Button Rock Preserve

Forest Stewardship Plan

March 2017

City of Longmont

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Executive Summary

Button Rock Preserve
Forest Stewardship Plan Update
Executive Summary

<u>Overview</u>

Button Rock Preserve is owned and managed by the City of Longmont as a protected watershed for the City's municipal water supply, and as a passive recreation area. The approximately 3,000 acre Preserve is centered on North St. Vrain Creek four miles west of Lyons, Colorado in the foothills of the Front Range Mountains. The Preserve ranges in elevation from 6,000 feet at the eastern entrance to 7,500 feet atop Cook Mountain on the west side of the property.

The majority of the Preserve is forested by Ponderosa pine dominant stands. On higher elevation, north-facing, and wetter (mesic) sites the Ponderosa Pine forest also has a substantial Douglas fir component. Areas with Rocky Mountain Juniper are also common throughout the property.

North St. Vrain Creek flows for 4.25 miles from west to east through the middle of the property and contains two reservoirs, the large Ralph Price Reservoir in the center of the Preserve and small Longmont Reservoir at the eastern end. Ralph Price Reservoir, behind Button Rock Dam, provides 16,000 acre feet of water storage for the City while Longmont Reservoir is the point from which the City's drinking water is diverted from North St. Vrain Creek.

<u>Objectives</u>

This Forest Stewardship Plan establishes the following objectives for Button Rock Preserve:

Objective 1 - Water Quality: Button Rock Preserve's primary Objective shall be maintaining and operating the Preserve as a healthy and resilient landscape that provides a reliable, clean water supply to the people of Longmont.

Objective 2 – Natural Disturbance & Disaster Resiliency: The Button Rock Preserve landscape shall be maintained in a manner that is resilient to natural disturbances and disasters.

Objective 3 – Healthy Forest Matrix Ecosystem: The uplands of Button Rock Preserve shall be restored to and maintained as a healthy forest matrix that is functionally equivalent to a forest with an appropriate and functional fire regime.

Objective 4 – Recovered, Resilient, and Healthy River System: North St. Vrain Creek shall be managed as a functioning, healthy ecosystem.

Objective 5 – Meaningful Recreational Opportunities: Where not inconsistent with the above Objectives, Button Rock Preserve shall be managed as a public resource that can provide diverse low-impact recreation opportunities such as angling, hiking, and wildlife viewing.

Ponderosa Pine & Historic Changes

Like many Ponderosa Pine forests throughout the Colorado Front Range and Intermountain West, the forests of Button Rock Preserve are overgrown from a century of management without fire or harvesting. Prior to European settlement, these Ponderosa stands experienced regular fires from lightning strikes every few years. These ground fires would burn the surface fuels and most of the young ponderosa regeneration, but would not harm mature pines which are fire-adapted.

Without regular surface fires, more Ponderosa regeneration survived to become mature trees, which in turn has led to a much more densely stocked forest than existed historically. Fire intolerant species such as Douglas fir and Rocky Mountain Juniper have become much more prevalent than they were historically as well. The result of these structural changes is a forest that it is now much less resilient to fire. Instead of surface fires, more wildfires now result in catastrophic stand-replacing events that severely damage soils. Although some areas of the forest did historically experience high-severity stand replacing fire, it is now much more prevalent across the landscape and occurrences are no longer isolated between areas of low-severity surface fire.

Potential Drinking Water Impacts

While low-severity surface fires are not likely to adversely impact water quality, high-severity fire can lead to drastic changes in water quality and the timing of runoff after a fire. Areas that have experienced high severity fire do not have any surface litter to intercept runoff, and the soil itself develops water repellency (hydrophobicity). As a consequence, there is more runoff from a given storm over unprotected soil which results in much higher rates of erosion. This erosion can fill in reservoirs and affect other infrastructure, which is expensive to address.

Charcoal and ash from burned areas can also drastically change the water chemistry. Increased nutrient loads lead to algal blooms (eutrophication), and along with other compounds can dramatically increase the water treatment costs and still leave a bad taste in the water.

Forest Management to Date

In order to address these concerns associated with high severity wildfire, the City of Longmont developed a Forest Stewardship Plan in 2003 and initiated a forest restoration and wildfire mitigation program. Under the direction of this Forest Stewardship Plan, the City has received annual funding from the Colorado State Forest Service (CSFS) to carry out forest thinning prescriptions within Button Rock Preserve. Approximately 80 acres have been treated every year beginning in 2004. As a result, over 1,000 acres of forest in the Preserve have been treated to date. **This forest stewardship program has been successful in reducing forest densities across the Preserve and is a great foundation for continuing restoration and mitigation work**. Nevertheless, most forest stands are still more dense than the historic range of variability, and not all stands have been treated.

Updated Forest Inventory & Planning

The Colorado State Forest Service (CSFS) carried out an extensive forest inventory in the summer of 2016 which serves as the foundation of this updated Forest Stewardship Plan. Based on the data collected and additional information from the past decade of active management, CSFS delineated seventeen (17) forest management units (FMUs) in four regions of the Preserve. These regions are the "Front Country" on the eastern side of the Preserve, the "Back County" on the western side, the inaccessible but important "Southshore," and "Mullen Park." Updated treatment prescriptions were developed for each management unit. The table below shows the management priority and overview for each FMU.

FMU	Treatment Priority	Notes
FC 1	High	Includes area prioritized by CSFS. Directly impacts Longmont Reservoir and the municipal water supply.
FC 2	Moderate	Treated twice previously but still too densely stocked.
FC 3	High	Densely stocked and the subwatershed directly impacts Longmont Reservoir and the associated water supply. Areas that have not been previously treated may be difficult to operate in.
FC 4	Moderate	Large stand that has been previously treated but is still too dense.
FC 5	Low	Although it is adjacent to Longmont Reservoir the potential direct impacts are limited. Difficult to operate in.
FC 6	High (southern) & Low (northern)	Prioritized by CSFS on the flat, open, south side where it is adjacent to Hall Ranch. Steep north slopes are inoperable.
FC 7	Moderate	Previously treated but still overly dense.
FC 8	High	Surrounded by FC 1. May be difficult to operate in.
BC 1	Moderate	Remote but large FMU. Most has been previously treated but is still too dense.
BC 2	Moderate	Previously treated. Creates matrix with "borrow area" grasslands.
BC 3	Moderate	Large remote unit. Previously treated in part.
BC 4	High	Priority treatment identified by CSFS. Adjacent to Ralph Price Reservoir inlet. Good opportunity to extend landscape-scale fuel break created by Ralph Price Reservoir and grasslands.
BC 5	Moderate	In matrix with BC6. BC5 contains the denser portions of the matrix.
BC 6	Low	Relatively less dense, but large juniper component that could limit effectiveness of fuel break.
SS 1	Moderate	The Southshore unit has good potential for restoration and fire mitigation work, but is difficult to access and operate in. Subwatersheds have large potential impacts, but mostly from other land ownerships south of the Button Rock boundary. "Moderate" priority due to the inaccessibility and greater potential impact of projects on non-City of Longmont land.
MP 1	Low	Mullen Park is being treated in the winter of 2016-2017. Further prioritization depends largely on residual basal areas after treatment.
MP 2	Low	

In addition to FMU-specific prescriptions, general prescriptions were developed that apply across the Preserve. These general prescriptions ensure that wildlife habitat elements, legacy trees, and other important forest features are retained and enhanced across the landscape. The core of these general prescriptions is a methodology for creating a matrix of groups of trees, individual trees, and openings (meadows). It has been shown that the historic forest had this group-individual-opening structure, and that it is both more wildfire resilient and provides better habitat than a uniformly thinned stand.

Use of Prescription Fire

Prescribed fire, both in terms of burning slash piles and controlled broadcast burns, has the potential to reduce fuels in the forest more than mechanical treatments alone. Prescribed fire is also a cost effective way to maintain treatments in the long-term after the forest density has been reduced appropriately.

Prescribed fire has not been used as a tool by the City of Longmont to date, and there are justified concerns that fire has unacceptable risks if not associated with extensive, robust, and professional planning and management. Prescribed fire is recommended in this Forest Stewardship Plan, but only after extensive additional planning and with professional on-the-ground management. Where it is more economically feasible than mechanical removal of fuels, it is recommended that the City start with burning slash piles to remove fuels from mechanical treatments and consider controlled broadcast burning in the long term.

Collaborative Action

Button Rock Preserve is only a small part of the larger North St. Vrain watershed that ultimately affects our municipal water supply. It is therefore recommended that the City of Longmont work directly with the other major landowners in the watershed, Boulder County Parks and Open Space and the US Forest Service, to develop management strategies that will restore forests and increase wildfire resiliency within the greater watershed. These management strategies should in turn be informed by wildfire and erosion risk modeling that will allow us to identify the most critical areas for management treatments. This updated Forest Stewardship Plan includes two project areas prioritized by the CSFS to help begin this collaborative management program.

River Restoration

In addition to the forests of Button Rock Preserve, North St. Vrain Creek is a critical resource in need of restoration. North St. Vrain Creek was severely affected by the September 2013 floods. The river bed was scoured and most of the riparian plant community along the riverbanks was destroyed.

River restoration efforts are ongoing in Button Rock Preserve, including in-stream restoration and replanting of the native riparian corridor. A restoration project was implemented on the eastern end of the Preserve in March 2016 and another is scheduled for March 2017. These projects are intended to improve the channel for aquatic habitat as well as provide fish passage at barriers created during the floods. Riparian replanting is also underway, and it is recommended that a long term strategy for ongoing riparian restoration is implemented.

SECTION 1. Overview & Objectives

Button Rock Preserve is a protected watershed owned by the City of Longmont in Boulder County, Colorado. The Preserve is maintained primarily as a source watershed for the Longmont municipal water supply, but it is also managed to preserve natural resources and provide outdoor recreation in the foothills of the Front Range. The Preserve provides a unique opportunity to hike, view wildlife, rock climb, and fish. The Preserve dates to the early 1900s when Longmont Reservoir was built on North St. Vrain Creek to provide Longmont with a municipal water supply. In the 1960s the Preserve was expanded when Button Rock Dam was constructed to create Ralph Price Reservoir.

In 2003, a Forest Stewardship Plan was developed for the City of Longmont to guide the management of the nearly 3,000 acres of the preserve. This Forest Stewardship Plan is an update to the 2003 Forest Stewardship Plan. Since 2003, the City of Longmont has carried out a systematic forest restoration program across the Preserve, thinning roughly 80 acres a year. To date, nearly all of the accessible acreage north of North St. Vrain Creek in the Preserve has been treated with thinning at least once, and some areas have had a couple treatments. This plan includes a forest inventory that takes into account these thirteen years of management, and provides management prescriptions based on that inventory.

Additionally, North St. Vrain Creek experienced catastrophic flooding in September 2013. This updated plan incorporates the consequent landscape changes into the original Forest Stewardship Plan and expands the focus of management planning beyond the forest to include the river system, recreational considerations, emergency preparedness, and landscape resiliency.

1.1 Location and Climate

Button Rock Preserve is located four (4) miles west of Lyons, Colorado along North St. Vrain Creek in the foothills of the Front Range Mountains. The 3,000 acre Preserve ranges in elevation from 6,000 feet at the eastern entrance to nearly 7,500 feet atop Cook Mountain on the western end. The Preserve is centered on Ralph Price Reservoir at 6,400 feet.

The Colorado Front Range is bounded by the Great Plains to the east, higher elevation parklands to the west, and other mountain ranges within the Rocky Mountains to the north and south. Within a lateral distance of 20 miles the Front Range rises over a vertical mile from the plains to the continental divide, and is characterized by a wide variety of terrain. The Front Range historically had glaciers down to about the 8,000 foot level and consequently the geomorphology changes distinctly at that elevation. Above 8,000 feet the river valleys are broader and have the characteristic “U” shape of glacial valleys. Below 8,000 feet, including in Button Rock Preserve, the valleys are distinctly “V” shaped and confined. The geology is characterized by Precambrian granites and metamorphic rocks, with sedimentary rocks in the lower foothills. The granitic nature of the Preserve results in soils that are generally course-textured and shallow (Marr 1961).

In addition to being the dominant geographic feature, the Front Range Mountains are also the dominant climatic modifier of the region. The climate is generally cooler and wetter with elevation, resulting in a series of ecosystem bands striated by elevation. Below 6,000 feet, Ponderosa Pine is interspersed with the grasslands of the Great Plains. Above 6,000 feet in the lower montane ecosystem Ponderosa Pine is dominant, forming park-like stands on southerly slopes and denser stands with a Douglas fir component on northerly slopes. Above approximately 8,000 feet is the upper montane ecosystem, where Ponderosa Pine is less dominant as Lodgepole Pine increases in dominance (Marr 1961). Button Rock Preserve is solidly in the lower montane ecosystem, and specific forest characteristics are discussed in section 2.2. Within this general pattern there is also a wide variety of microclimatic differences over short distances that result from slope, aspect, and other factors. In Button Rock Preserve this results in a wide variety of stand types and densities within the general parameters of the lower montane ecosystem.

Precipitation along the Front Range is generally greatest in the spring months of April and May, followed by the summer monsoon season and a relatively dry winter. The figures on the following page show the mean temperatures in January and July, as well as the mean precipitation and humidity in the Front Range region (Hansen, Chronic, and Matelock 1978). The Front Range is also subject to strong westerly downslope winds, primarily in winter. These foehn or “chinook” winds are relatively warm and dry and can have a major effect on the climate (Marr 1961).

