights of different sizes of shrubs from Table 3.

9. Additional Monitoring Method: Surface Fuels Measurements

The untreated forests and woodlands of Sugarite Canyon are at risk from crown fire, but in general, such fires, if they occurred, would be fueled by the large amount of live standing biomass, primarily in the form of dense young trees. Generally speaking, there is not enough dead and down wood on the forest floor to make a significant contribution to fueling a crown fire.

The objective of monitoring surface fuels is to track the level of contribution of dead and down wood to ladder fuels, and thus to a crown fire. Acceptable target surface fuel levels, then, depend on the forest type and structure. An example of an acceptable surface fuel load in ponderosa pine woodland is about 16 tons per acre. The sampled level of 4 tons per acre in the ponderosa pine woodland to the east of Lake Maloya is well below a level of concern. More moist forest types, such as mixed-conifer forest, can tolerate higher levels of surface fuels. If surface fuels are to be tracked, target acceptable values should be developed for each site from information on similar sites.

The recommended monitoring method for surface fuels is Brown's Transects, a standard method used by the US Forest Service. Since the method, which relies on the abundance of woody debris in a series of size categories, is widely used, there are values from many similar forests to use as a comparison. The method is published in: Brown, J.K. 1974. Handbook for inventorying downed woody material. General Technical Report INT-16. Ogden, UT: USDA Forest Service, Intermountain Research Station, and available online at <http://www.fs.fed.us/rm/pubs_int/int_gtr016.pdf>. The description of the surface fuel method and its analysis is lengthy and not included here, since it is not expected that surface fuel monitoring will be a priority for vegetation communities in the watershed.