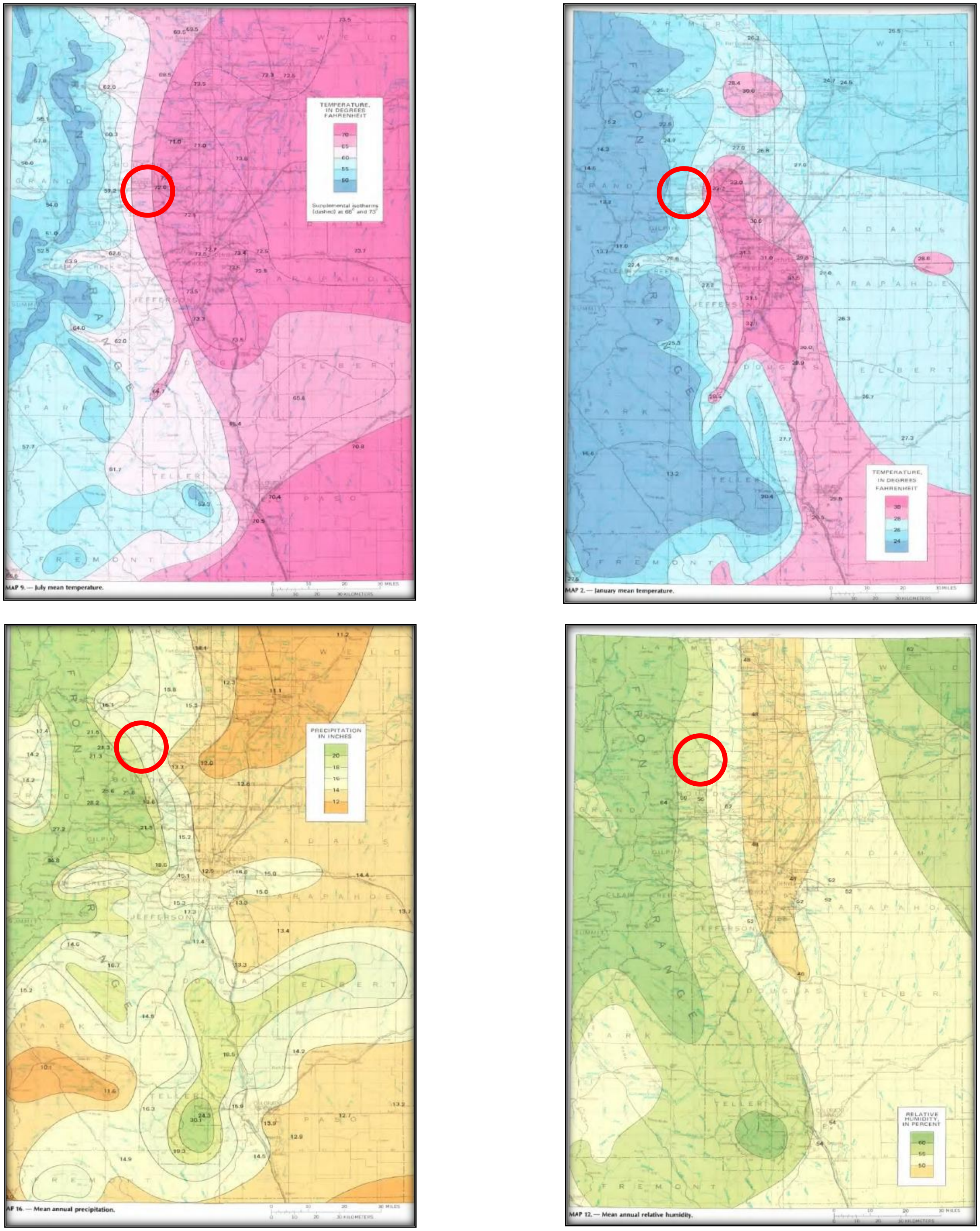


FIGURE 1.1 - *Mean July (top left) and January (top right) temperatures, annual precipitation (bottom left), and average annual relative humidity (bottom right) for the Front Range Region. Button Rock Preserve circled in red. From Hansen, Chronic, and Matelock 1978.*

1.2 Forestland in Button Rock Preserve

The 2003 Forest Stewardship Plan delineates twenty-two (22) Forest Management Units (FMUs) categorized into six Management Compartments. The FMUs average 110 acres for a total of 2,416 acres in forest management. FMUs are delineated based on access, natural delineations, aspect, and forest composition.

There are generally three major land cover types within Button Rock Preserve Forests. North facing aspects tend to wetter (mesic), densely stocked, and have a mixed conifer composition with Ponderosa Pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) dominant. All other forests are Ponderosa pine monodominant, tend to be more xeric, and have a wide range of stocking densities and canopy closure. Button Rock Preserve also contains a variety of meadows and grasslands with native and non-native grasses dominant depending on the site. The grasslands tend to form a matrix with the Ponderosa Pine forest. The largest of the grasslands occur in the "Borrows Area" where material was excavated in the 1960s to build Button Rock Dam, which was subsequently revegetated (mostly with non-native grasses).

Over thirteen years of active forest stewardship work has taken place in Button Rock Preserve, guided by the prescriptions included in the 2003 Forest Stewardship Plan. Roughly 80 acres have been thinned every year under partnership with the Colorado State Forest Service (CSFS), with approximately 1,000 acres treated to date. **The forest inventory and management prescriptions included herein take into account this decade of forest stewardship work, assess the impacts of the program, and build upon it.**

1.3 River & Reservoirs of Button Rock Preserve

Button Rock Preserve has a large riparian corridor along North St. Vrain Creek that contains a riparian forest, over two miles of stream habitat and two reservoirs, Ralph Price and Longmont, that provide lake habitat. These freshwater ecosystems were not considered in the original Forest Stewardship Plan, but are an integral part of the Button Rock Preserve Landscape and were severely affected by the floods of September 2013.

Construction on Ralph Price Reservoir was started in 1965 and completed in 1969. The reservoir has a storage capacity of 16,197 acre-feet and a lake surface area of 222 acres. Longmont Reservoir was constructed in 1912 to provide hydraulic head for the municipal water supply line, and has no useable storage capacity. Longmont Reservoir has a surface area of 3 acres.

North St. Vrain Creek experienced a major flood in September 2013 that scoured the streambed and removed the majority of the riparian plant corridor. Infrastructure was repaired after the flood, and river restoration efforts began in 2016 and are ongoing to ensure the river system is more quickly restored and maintains high quality habitats.

1.4 Objectives

Objective 1 - Water Quality: Button Rock Preserve's primary Objective shall be maintaining and operating the Preserve as a healthy and resilient landscape that provides a reliable, clean water supply to the people of Longmont. The landscape shall be particularly resilient to wildfire such that when a fire occurs on Button Rock Preserve it does not adversely affect the municipal water supply, and recovery from that type of catastrophic incident is as rapid as possible.

Objective 2 – Natural Disturbance & Disaster Resiliency: The Button Rock Preserve landscape shall be maintained in a manner that is resilient to natural disturbances and disasters. This includes resiliency to fire, flooding, pest infestations, and other disturbances. Safe zones, emergency egress, and emergency access routes to critical infrastructure shall be created and maintained.

Objective 3 – Healthy Forest Matrix Ecosystem: The uplands of Button Rock Preserve shall be restored to and maintained as a healthy forest matrix that is functionally equivalent to a forest with an appropriate and functional fire regime. The forest matrix shall be resistant and resilient to catastrophic wildfire, particularly large crown fires, and shall provide for heterogeneous habitat needs including open ponderosa-grassland savanna. The forest matrix shall actively contribute to the provision of clean water (Objective 1), and the provision of clean water shall be resilient in the face of wildfire.

Objective 4 – Recovered, Resilient, and Healthy River System: North St. Vrain Creek shall be managed as a functioning, healthy ecosystem. This ecosystem shall be resilient to future disturbance, particularly from floods and wildfire, and shall actively contribute to the provision of clean water (Objective 1).

Objective 5 – Meaningful Recreational Opportunities: Where not inconsistent with the above Objectives, Button Rock Preserve shall be managed as a public resource that can provide diverse low-impact recreation opportunities such as angling, hiking, and wildlife viewing. Recreation shall only include those activities normally associated with low-impact nature preserves and shall not include recreational or sports use such as organized games, non-pedestrian access of any kind, mechanized objects of any kind or landscape disturbing activities. Button Rock Preserve shall provide recreational access to those with disabilities where possible and consistent with this objective.

SECTION 2. Introduction

2.1. Management History

2.1.1 Land Use History

From at least the time when Aldo Leopold articulated his 'Land Ethic' in 1948 it has been understood that the history of how people have used a landscape effects the structure and function of the ecosystems that currently exists on that landscape (Brown et. al. 2005). It is therefore vital to have a sense of the land use history along the Colorado Front Range in general and Button Rock Preserve in particular in order to properly manage the Preserve and understand the context of historic ecosystem structure and process. While fully recreating the historic landscape is likely not feasible in most cases, or even advisable in some instances given modern land use constraints, it does provide an important guide for restoration (Brown, Agee, and Franklin 2004). Historic context is of particular importance when considering reference stream reaches, forest reference stands, or other ostensibly intact ecosystems used to guide restoration. These reference ecosystems have to be understood in the context of a place in time, and that they may not fully represent the complete picture of a reference ecosystem (Whol 2001).

<u>Colorado Front Range</u>

People have been affecting the landscape of the Front Range for over ten thousand years. Before European settlement, nomadic Native Americans used fire as a tool for herding game and possibly to improve grazing conditions. These intentional fires occurred on a temporal and spatial scale within the natural range of variability of the fire regime and therefore are not believed to have moved forests out of their historic stand structure and distribution. Natural fires were also very common from lightning strikes, and consequently this pre-settlement forest was characterized by broad heterogeneity in spatial and temporal forest structural patterns driven by fire and other natural disturbances (Hessburg, Agee, and Franklin 2005).

This natural disturbance pattern and consequent forest structure changed during the mining boom along the Front Range in the latter half of the 19th century. The mining boom catalyzed intensive logging for timber to build towns and infrastructure. Extensive fires were also set by miners to make ore more accessible (Hunter et. al. 2007). As a result of these activities, large legacy trees that date back to pre-settlement times are underrepresented on the landscape today. At the same time, grazing, logging, and urbanization all directly or indirectly lead to the exclusion of fire after that period of initial exploration for minerals (Hessburg, Agee, and Franklin 2005). Ultimately these changes in land use resulted in a forest structure that has much less of the temporal and spatial heterogeneity than the pre-European settlement landscape. Hessburg, Agee, and Franklin (2005) ultimately conclude that "it has taken more than a century for the conditions to develop that exist today, and at best, it may take several decades to make substantive and widespread improvements."

P.F. Hessburg et al. / Forest Ecology and Management 211 (2005) 117–139 121

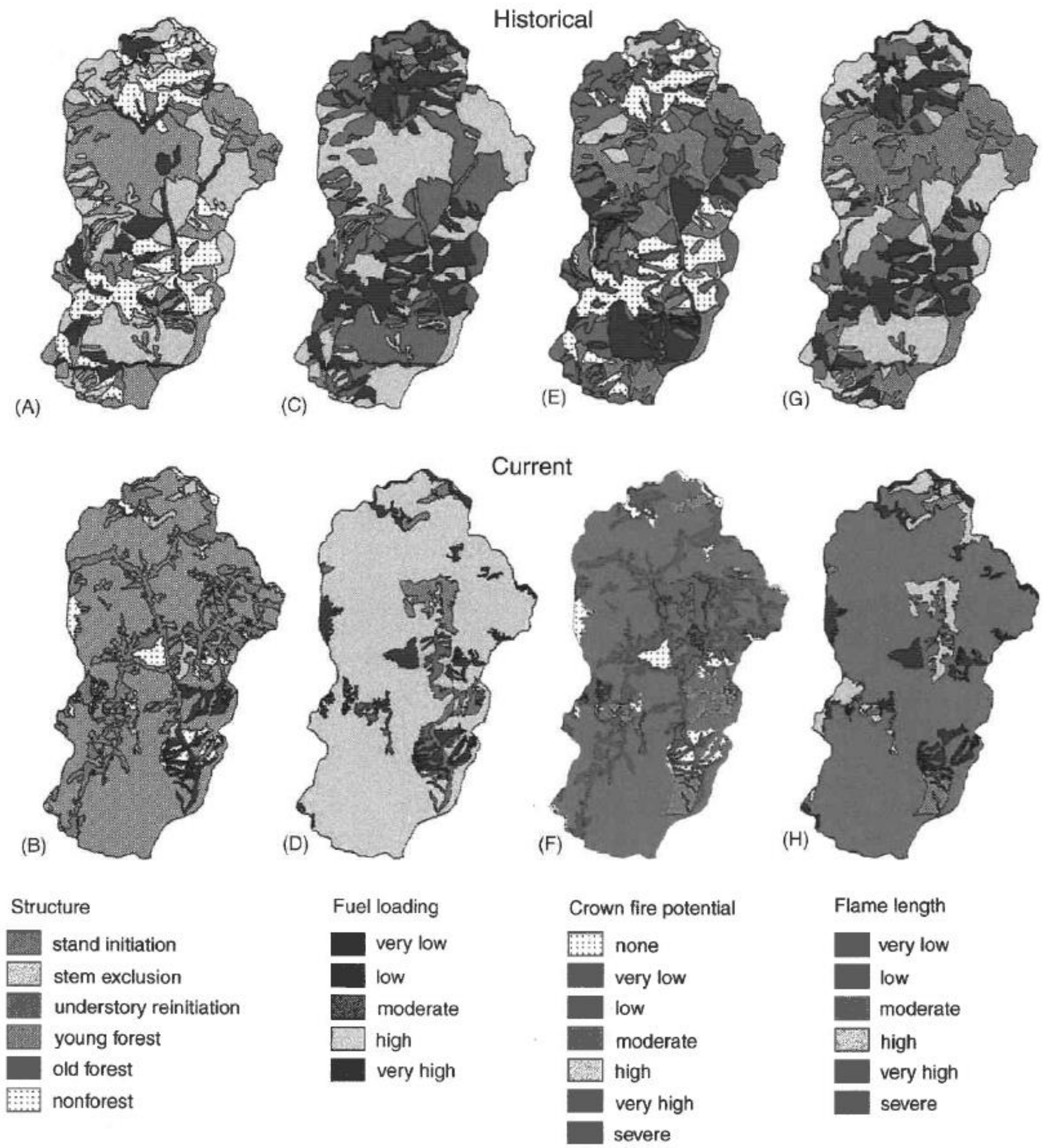


Fig. 3. Reconstructed historical (1900s) and current (1990s) maps of the Peavine Creek drainage, a dry forest subwatershed of the Lower Grand Ronde subbasin in the Blue Mountains province displaying historical and current structural classes (A and B), fuel loading (C and D), crown fire potential under average wildfire conditions (E and F), and flame length under average wildfire conditions (G and H), respectively (from Hessburg and Agee, 2003). Structural class abbreviations are: si, stand initiation; se, stem exclusion (both open and closed canopy conditions); ur, understory reinitiation; yfms, young multi-story forest; of, old multi-story and single story forest; nf, non-forest. Fuel loading classes are: very low < 22.5 Mg/ha; low = 22.5–44.9 Mg/ha; moderate = 45–56.1 Mg/ha; high = 56.2–67.3 Mg/ha; very high > 67.3 Mg/ha. Crown fire potential classes were a relativized index. Flame length classes were: very low < 0.6 m; low = 0.7–1.2 m; moderate = 1.3–1.8 m; high = 1.9–2.4 m; very high = 2.5–3.4 m; severe > 3.4 m.

FIGURE 2.1.1 – *Figure 3 from Hessburg, Agee, and Franklin (2005) showing the loss of the forest landscape spatial heterogeneity over the 20th century on the Front Range*

Button Rock Preserve

Button Rock Preserve was created through a series of land acquisitions by the City of Longmont, explicitly for the purpose of protecting a municipal water supply for the city. The first parcels were purchased by Longmont in 1916 and coincided with the construction of Longmont Reservoir and the associated water supply line. Around this same time the City of Longmont developed storage rights in the uppermost North St. Vrain watershed, in what is now Rocky Mountain National Park. In 1933 the City of Longmont bought the 1902 “Arbuckle” decrees in Bluebird, Pear, and Sandbeach lakes (Longmont Ledger 1947), which allowed water storage for the summer before the construction of Button Rock Dam. Given the importance of the North St. Vrain watershed to the City of Longmont, the City continued to acquire land around and upstream of Longmont Reservoir from the Billings and other families.

As the City of Longmont grew over the next few decades it approached a situation where the demand for municipal water was projected to exceed the supply. In response to this predicted shortage the Longmont City Council unanimously approved a bond for $4.8 million to construct Ralph Price Reservoir, which was in turn paid for by an increase in the water utility rate (Reeves 1965). The construction of Button Rock Dam and Ralph Price Reservoir coincided with the acquisition of additional land holdings, including the TO1 Ranch and St. Vrain Ranch (“Professor’s Ranch”), ultimately resulting in the current Button Rock Preserve land base of over 3,000 acres.

The construction of the reservoirs along North St. Vrain creek undoubtedly affected the river’s hydrograph below the dams and impacted habitat connectivity throughout the reach. The North St. Vrain watershed was, however, spared other impacts of the 19th and early 20th century. While beaver were trapped along the river and timber harvested in the forest, this watershed was not subject to placer mining or the floating of logs down the river (“tie drives” for the railroad) and consequently may have stayed much more intact than other Front Range rivers (Whol 2001).

2.1.2 2003 Forest Stewardship Plan

In 2003 a Forest Stewardship Plan was completed for Button Rock Preserve (City of Longmont 2003), and is available for review here: http://www.longmontcolorado.gov/home/showdocument?id=6912 . This management plan separated the Preserve into twenty-two management compartments which were then inventoried. The Stewardship Plan provides management recommendations for each management compartment, with an emphasis on thinning the stands to between 10% and 30% canopy closure and reducing the component of Douglas fir and junipers across the Preserve. Four of the management units on the south side of the property and near the entrance to the preserve had no recommended treatments due to steep slopes and inaccessibility. An additional management compartment was recommended for broadcast burning but not thinning. The remaining management compartments were recommended for thinning to 30-100 ft^2/ Ac depending on the site. Additional management recommendations for most sites include retention of snags as wildlife trees, creation of openings, promotion of a forest mosaic, and broadcast burning. This Forest Stewardship Plan has been used to guide management activities at Button Rock Preserve since its adoption in 2003.

2.1.3 Forest Thinning Treatments

Since the Forest Stewardship Plan was developed in 2003, the City of Longmont has carried out a forest management treatment in Button Rock Preserve each year. These thirteen years of active management of approximately 80 acres a year has resulted in the treatment of nearly 1,000 acres across the Preserve. This decade and more of active management has reduced forest densities across Button Rock Preserve, bringing most of the stands closer to the historic range of variability. In doing so it has also increased the wildfire resiliency of the property and helped create defensible space within the North St. Vrain watershed. These lower densities will also allow ongoing management to reach target stand densities for fewer dollars per acre going forward.

These treatments have generally followed the prioritization and recommendations of the 2003 Forest Stewardship Plan. They have occurred mostly on the south-facing north side of the preserve, which is historically less dense and was shown to be more fire prone in the Forest Management Plan. Treatments to date are shown in the table and figure below. These previously treated management units were assessed as part of the forest inventory associated with this updated Forest Management Plan. Further prescriptions and priorities for these stands were developed in response to the success of the original treatment and years since treatment as part of the adaptive management process.

TABLE 2.1.3 – Forest management thinning prescriptions implemented under the 2003 Forest Management Plan. "Priority" was established in the 2003 Forest Management Plan.

Management Unit	Acres	Year	Priority
Demonstration Unit	41.7	2004	1
2005 Unit	45.0	2005	2
Spillway Unit	12.2	2006	1
North Shore Unit	111.4	2006	2
2007 East Unit	74.4	2007	2
2007 Northwest Unit	8.6	2007	-
2007 West Unit	20.4	2007	2
Cook Mountain	186.6	2009	1
2010 West Unit	74.1	2010	3
2010 South Unit	10.3	2010	2
Schreiber Point	68.6	2010	1
2011 Unit	28.7	2011	2
Coulson Ridge	59.5	2011	3
Bear Brush	58.7	2012	3
Rattlesnake Gulch	80.0	2012	1
Two Pockets	29.1	2013	1
Powerline	48.1	2014	1
South Draw	40.5	2015	4

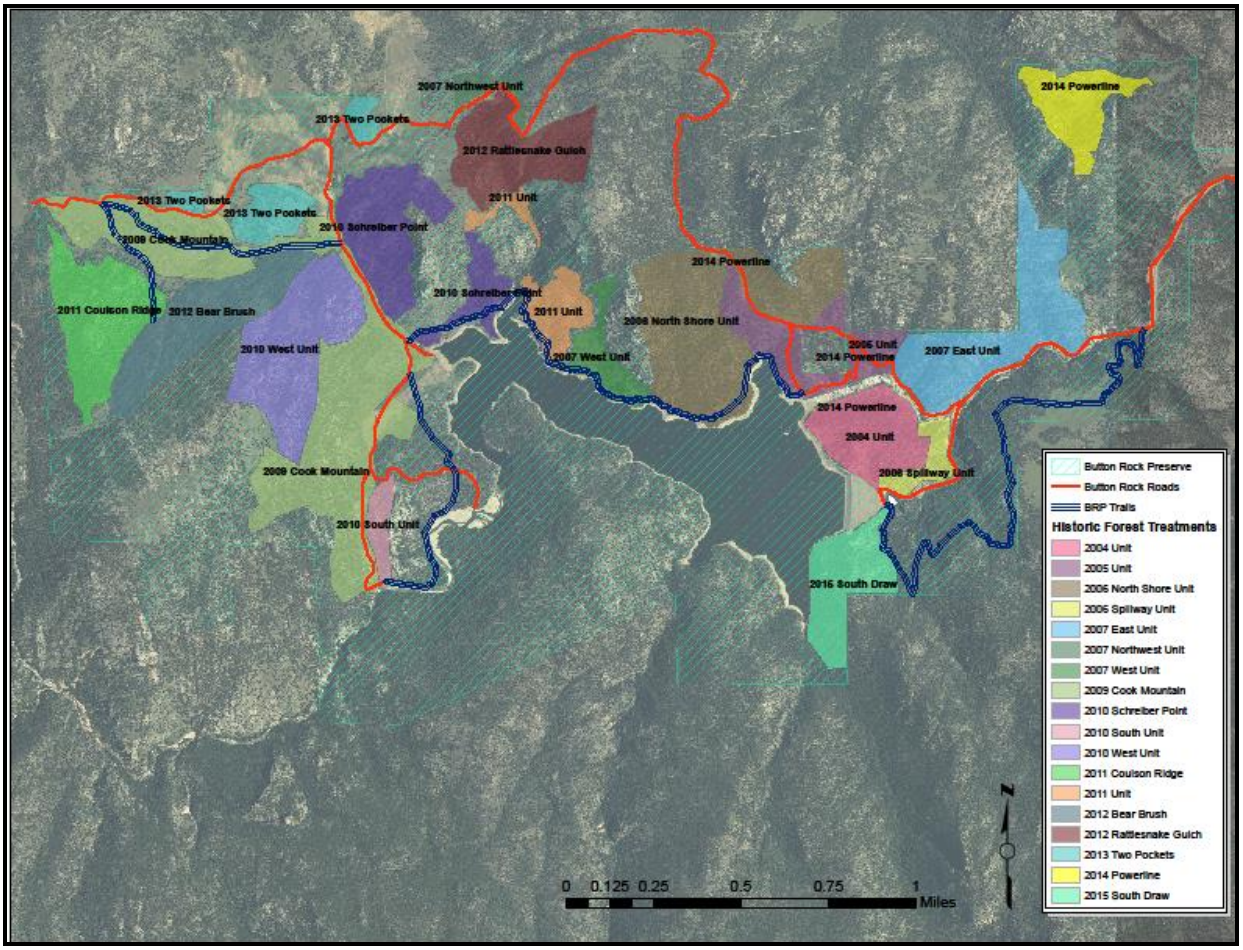


FIGURE 2.1.3 – Map showing forest management to date in Button Rock Preserve. A larger version of this map is included as Map 2 in Section 10.

2.2. Front Range Montane Forests and Fire Regimes

The forest structure in Button Rock Preserve is highly heterogeneous, as demonstrated by the forest inventory included in this Landscape Management Plan. While all of the forests in the Preserve are Ponderosa Pine (*Pinus ponderosa*) dominant, the natural fire regime and associated historic stand structure varies throughout the Preserve as dictated by elevation, aspect, and topography. Understanding this natural fire regime and historic stand structure is vital to creating a resilient water supply in the event of wildfire (Objective 1), maintaining a forest that is resilient to natural disturbances (Objective 2), and moving the forest toward a structure and function characteristic of the natural fire regime (Objective 3).

A fire regime as defined by Kauffman et. al. (2006) is "a summary of fire occurrence, behavior, and effects within a specified area, including specific parameters such as fire frequency, extent, seasonality, behavior (e.g., surface vs. crown fire), intensity (defined as heat release), and severity (defined as impacts on organisms and the abiotic environment)." Generally a fire is considered low-severity when there is less than twenty percent (20%) mortality of the trees in the canopy. Mixed-severity fire regimes have twenty to seventy percent (20%-70%) canopy mortality, while high severity have greater than seventy percent (70%) mortality (Hessburg, Agee, and Franklin 2005).

Much of the research on natural fire regimes in Ponderosa Pine systems focuses on forests of the southwestern US. Southwestern forests are characterized by a low-severity regime with a frequent fire return interval of 2-23 years, with fires that generally occur in the spring and the early summer (Hunter et. al. 2007). In contrast to the southwest, Ponderosa Pine forests of the Colorado Front Range have a much wider fire return interval (5-118 years) and are generally dominated by a mixed-severity fire regime (Boyden, Binkley, and Shepperd 2005). In addition to low-severity surface fires, this mixed-severity fire regime includes isolated patches of stand-replacing crown fire (Kaufmann et. al. 2001). Where mixed-severity fires have occurred in forests in California that are within their historic range of structural variability, Collins and Stephens (2010) found that stand-replacing fire accounted for approximately fifteen percent (15%) of the burned area. This stand-replacing component of the mixed-severity fire contained many small patches (less than 4 hectares) and a few large (greater than 60 hectare) patches. These stand-replacing fire patches were more common in structurally complex stands with a greater component of shade-tolerant species. On the Front Range this would likely correspond to north facing slopes with a larger Douglas fir (*Pseudotsuga* menziesii) and true fir component. Collins and Stephens (2010) go on to conclude that "although stand-replacing fire is not the dominant process operating in these upper elevation mixed-conifer forests, it is an important component of the fire regime."

Generally, fires are more frequent but lower-severity at lower elevations, and less frequent but higher-severity at higher elevations and on north aspects. In the Front Range, historical low-severity fire regimes that maintain extensive areas of open pine savanna only apply to portions of the lowest elevations (Sherriff and Veblen 2007; Veblen, Kitzberger, and Donnegan 2000). Kauffman et. al. (2006) estimate that only twenty percent (20%) of Ponderosa Pine dominant forests in Boulder County historically had a low-severity fire regime. Throughout most of the middle and higher elevations within the Ponderosa Pine band on the Front Range, mixed-severity fire regimes were the dominant disturbance and resulted in heterogeneous stand conditions including openings, areas of old growth, areas of pure Ponderosa Pine, and mixed conifer areas with a substantial Douglas fir component (Hunter et. al. 2007, Kauffman et. al. 2006, Moody and Martin 2001).

Button Rock Preserve ranges in elevation from 6,000 feet to over 7,500 feet, has forests on all aspects, and has very heterogeneous topography. The natural fire regime therefore likely varies widely throughout the Preserve, and the restoration strategies employed need to be equally as diverse. The forests of the lower montane on the Front Range are in many areas unnaturally dense and well outside of their historical range of variability (Pinchot Institute 2007), while forests on northerly aspects at higher elevations may not be outside of their natural range of variability. As stated by Kauffman et. al. (2006):

> "This is a critically important aspect of the historical fire regimes of the Colorado Front Range, an aspect that cannot be overemphasized. This landscape probably was never characterized by large, homogeneous stands with low tree densities. On the contrary, variation in forest structure was important across the

> area, as were changes over decades and centuries. For these reasons, creating large landscapes with uniformly low tree densities probably would be unprecedented in the ecological history of this area."

Sherriff and Veblen (2007) strongly emphasize this point as well:

> "The most important management implication of this study is both simple and robust: only a small fraction of the ponderosa pine zone of the northern Front Range fits the widespread notion that the historic fire regime was characterized mainly by frequent (that is, return intervals < 30 years) low severity fires that maintained open woodlands. This is a critically important finding, because much of the current fuels reduction management in this landscape is based on the belief that thinning of stands throughout the ponderosa pine zone would both reduce fire hazard and restore the vegetation to an open structure formerly maintained by relatively frequent fires"

Although stand-replacing fires were a component of the historic fire regime (Sherriff and Veblen 2007), changes over the past century have resulted in conditions whereby the stand-replacing component of any given fire will likely be much more extensive due to denser stands and a higher component of fire-intolerant tree species across the entire landscape. On north facing slopes at higher elevations, stands were historically dense and may not currently be outside of their historic range of variability (Hunter el. 2007). However, these naturally dense stands are now less isolated on the landscape since they are no longer flanked by less-dense stands resilient to crown fires.

While there may still be a stand-replacing component of any wildfires that occur, the forest of Button Rock Preserve should be managed in a manner that isolates their occurrence and reduces their impact on the overall landscape. At the same time, some dense stands of Ponderosa Pine and Ponderosa Pine – Doug Fir should be retained as part of the natural and historic forest landscape (Kauffman et. al. 2006). The forest restoration and wildfire resiliency strategy for Button Rock Preserve is therefore to:

1) Restore historically open Ponderosa Pine stands adapted to a low-severity fire regime to their historic density, and
2) Create structural heterogeneity in the forests adapted to a mixed-severity fire regime in a manner that effectively isolates areas susceptible to stand-replacing fires.

2.3. Watershed Effects of Wildfire

The Longmont municipal water intake at Longmont Reservoir and municipal water storage in Ralph Price Reservoir are completely surrounded by Button Rock Preserve. The Preserve is in turn surrounded by forested land managed by Boulder County Parks and Open Space, the US Forest Service, and a few private landowners (see MAP 1). Protected forest catchments such as this have been shown to be very advantageous for producing high quality municipal water at the source (Smith et. al. 2011) due to high infiltration of precipitation, low overland flow, and low erosion rates (Benavides-Solorio and MacDonald 2001). This high quality source water provides both a direct benefit to residents of Longmont and Lyons who drink the water, and reduces the cost burden of treating the water supply.

This high quality water supply provided by the forested watershed of North St. Vrain Creek is vulnerable to the effects of severe wildfire, however. Potential effects of severe wildfire on the watershed and water supply include an altered runoff hydrograph, increases in dissolved organic compounds, increased major ion and mineral concentrations, and increases in the sediment and debris produced by the watershed (Baker 1988, USGS 2012, Writer et. al. 2014). Wildfire both changes the infiltration properties of forest soils and reduces the cover of materials that protect the soils from rainfall impact (e.g. the forest canopy, and litter on the forest floor), which in combination increase runoff and erosion from burned areas (Front Range WPDR Work Group 2009; Huffman, MacDonald, and Stednick 2001; Moody and Martin 2001). In Ponderosa Pine stands on sandy soil, Baker (1988) demonstrates that the initial infiltration of precipitation can be cut in half after a wildfire. This is a result of hydrophobic compounds contained within organic matter vaporizing during a fire and then settling on soil particles, which in turn increases water repellency (hydrophobicity) (Huffman, MacDonald, and Stednick 2001). Due to this change in hydrology, wildfire-affected watersheds are susceptible to flash floods that transport substantial amounts of sediment downstream (USGS 2012). In addition to water and sediment, the runoff of nutrients and dissolved organic compounds from severely burned watersheds can be one or two orders of magnitude greater than from unburned watersheds.

The reduction of water quality from a wildfire-affected watershed results in greater water treatment costs, while the sediment runoff can fill reservoirs and damage other infrastructure. **For these reasons, the primary objective of this Management Plan (Objective 1) is to protect the quality of water produced by the North St. Vrain watershed in Button Rock Preserve, particularly as it relates to resiliency in the event of a wildfire.**

Many Colorado Front Range wildfires have already severely affected municipal water supplies, including the 1996 Buffalo Creek Fire, 2000 Bobcat Fire, and 2002 Hayman and Schoonover fires (Front Range WPDR Work Group 2009). The 2012 High Park fire burned 87,000 acres and resulted in the forced temporary diversion of the Fort Collins municipal water supply from the Poudre River to another source. Additionally, the long term treatment impacts of addressing ash and particulates in the water from the Poudre River resulted in a water utility rate increase for Fort Collins' residents (Thompson et. al. 2013). As a result of the 2002 Hayman fire, $300,000 has been spent annually on fire-related maintenance in Cheesman Reservoir, which is a primary water source for Denver (Pinchot Institute 2007).

After a wildfire the majority of sediment is produced not from erosion on the hillsides (rill and interrill), but from gully erosion. In a storm event following the Buffalo Creek wildfire, Moody and Martin (2001) observed that interrill erosion accounted for 14% of the sediment production and rill erosion accounted for 6%, while the remaining 80% of the erosion was produced via gully erosion in the drainages. In this specific case, 1.1 million cubic meters (892 acre feet) of sediment was produced in the first summer after the fire. Most of this sediment was produced in low order watersheds and was stored in higher order channels, floodplains, and alluvial fans with a predicted residence time of approximately seven (7) years. Smith et. al. (2011) demonstrate that downstream channel conditions can affect how much sediment is stored and when it is remobilized, ultimately affecting the rate at which the sediment is delivered to the drainage outlet. These post-wildfire sediment dynamics suggest that managing the drainages that flow into Button Rock Preserve in a manner that increases the storage of sediment produced in the first few years after a fire may be an effective strategy to employ in conjunction with strategies that reduce the severity and distribution of potential wildfire.

The period over which watershed scale effects of wildfires last varies, but the most acute impacts generally resolve after a few years. The attenuation of wildfire impacts over a few years has been observed for dissolved pollutant concentrations (Smith et. al 2011), erosion (Benavides-Solorio and MacDonald 2001, Moody and Martin 2001, USGS 2012), and soil hydrophobicity (Baker 1988; Huffman, MacDonald, and Stednick 2001). Moody and Martin (2001) cite relaxation rates to normal sediment dynamics in 1-4 years, while hydrology can ultimately take 30 years to return to normal. By managing the forest in a manner that reduces the severity and extent of any wildfire that occurs in the watershed, the time it takes for watershed dynamics to return to normal will hopefully be reduced. To further aid the recovery in watershed dynamics after wildfire, Benavides-Solorio and MacDonald (2001) suggest that ground cover should be maximized during the post-fire restoration.

The duration and type of precipitation also affects the ultimate sediment and pollutant load produced from burned watersheds. Huffman, MacDonald, and Stednick (2001) show that soil hydrophobicity is mitigated as soil moisture increases, concluding that:

> "the effect of soil moisture on soil hydrophobicity means that runoff from spring snowmelt should be less affected by soil hydrophobicity than runoff from summer rainstorms. The slow rate of snowmelt should wet the soil above the soil moisture threshold and allow melt water to infiltrate readily. High-intensity summer convective storms are more likely to occur when the soil surface is dry and the hydrophobic layer is more likely to limit infiltration. This means that mid- and late-summer precipitation events are of greatest concern for increasing runoff from burned watersheds in Colorado."

Reservoirs have also been shown to have a considerable capacity to mitigate the impacts of fire on water quality (Smith et. al. 2011). This is aided by both the ability of reservoirs to trap sediments and other pollutants, as well as the long residence time of water in reservoirs that attenuates contaminant pulses. This mitigation capacity of reservoirs suggests that management of Ralph Price Reservoir should be integrated into the wildfire mitigation strategy for Button Rock Preserve. It also suggests that the drainages which flow into Button Rock Preserve below Ralph Price Reservoir may be particularly vulnerable to wildfire impacts that threaten the municipal water supply since they do not benefit from any potential ameliorating effects of the reservoir.

2.4. Forest Management Considerations

Forest management prescriptions are the primary tool that will be used in Button Rock Preserve to promote a healthy forest matrix (Objective 3), promote resiliency to wildfire and other natural disturbances (Objective 2), and ultimately protect a clean water supply for the citizens of Longmont (Objective 1).

As discussed in the Watershed Effects of Wildfire section, Front Range municipal watersheds have been shown to be particularly vulnerable to catastrophic wildfire and the resultant degradation of water quality and sedimentation of reservoirs. It is ecologically inadvisable and logistically impossible, however, to carry out fuel treatments across enough of the landscape to ensure that wildfires, or even crown fires, never occur in the upper North St. Vrain watershed. **Instead the forests of Button Rock Preserve and the larger watershed should be managed in a way that reduces the likelihood of wildfire, reduces the extent of crown fire when a wildfire does occur, and protects the most sensitive drainages and infrastructure from the effects of fire.**

Multiple studies in the published literature emphasize that while forest management should be used as a tool to reduce fire behavior and effects, managers *should not* implement uniform thinning treatments that seek to completely prevent fire on the landscape. Brown, Agee and Franklin (2004) state "A forest that is fire-resilient has characteristics that limit fire intensity and increase the resistance of the forest to mortality," while Stephens and Ruth (2005) state that:

> "The primary objective of fuels-management projects should be a reduction of potential fire behavior and effects, not simply the reduction of forest fuels. Recent federal fire policies and initiatives all seek to reduce fire hazard by reducing fuels. This strategy possesses an intuitive appeal, but application of the strategy may not significantly alter fire hazards. Fire behavior is not simply a function of fuels, but also of weather and topography."

Hessburg, Agee, and Franklin (2005) further suggest that "As an alternative to blanket prescriptions that simply reduce fuels and thin dry forests, we suggest a more ecological approach is warranted; one that would restore more natural spatial and temporal patterns of dry forest structure, composition, snags and down wood."

2.4.1 Landscape-Scale Planning

There are significant logistical and economic constraints that hinder the ability to conduct intensive thinning treatments across a landscape. In Button Rock Preserve this is particularly true for the stands on the south side of the reservoir that are inaccessible and steep. Since conducting fuel treatments across the entire landscape may not be logistically feasible nor ecologically advisable, fuel treatments that are implemented need to be strategically placed so that they protect untreated areas and other values at risk from catastrophic fire.

At a landscape level the primary objective of forest management with respect to wildfire should be to reduce the spread of catastrophic fire by using fuel treatments that address overall fuel loading, fuel continuity, and fuel depth and structure (Brown, Agee, and Franklin 2004; Hunter et. al. 2007). Hessburg, Agee, and Franklin (2005) recommend starting with a series of prioritized fuelbreaks. Several fuel treatments that overlap in the direction a wildfire is heading can reduce the spread of the fire (Hunter et. al. 2007), ultimately reducing the overall proportion of a watershed that is subject to catastrophic stand-replacing running crown fire. Additionally, it is critically important to have a long-term strategy for maintaining these fuel treatments so that a pulse of regeneration does not result in a drastic increase in fuel continuity and reduce the effectiveness of the fuelbreaks (Hunter et. al. 2007, Pinchot Institute 2007).

When managed at the forest landscape level, treated areas should reduce the spread of running crown fire, increase the patchiness of any wildfire that occurs on the landscape, and ultimately reduce the proportion of the landscape that is subject to catastrophic wildfire. Where stands susceptible to stand-replacing catastrophic fires are not treated either because they are inaccessible or on sites where they are not outside of the their natural range of variability, treatments elsewhere on the landscape should protect and isolate these stands so that the proportion of them that are burned in a wildfire is limited.

2.4.2 Stand Level Treatments

At the stand level Brown, Agee, and Franklin (2004) recommend thinning treatments based on the principles of:

1) Managing surface fuel to limit flame lengths,
2) Increasing the height to canopy fuels through the management of ladder fuels, and
3) Decreasing crown density.

Hunter et. al. (2007) further emphasize that fuel treatments need to be explicitly directed at reducing the potential for crown fire, cautioning that treatments can have adverse effects that need to be taken into account. For example, reducing canopy density can adversely change microsite climate by increasing ground level temperatures and wind speeds (Stephens and Ruth 2005).

Fuels also need to be removed from the treatment area either physically or through burning so that the fuels are not just simply redistributed. Fuel treatments should follow the ordinary effects of surface fires, which reduce small size classes, surface and ground fuels, and fire-intolerant species such as Douglas fir and true firs (Hessburg, Agee, and Franklin 2005).

Brown, Agee, and Franklin (2004) recommend securing areas with high ecological integrity (“anchor habitats”), extending those areas with restoration techniques, and connecting them at the landscape level. They ultimately reemphasize that forest managers should “consider a range of restoration steps, rather than attempt complete restoration with a single treatment everywhere.”

Finally, large fire-resistant trees should be retained to provide important restoration and habitat attributes. Generally flame lengths only need to be reduced below 4 feet (1.2m) to limit mortality in mature Ponderosa Pine stands such as those found in Button Rock Preserve, ensuring that retained legacy trees do not suffer mortality or contribute fuel to the fire. Ultimately, thinning in a manner that replicates natural surface fires including the removal of fuels, retention of large legacy trees, and creating heterogeneity across the landscape will ensure that fuel treatments will help restore the forest to its natural range of variability instead of moving it further from it.

2.4.3 Prescribed Fire

To achieve the goals of reducing fuel loads, mitigating wildfire risk, and restoring forest conditions, any forest restoration and fuel treatment initiative in Ponderosa pine dominant forests should have a prescribed fire component (Brown, Agee, and Franklin 2004; Hunter et. al. 2007; Stephens and Ruth 2005). Stephens et. al. (2012) emphasize that mechanical treatments alone are not surrogates for a historic natural fire regime in that they 1) lack the heat to kill fire-sensitive tree and shrub regeneration that in turn maintains fuel discontinuity, 2) they do not provide for the germination of fire-dependent species, and 3) they can damage non-target species. In fact, if not used in conjunction with prescribed fire or other fuel removal techniques, overstory removal ("thinning from above") is likely to actually decrease fire resistance (Stephens et. al. 2012). If residual fuels from thinning treatments are left on-site, fire behavior is likely to be similar to or even more extreme than in an untreated stand (Stephens and Ruth 2005). It is therefore imperative that either prescribed fire be implemented after a fuel treatment, fuels are mechanically removed from the forest, or both. While removing fuel from the forest mechanically will address fire risk in the short term, it is unlikely to have the same long-term wildfire mitigation or forest restoration benefits as reintroducing fire onto the landscape.

2.5 River Restoration and Flood Recovery

2.5.1 September 2013 Flood and Effects

In September 2013 the St. Vrain watershed experienced a dramatic flood event that substantially altered the river. The channel experienced alternating sections of severe deposition and scour, while the riparian vegetative corridor was mostly lost. A Colorado Dept. of Transportation and Colorado Water Conservation Board (CDOT / CWCB) memorandum estimates that the peak discharge on North St. Vrain Creek was in excess of 12,000 cfs, which is equivalent to a greater than 500-year flood event (Houck 2014). Emergency stabilization, transportation, and utility infrastructure was installed throughout the watershed following the flood. Currently a river restoration project is under way in Button Rock Preserve in response to the flood effects and to enable recovery within the new infrastructure context.

Flood events, including large and rare flood events like that of September 2013 on the Colorado Front Range, are a natural process to which river systems are adapted. While the 2013 flooding had devastating effects on communities and infrastructure, it likely had some beneficial effects on river ecosystems and steam function (Richer, Kondratieff, and Swigle 2015). Large floods clear out riparian vegetation and rework the river channel. In the years following a flood the riparian vegetation recolonizes disturbed areas, narrowing the river and creating channels within a forested corridor until the next flood resets the process (Kondolf 2006). Aquatic and riparian species have adapted to flooding "to such an extent that the absence of flooding becomes a disturbance." Biotic responses to floods include both resistance to the effects of the flood, and adaptive strategies that allow for resilient recovery after a large flood (Swanson et. al. 1998). In the case of the North St. Vrain restoration in Button Rock Preserve, the goal of the river restoration projects is to speed up the natural flood recovery process of recreating a morphologically appropriate river channel within a forested riparian corridor for the sake of wildlife habit, water quality, angling and other recreational uses.

2.5.2 River Restoration

In the US, over $1 billion is spent on river restoration projects annually. A successful river restoration project can provide instream and riparian habitat, assist with species recovery, and provide for recreational activities (Bernhardt et. al. 2005). Palmer et. al. (2005) list five criteria for successful river restoration, which are:

- A design based on a guiding image of a dynamic and healthy system
- Measurable improvement in ecological conditions
- A final project that is self-sustaining and resilient with respect to external perturbations
- A project that does not inflict any lasting harm to the system
- Pre- and post-assessments of the project are conducted and the data is made publically available

A stable system is often the goal of restoration projects because it is assumed that stability is inherently preferable, however this is not necessarily the case. Rivers are naturally dynamic systems, and this dynamism needs to be accounted for in order to create an ecologically successful river restoration project. Intact ecosystems have evolved in concert with natural disturbance regimes, and both the river channel and the biota should be given the room to naturally shift in response to natural variability (Lytle and Poff 2004). Projects need to be evaluated on their ecological merits and should not simply be assumed to be beneficial (Palmer et. al. 2005). According to Kondolf (2006), "stability is often a goal of channel reconstruction projects, despite a body of scientific literature indicating that dynamic, actively migrating channels provide the best ecological habitats and that the ecological value diminishes with decreased flow and channel dynamics."

River channel morphology is a response to the slope, hydraulic regime, and sediment supply of the watershed. General characteristics of natural stream systems based on their slope, sediment, meander frequency, and width to depth ratios have been developed into classification schemes. The most commonly used system is from Rosgen, which is based on data from 450 rivers throughout the US, Canada, and New Zealand (Rosgen 1994). While classification schemes are invaluable as guides, they should not be used as river restoration prescriptions (Palmer etl. al. 2005). Successful ecological restoration requires more than reshaping the river planform in a manner that creates physical habitat. Hydraulic and sediment processes have to be considered, as does the biota of the riparian corridor. Even if a river is restored in form, the ecosystem will not recover if ecological processes are not in place (Whol 2001). An important example of this is hyporheic flow, which is the water that flows through the sediment on the bottom of the stream and provides important habitat to benthic macroinvertebrates and other biota. Accumulation of fine sediments can impede hyporheic flow while coarser sediments promote it. A natural flow regime is generally critical to maintaining this balance and should be considered alongside other restoration considerations (Hester and Gooseff 2010).

As river restoration and flood recovery proceed in Button Rock Preserve they need to take into account these natural dynamics and be built to respond well to disturbance regimes, not resist them. The river restoration and management plan is contained in Section 8 herein.

SECTION 3. Forest Inventory

3.1 Forest Inventory Methodology

The Colorado State Forest Service (CSFS) Boulder District staff carried out a forest inventory in Button Rock Preserve in the summer of 2016. They delineated seventeen Forest Management Units (FMUs) based on stand conditions and natural boundaries. The FMUs roughly align with the twenty-two management compartments in the 2003 Forest Stewardship Plan, but take stand condition continuity and the past 13 years of forest management activity into greater consideration. These seventeen FMUs are the basis of prescriptions used in this report and supersede the management units delineated in the 2003 Forest Stewardship Plan as well as the *de facto* management units defined by the past thirteen years of active management. Map 4 shows these seventeen management units as well as the area that has been actively managed to date. Active management to date by year is also shown in Map 2.

Four hundred and twenty-eight (428) sample plots were established across the Preserve using standardized forest inventory methods. A variable radius plot was established from each plot center using a 20 Basal Area Factor (BAF) prism. For every tree within the plot the following data were collected: species, diameter at 4.5 feet (DBH), total height, tree condition, and crown ratio (%). A core sample was taken from a representative site tree in roughly every third plot using an increment borer, and total age and growth in the past ten years was tallied.

A fixed radius plot of 0.01 ac with a radius of 11.8 feet was also established from each plot center. Within the fixed radius plot all seedlings and saplings were counted. Seedlings were defined as trees less than three feet (< 3') in height and saplings as trees greater than three feet in height but less than five inches (< 5") in diameter.

A panoramic photograph was also taken from each plot center, and any additional salient data was noted including prevalence of beetle damage, mistletoe, or distinctive site conditions.

The inventory data was processed using the US Forest Service's Forest Vegetation Simulator (FVS) modeling software using the Central Rockies (CR) geographic variant. Estimates were created for basal area (BA), trees per acre (TPA), average height, and total cubic feet for each tree species and diameter class (2" intervals) within a FMU. Ten year growth projects were also created. Summaries of these data are shown below, and diameter-class distributions for each FMU are shown in Section 5.

3.2 Summary Data

The tables below show summary data from the 2016 forest inventory in Button Rock Preserve. Diameter class distribution charts for each forest management unit (FMU) are shown in Section 5. The FMUs demonstrate a wide range of densities, with the north-facing and mesic stands generally being denser. Most of the Front Country (FC) and Back Country (BC) forest management units have lower stocking densities and healthier forests than they otherwise would have due to the past decade of active management, as detailed further in Section 5.

Forest Vegetation Simulator (FVS) growth modeling results are shown and discussed in Section 5.8

TABLE 3.2 – Summary inventory data from the 2016 forest inventory carried out by the CO State Forest Service (CSFS) in Button Rock Preserve.

FMU	Average Height	Trees per Acre (TPA)	Basal Area (ft^2/ac)
FC1	20.4	177.8	72
FC2	25.7	195.9	89.7
FC3	22.6	357.7	115.3
FC4	31.3	99.4	69.9
FC5	25.6	431.8	110.7
FC6	20.4	462	106.6
FC7	37.7	126.1	83.1
FC8	17.4	226	70.8
BC1	21.6	285.5	96
BC2	18.9	125.9	65.2
BC3	27.9	134.6	74.3
BC4	25	261.6	104.3
BC5	26.4	186.8	96.2
BC6	14.7	131.6	31.9
MP1	15.6	414.5	103.6
MP2	15.7	698.6	103.6
SS1	15.6	425.8	84.3

3.3 Mortality, Insects, and Disease

Tree mortality (standing dead) was found to be very limited in Button Rock Preserve. Out of 2,226 individual trees recorded in all variable radius plots there were only 53 dead trees (snags), which is 2.4%. Additionally, only twelve of the 428 inventory plots (2.8%) were noted to contain mistletoe, although those that did have it often had heavy prevalence. From the inventory notes it can be inferred that mistletoe occurs on the landscape only in isolated pockets, but within those pockets it can be dense. Only one instance of beetle damage was noted in an inventory plot, and in that instance the tree was still alive. Although the forests of the Preserve are overstocked they are otherwise very healthy.

Where diseased trees are encountered on the landscape, they are prioritized for removal per the general management prescriptions contained in Section 5. At the same time, the lack of mortality may require that dead wildlife trees (snags) should be actively created on the landscape.

3.4 Wildfire Hazards

As discussed above in Section 2, the densely stocked stands and general lack of heterogeneity in Button Rock Preserve present a substantial wildfire risk and consequently a risk to the Longmont municipal water supply. Fortunately, the general lack of mortality, disease, and parasites provides a strong foundation from which to restore a resilient forest through active management.

Wildfire modeling was not carried out as part of this management plan, although it is recognized to be a vital component of management planning. While modeling will help further prioritize forest management work within Button Rock Preserve, it is more valuable as a prioritization guide for the larger landscape that includes Boulder County Parks and Open Space and US Forest Service ownership. The Colorado Forest Restoration Institute (CFRI), a department of Colorado State University, has developed valuable modeling tools for understanding wildfire risk and associated post-fire erosion risks. **It is recommended that the City of Longmont work with CFRI or an alternate provider of this service to carry out a wildfire and erosion risk analysis for the effective watershed above the municipal water supply intake at Longmont Reservoir.** When developed, the risk assessment and analysis should be appended to this Forest Stewardship Plan and used to prioritize landscape-scale wildfire mitigation treatments. **This planning should include identifying areas where intensive fuel break treatments could be put in place to reduce the overall coverage and impact of high severity wildfire, and a long term management strategy for those treatments.**

SECTION 4. Non-Inventoried Management Considerations

4.1 River and Riparian Corridor

North St. Vrain Creek through Button Rock Preserve was severely impacted by the major flooding event in September 2013, and management of the river corridor in response to the flood is discussed in Section 9. Riparian forest assessment was not included as part of the inventory, and no inventory plots were placed within the riparian corridor. For the sake of forest management prescriptions, a non-harvest area is established around all riparian corridors through the general instructions in Section 5.1.3.

4.2 Noxious Weeds

An assessment of noxious weeds in Button Rock Preserve was not carried out as an explicit component of this Forest Stewardship Plan, but they are known to exist throughout the preserve and are a significant management concern. Anecdotal observation suggests that noxious weeds occur most often in disturbed areas such as flood-impacted drainages or along roadways. They are also more common in grassland areas than within the forest stands themselves.

Forest management activities have a strong potential to adversely affect site conditions by introducing noxious weeds or creating disturbances in which they will flourish. Forestry operations shall use the utmost care to maintain clean equipment, minimize soil disturbance during operations, and not move materials that can reasonably be suspected to be vectors for noxious weeds.

4.3 Wildlife

Button Rock Preserve provides a wide variety of habitats for birds, mammals, fish, and other wildlife. Notable observed wildlife in the Preserve include beaver, elk, Abert's squirrel, mule deer, moose, black bear, mountain lion, turkey, bald eagle, and osprey. A wide variety of fish and passerine bird species are also present. **Forest management under this Forest Stewardship Plan shall to the greatest extent feasible take into account protecting and restoring wildlife habitat elements**. This includes retaining large trees and snags for wildlife habitat, and maintaining grasslands for forage. Management activities shall follow all prescriptions in Section 5 to protect riparian corridors and known existing wildlife trees. Retention of some Rocky Mountain Juniper and creation of dead wildlife trees (snags) through girdling should also be implemented where appropriate.

SECTION 5. Forest Management Prescriptions & Implementation

5.1 General Forest Management Prescriptions

5.1.1 Residual Stand Densities

Residual stand prescriptions are included for each forest management unit in sections 5.4 to 5.7 below. Three sources were used to develop residual stand basal area (BA) prescriptions. US Forest Service General Technical Report 310, *Restoring Composition and structure in southwestern frequent-fire forests* (Reynolds et. al. 2013) provides residual stand prescriptions for southwestern Ponderosa Pine fire-adapted forests. While not Front Range specific, this is still a good guiding document. Historical stand reconstruction information was presented by Brown et. al. (2015) for thirteen stands in Hall and Heil Ranches, which are adjacent to Button Rock Preserve and at the same approximate elevation and therefore a good representation of the known historical range of variability. Lastly Addington et. al. (2016) provide summary information on four different density matrices specific to Ponderosa Pine dominant forests of the Front Range. A summary of these three sources is shown in the table below.

TABLE 5.1.1 - Residual stand basal area (BA) and trees per acre (TPA) from three separate literature sources.

SOURCE	STAND TYPE	BA (ft^2/ac)	TPA	Canopy Cover*
Reynolds et. al. 2013	Ponderosa Pine pure type	20-90	11-124	
	Dry Mixed Conifer type	40-125	20-100	
Brown et. al. 2015	Historical Reconstruction, Hall & Heil Ranches (range)	1.3-74.5	8-130	
	Historical Reconstruction, Hall & Heil Ranches (avg.)	26	36	
Addington et. al. 2016	Openings	0-20		< 10%
	Low-Density Matrix	20-40		< 30%
	Medium-density Matrix	40-60		30% - 60%
	High-density Matrix	80+		> 60%

** Canopy cover estimates were taken from Section 3.3 of Addington et. al. and correlated with the basal areas and stand types provided in Appendix B of the document.*

All of these residual stand prescriptions overlap, and they all have broad ranges as well. Ultimately this emphasizes the need for stand-level heterogeneity in prescriptions, but also the necessity of further reducing stand densities across Button Rock Preserve. Most of the inventoried forest management units are outside of the range of variability shown in the table above, and only one management unit (BC5) is below even 65 ft^2/ac basal area.

The residual stand guidelines provided in Addington et. al. (2016) were relied on most heavily for developing residual stand prescriptions given that the most distinction is made between stand types. These guidelines are also included herein as Appendix 2.

5.1.2 General Operating Instructions

These general operation instructions were developed in coordination with the Forest and Fire program at the Colorado chapter of The Nature Conservancy (TNC), and apply to all forest management units.

Felling

1) Only cut Ponderosa pine and Douglas fir less than 18" diameter, unless it is a management or safety issue. Examples of management issues include transportation corridors, fire breaks, power line corridors, or corridors for other infrastructure.
2) Follow general prescriptions as well as forest management unit specific instructions.
3) If something is unclear, ask questions.

Moving Material

1) Small diameter material less than 6" diameter resulting from felling operation (activity fuels) should be piled.
2) When possible, material greater than 6" diameter (e.g., tree boles) should cut to 8' – 10' lengths and moved to the road for removal.
3) Material greater than 6" diameter, not within a reasonable distance from the road, should be piled for later burning or left in open meadow areas.
4) Dead ground fuels greater than 3" diameter and sound should be cut and piled.
   - ✓ **Exception**: an average of 2-3 large diameter logs per acre should be left on site. *Preference for retention* will be given to large diameter logs, greater than 10' in length, in advanced stages of decomposition
4) Skidding and forwarding shall avoid sensitive areas.
5) When possible avoid skidding (dragging) material along the same path repeatedly when creating piles in order to minimize soil disturbance. This is especially important when skidding large material such as tree boles (trunks) to the road.
   - ✓ **Methods:** Skidding should use the lowest-impact method available. The City should consider purchasing a skidder as well so that material can be moved between forestry contracts.

Piles

1) Piles should be placed in existing or created openings. *At a minimum* they should not be within the drip-line of leave trees.
   - ✓ Pile size should correlate with opening size. That is, smaller piles should be placed in smaller openings and vise-versa.
   - ✓ Piles should not be placed within 10' of another pile.
   - ✓ When possible piles should be placed in areas with bare, rocky soils.
   - ✓ Piles *should not* be placed near stumps, exposed tree roots, or other flammable materials.

  - ✓ Piles should not be placed within 30’ of riparian areas.

2) Piles should be no smaller than 4x4’ and no larger than 12x12’
   - ✓ Piles should be at least as tall as they are wide
   - ✓ The core (center/bottom) of the pile should consist of small diameter (< 3”) material especially sticks, twigs, and branches with needles. Progressively larger material should be placed on pile with tree-boles and heavy materials on top to ensure the pile is compact.
   - ✓ Piles should not contain branches, logs, or other material extending more than 2-3’ beyond the outside edge of the pile. This material should be cut and placed on top.

5.1.3 General Marking Instructions

General marking instructions apply to all forest management units (FMUs). They should be used in concert with FMU – specific prescriptions included in sections 5.4 – 5.7.

No-Harvest Delineations

1) Riparian Areas – Identify no-harvest areas along riparian corridors:
   - ✓ Riparian areas are defined by riparian-associated plant species (e.g. alder, birch, willow, cottonwoods) that exist along both perennial and ephemeral streams.
   - ✓ No harvest shall take place within 100 feet of the stream edge, or 30 feet of the outer edge of the riparian plant community, whichever is greater.

2) **Leave Trees** - Identify and retain the following types of trees:
   - ✓ **Old Trees**, including pre-European settlement trees generally greater than 150 years old. These are generally identified by flat tops, large branches, or thinning tops
   - ✓ **Live Habitat Trees**: visual nesting cavities or favorable conditions; trees with forks, broken tops, large branch platforms. Retain 2-5 live habitat trees per acre.
   - ✓ **Dead Habitat Trees (Snags)**: Retain all snags greater than 20” in diameter. Leave a 20’ no-cut buffer around snags to protect them. Retain 1-3 dead habitat trees per acre.
   - ✓ **Non-cut Species**: Aspen, Limber pine, and riparian trees shall not be harvested.
   - ✓ **Trees greater than 18”** dbh unless they are a safety hazard or occur in a critical corridor for infrastructure protection.

Matrix of Individual Trees, Groups, and Openings

As important as reducing stand densities is creating heterogeneous stand conditions with some groups of trees, some individual trees, and openings. A uniformly thinned stand, even if it reaches a certain basal area target, will still not be within the natural range of variability of the historic stand and will not provide the same values.

This prescription for stand heterogeneity is based upon the Individual, Clump, and Openings (ICO) methodology described in Churchill et. al. (2013). ICO proportions for Button Rock Preserve were developed using the historical stand reconstruction information presented in Brown et. al. (2015) for Heil and Hall Open Spaces, which are adjacent to Button Rock Preserve and therefore good approximations. These ICO ratios were developed from both information provided directly in Brown et. al. (2015) and the stem maps used in development of that paper, which were provided by the authors. The table in Appendix 1 shows the information used to develop these ICO ratios.

1) Leave trees and other no-harvest areas shall serve as the foundation upon which the rest of the stand structure is formed through marking and harvest. Often the location and distribution of leave trees and other no harvest areas suggest the Individual-Group-Opening structure for the rest of the stand.
2) Follow the prescriptions for residual basal area (BA) provided for each management unit.
3) Mark the stand in a manner that leaves a matrix of individual trees, groups, and openings:
    - ✓ **Individual** trees do not have, and will not develop, canopies that interlock with other trees.
    - ✓ **Groups** of trees are defined by interlocking canopies.
    - ✓ **Openings** are outside of the canopy cover of groups and individuals. They may have a few individual isolated trees, but no more than 10% canopy cover.
    - ✓ Generally 20’ from trunk to truck is a good estimate for the difference between groups and individual trees. That is, < 20’ makes a group, > 20’ makes an individual or opening.

4) A third (~33%) of all residual trees should be individuals.
5) Slightly less than half (~45%) of all residual trees should be in small groups of 2-5 trees.
6) Slightly more than ten percent (~13%) of all trees should be in medium size groups of 6-10 trees, and slightly less than ten percent (~8%) of all trees should be in large groups of 11-16 trees.
7) There should be a few very large groups (~4%) with more than 16 trees in the group.
8) Wetter (mesic) and north-facing sites should have a higher proportion of larger groups and fewer individual trees, while drier (xeric) and south-facing sites should have a higher proportion of individual trees and smaller groups.
9) Treatments should balance out across the Management Unit to achieve the ratios above, but within the unit variability from site to site is preferable.

<u>Prioritization of Removals</u>

1) Use identified leave trees to serve as the foundation for the structure of the residual forest.

2) Only remove trees less than 18” in diameter.
3) Thin from below, prioritizing the removal of trees with poor crowns (< 35% live crown ratio). Retain occasional mid-story and understory trees as individuals or in groups (can be inferior trees).
4) The priorities for removal are:
   - ✓ First remove trees impacted by insects or disease (e.g. beetles and mistletoe), then
   - ✓ Prioritize removing Juniper, then
   - ✓ Prioritize removing Douglas fir, then
   - ✓ Remove Ponderosa Pine
5) Remove 90% of Douglas fir less than 10” diameter.
6) Remove trees less than 10” diameter beneath or within 20’ of the canopy of identified leave trees.
7) Remove encroaching Ponderosa pine and Douglas fir within 50’ of an aspen, where the encroaching tree is less than 14” diameter and not identified as a leave tree.
8) The residual stand should be limbed to 6’ off the ground, or as high as safety allows.

Resulting condition: Isolated trees and groups of trees should surround openings from 0.5 to 10 acres in size. Openings may contain individual leave trees or small groups but generally have less than 10% canopy cover. Stand composition will be mostly Ponderosa Pine, with some Douglas-fir and a few Rocky Mountain Juniper retained. Any Limber pine or Aspen are retained and riparian corridors are left intact.

5.2 Prescription Fire

It is recommended that residual fuels (slash) from thinning treatments should be burned so that the fuels are consumed, not simply redistributed. This is a key element in mitigating wildfire risk. Pile burns are suitable for all forest management units (FMUs) and broadcast burning is suitable for many FMUs as discussed in Sections 5.4 – 5.8 below.

Both slash pile burning and broadcast burning are regulated by Boulder County per County Ordinance 2014-1 and require a burn permit. All prescription burns in Button Rock Preserve shall have both an applicable burn permit and professionally-developed burn plan.

Any slash pile burns of more than 50 piles or broadcast burns greater than five acres also require an applicable smoke permit from the Colorado Department of Public Health and Environment (CDPHE).

Per Boulder County regulation, no fires are permitted, even when a valid permit has already been obtained, when *any* of the following occur:

- A High Wind Warning or Watch, Red Flag Warning, or Fire Weather Watch
- Air Quality Action Day
- Burn Ban

Any prescribed burn requires notification of both the Fire Protection Agency with jurisdiction and Boulder County Communications before the fire is set. Additionally, when a smoke permit is required the Colorado Dept. of Public Health Air Pollution Control Division shall be notified.

Pile Burning

Per Boulder County regulations and guidelines, pile burning *cannot* take place unless:

- ✓ There are at least five inches (5") of snow cover extending in all directions for thirty feet (30') from any and all piles to be burned
- ✓ There is a trench at least six inches (6") wide dug to mineral soil completely surrounding the pile
- ✓ The pile is situated on bare ground or sparse grass away from the forest canopy
- ✓ All material in the piles is less than six inches (< 6") in diameter
- ✓ There is no infrastructure or property at risk within thirty feet (30')
- ✓ Burn piles are separated by at least thirty feet (30')

Piles should be created with smaller materials (e.g. branches with needles) in the center and gradually larger material moving outward. This allows the pile to stay compacted. The largest material should be toward the top center of the pile. No materials greater than 6" in diameter should be placed in the burn pile. Ideally piles should be left to cure for one year before burning.

Broadcast Burning

Broadcast burns shall have a burn plan as required by Boulder County. The burn plan shall be developed in direct coordination with a professional prescribed fire team (e.g. CO State Forest Service, Boulder County Sheriff's Office, The Nature Conservancy) and shall pass review by an additional professional prescribed fire team that was not involved in the plan's development. The broadcast burn plan shall also pass review by a City of Longmont prescription fire review team.

Any broadcast burns shall be implemented by *at least* a Type 2 hand crew with experience safely implementing prescribed burns. At least one engine shall also be available unless a specific rationale is given in the burn plan for not using one. Additional equipment and personnel requirements for a given burn shall be explicitly stated in the burn plan.

5.3 Watershed-Scale Planning and Management

Despite the best management efforts that can be made within Button Rock Preserve, the effective watershed that ultimately impacts North St. Vrain Creek and provides Longmont's water supply is much larger than the Preserve itself (see Map 1). As part of the current management planning effort the City has therefore started working with the other major landholders in the middle North St. Vrain Creek watershed, namely the Boulder Ranger District of the US Forest Service and Boulder County Parks Open Space, to begin considering forest management on a watershed scale. These three public land managers, along with assistance from the Colorado State Forest Service (CSFS), have informally organized as the "Button Rock Collaborative." Two field tours were organized in the summer of 2016 to review cross-boundary risks and management opportunities that were attended by all entities.

It was recognized that some of the potentially greatest risks to Longmont's water supply come from the subwatersheds that drain into North St. Vrain Creek below Ralph Price Reservoir but upstream of the municipal water intake at Longmont Reservoir. Since runoff from these subwatersheds does not benefit from the potentially ameliorating effects of Ralph Price Reservoir (i.e. the reservoir acts as a sedimentation basin, and provides residency time for all inflows) they are at a higher risk of directly impacting the water supply should there be a high-severity fire in any of these subwatersheds (see Map 5). There is therefore general consensus that initial cross-boundary project work under the *Button Rock Collaborative* should focus on these subwatersheds.

It is therefore recommended that the City of Longmont continue working to manage the greater North St. Vrain Creek watershed collaboratively with the other major landholders including Boulder County Parks and Open Space and the US Forest Service, and that the subwatersheds between Longmont Reservoir and Ralph Price Reservoir are prioritized in these efforts. The priority treatment areas recommended by the CSFS discussed below take these considerations into account.

5.4 Front Country Forest Management Unit Prescriptions

There are eight "Front Country" (FC) forest management units (FMUs), most of which have received treatments under the 2003 Management Plan. The exception are the management units on the steep north slopes south of St. Vrain Creek, which have not been treated. These are the Front Country 5 (FC5), Front Country 6 (FC6), and the east side of Front Country 3 (FC3). Basal Areas in the Front Country run from 70 to 115 ft^2/ac.

Given that the eastern Front Country management units encompass potentially vulnerable subwatersheds that drain directly into North St. Vrain Creek above Longmont Reservoir and are adjacent to lands actively managed by Boulder County Parks and Open Space and the US Forest Service, as discussed above in Section 5.3, these management units contain two priority treatment areas.

The Front Country FMUs are the most accessible in the Preserve and therefore have the greatest potential for harvesting commercially viable timber. As long as it aligns with the management prescriptions for the unit, any commercial harvest will offset some of the cost of prescription thinning and make management under this plan much more economically viable.

Broadcast burning after treatment should be considered in all Front County forest management units (FMUs) north of North. St. Vrain Creek. Broadcast burning will remove fine fuels, increase the ecological effectiveness of the treatments, and is the most cost efficient long term strategy for maintaining appropriate stand structure and density. The Front Country FMUs with the best potential for prescribed broadcast burns are units 2 and 4 given their relatively less steep slopes and the strong control points provided by the road, spillway, and Ralph Price Reservoir.

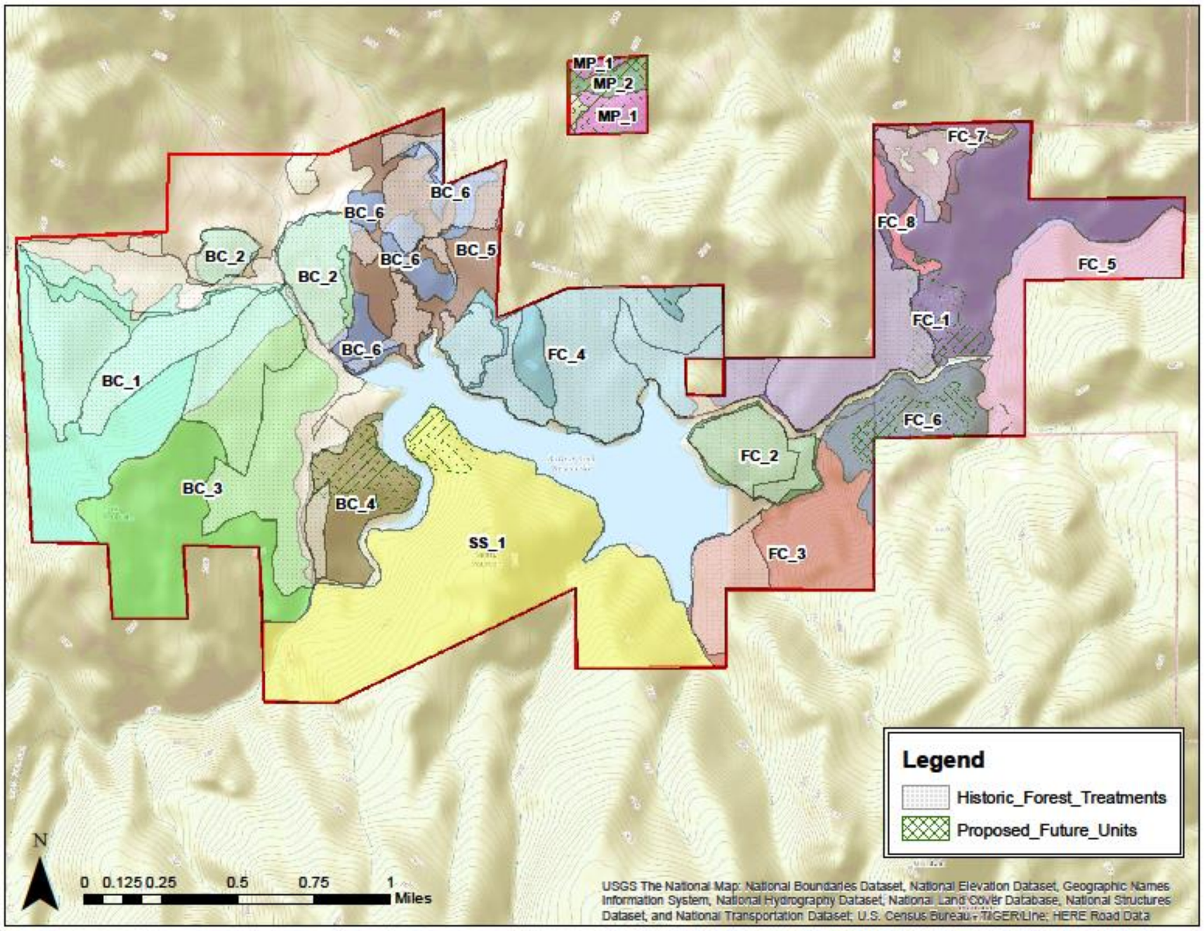
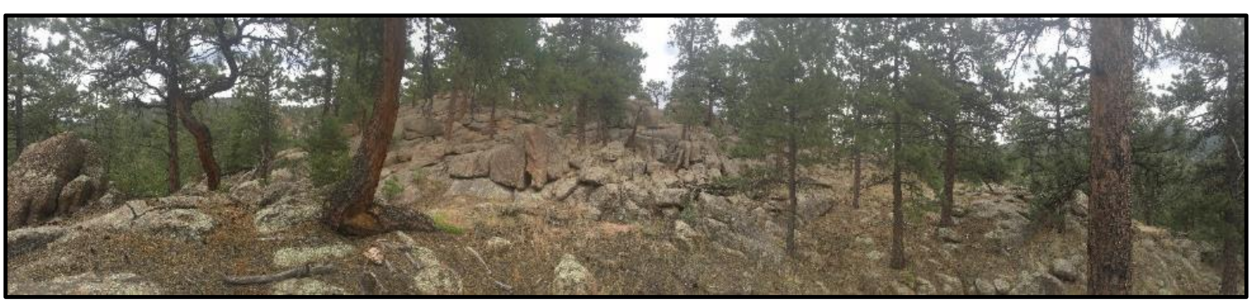
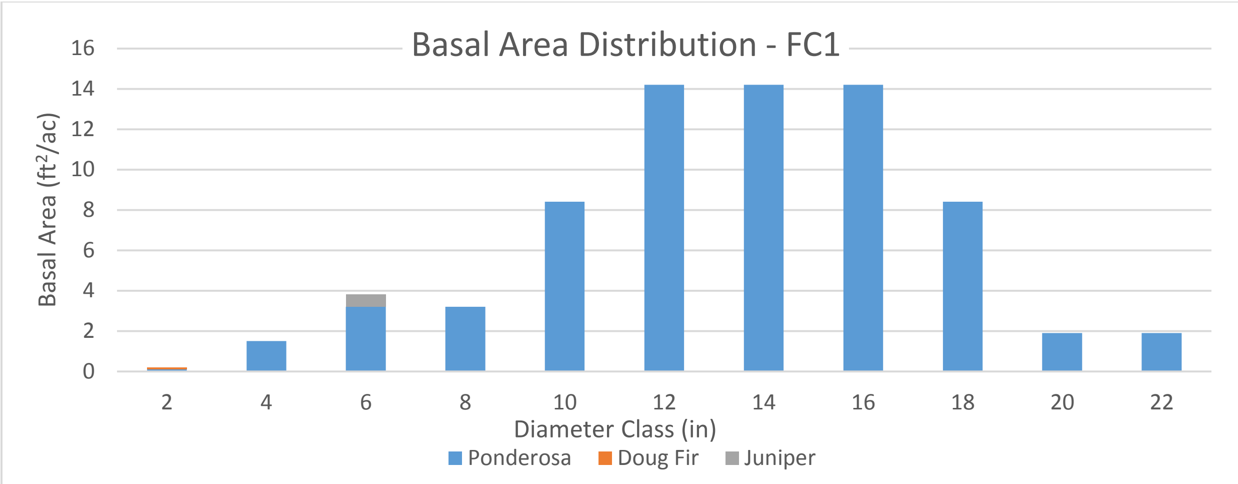


FIGURE 5.4 – Maps showing Front Country (FC), Backcountry (BC), Southshore (SS) and Mullen Park (MP) forest management units. A larger version of this map is included as Map 4 in Section 10.

5.4.1 Front Country FMU 1

Front Country forest management unit 1 (FC1) is north of North St. Vrain Creek on the east side of the preserve. It surrounds forest management units FC7 and FC8. The western side of FC1 was treated in 2007. FC1 is moderately dense with an average basal area of 72 ft^2/ac and 177.8 trees per acre. The vast majority of the stand composition is Ponderosa Pine; Douglas fir only accounts for 0.1 ft^2/ac of the basal area and Rocky Mountain Juniper accounts for 0.7 ft^2/ac of the average basal area. The picture below shows the panoramic plot photo for plot #113 in FC1 and the chart shows the basal area distribution.



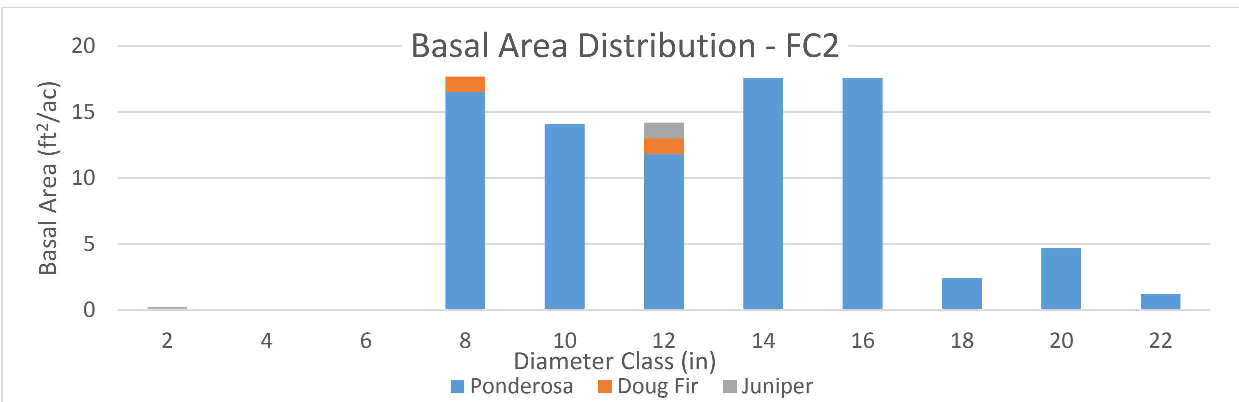


FC1 contains Cottonwood Gulch, which is the largest subwatershed between Button Rock Dam and Longmont Dam. Given this drainage immediately above the Longmont water supply intake at Longmont Reservoir, FC1 contains one of the priority treatment areas identified by the CSFS. The target prescription residual basal area (BA) for FC1 is **20 – 40 ft^2/ac.**

5.4.2 Front Country FMU 2

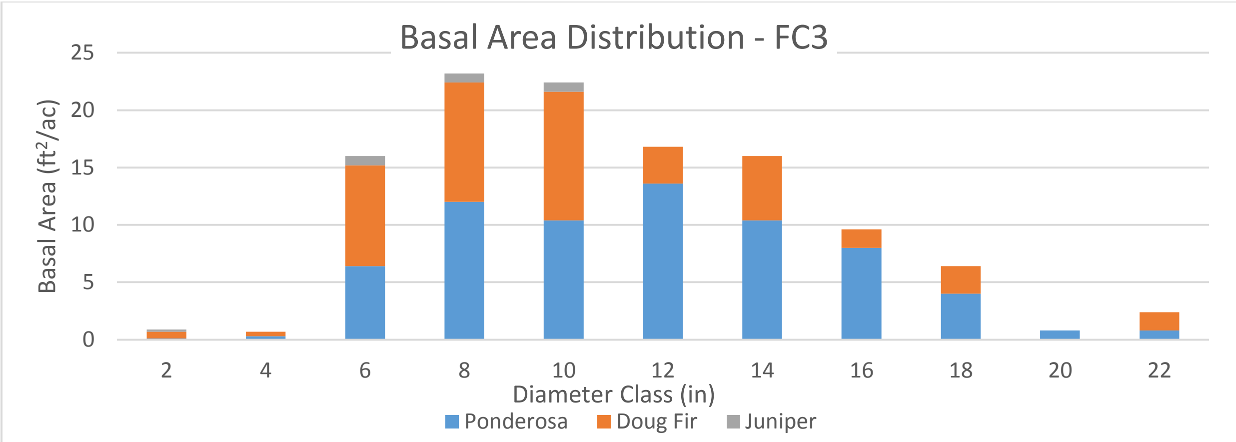
Front Country forest management unit 2 (FC2) is on the hill between Ralph Price Reservoir, the reservoir spillway, and North St. Vrain Creek immediately below Button Rock Dam. Most of the FMU was treated in 2004 as a demonstration project for the 2003 Management Plan. The east end of the FMU was also treated in 2006 and a northern piece was treated as part of the 2014 powerline cut. Given that this FMU is contiguous with the effective fire breaks of Ralph Price reservoir and the spillway, it is an important component of the landscape-wide fire mitigation strategy. It is also easily operable. This continuity with fire breaks and operability also make FMU 2 a good candidate for an initial broadcast burn in Button Rock Preserve.

FC2 is moderately dense with an average basal area of 89.7 ft^2/ac and 195.9 trees per acre. As shown in the basal area distribution chart below, FC2 is mostly comprised of large Ponderosa Pine. The lack of small diameter classes and non-pine species is likely a result in part of multiple thinning entries. The inventory photo for plots 102 (above) and 105 (below) in FC2 are also shown. Despite two previous thinning projects, FC2 is still too densely stocked. The residual target basal area for FC2 is **20 – 40 ft^2/ac.**



5.4.3 Front Country FMU 3

The FC3 forest management unit is on the south side of the property adjacent to Button Rock Dam. This north-facing management unit is the most dense in Button Rock Preserve, with a basal area of 115.3 ft^2/ac and 106.6 trees per acre. Given the mesic, north-facing nature of the management unit, it also has a relatively high density of Douglas fir. The western end of the management unit was treated in 2015 and the residual fuels were piled but not removed. The eastern end of the unit has not been treated. The panoramic photo for plot 56 is shown below.



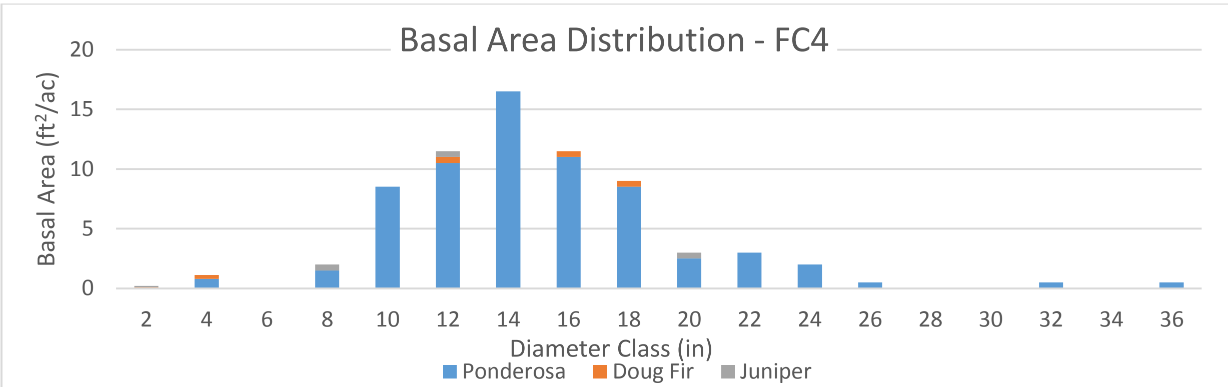
Given the dense stocking of this unit, that it drains into the Longmont Reservoir water supply without the potentially ameliorating effects of Ralph Price Reservoir, and that the unit provides flanking protection for the densely stocked and remove Southshore, it is recommended that this unit be prioritized for additional treatment and removal of fuels. The residual stand should have a basal area of **80 ft^2/ac** given the site characteristics of a high-density matrix as outlined by Addington et. al. (2016). Strategic fuel breaks with a much lower density than this target should also be considered in addition to general thinning.

To effectively manage the larger subwatershed, this work should be carried out in coordination with Boulder County and the US Forest Service, who manage the majority of the land is this subwatershed, as discussed above in Section 5.3

Residual fuels from the recent treatment should also be pile burned as soon as feasible within prescription, as discussed above in Section 5.1 and 5.2

5.4.4 Front Country FMU 4

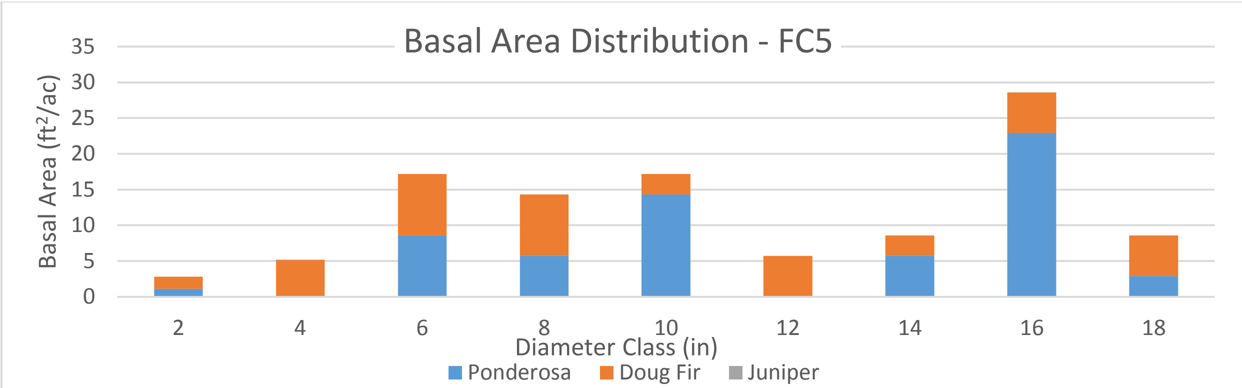
Front Country forest management unit 4 (FC4) is a relatively less dense, open stand of mostly pure Ponderosa pine on the north shore of Ralph Price Reservoir. FC4 has an average basal area of 69.9 ft^2/ac and 99.4 trees per acre. This stand structure is a result of its site conditions and south-facing aspect as well as multiple thinning entries. Different portions of the stand have been treated in different years, including in 2005, 2006, 2007, and 2011 (see Map 2).



This large stand is in relatively good shape but is also one of the more operable stands. Additional work is therefore medium priority. There is opportunity to continue to bring the basal area on this parcel down to **20-40 ft^2/ac** and maintain the open stand conditions with broadcast burning.

5.4.5 Front Country FMU 5

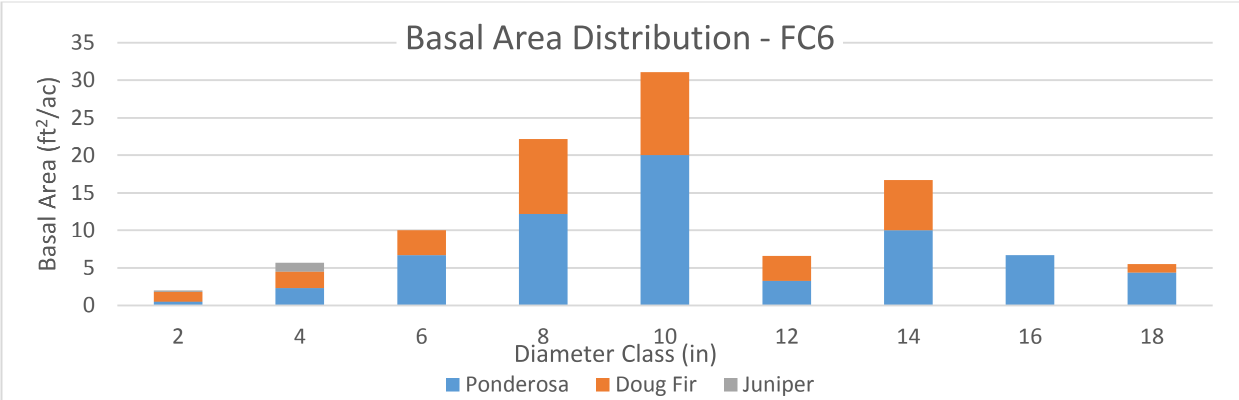
Front Country unit 5 (FC5) is a very steep parcel south of North St. Vrain Creek at the eastern end of Button Rock Preserve. This is a mesic, north-facing parcel with an average density of 431.8 trees per acre and a basal area of 110.7 ft^2/ac. This unit also has a distribution that skews toward smaller size classes and a higher component of Douglas fir, as shown in the panoramic photograph and chart below.



In addition to having steep slopes, this parcel is inaccessible due to its position on the far side of the creek from the road network. It is therefore difficult to implement management prescriptions. It will also be naturally denser and have a higher Douglas fir component that other management units due to its mesic north-facing site conditions. Additionally, although this unit is adjacent to the municipal water intake at Longmont Reservoir, the hillslope fetch is relatively short and does not collect in any particular drainage. It is therefore likely that any impact on the municipal water supply from this unit post-fire will be limited. It is therefore recommended that despite being dense, treating this unit should not be a priority. The exception is the draw located in the southwest corner along the Sleepy Lion trail, which could be treated in conjunction with work in FC6 and on Boulder County property. Where treated, the residual stand should have a basal area of **80 ft^2/ac**.

5.4.6 Front Country FMU 6

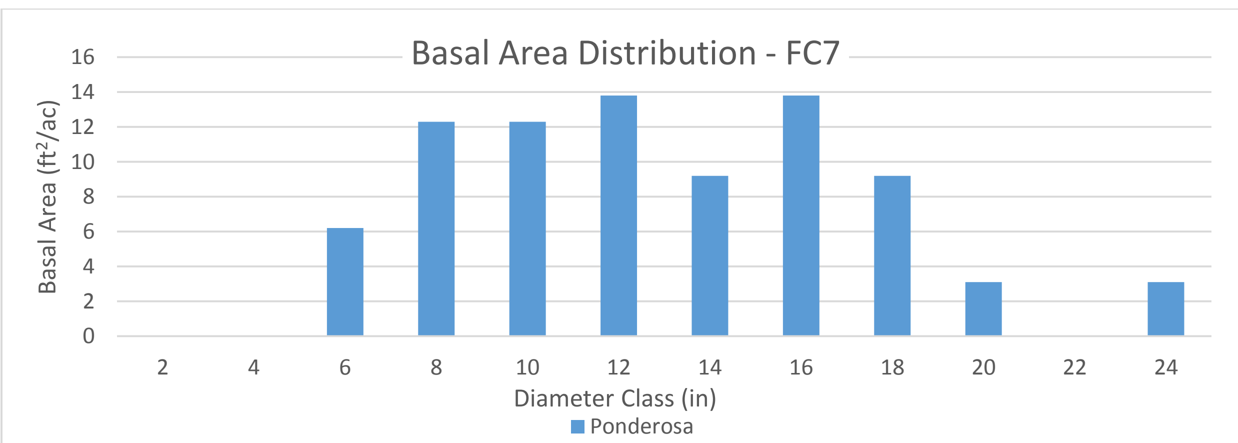
Front Country 6 (FC6) is south of North St. Vrain Creek on the west side of the Sleepy Lion trail draw. The northern sections of the management unit are steep and inoperable (see lower photo below), while the southern strip is relatively flat and open (see upper photo below). FC6 is a dense stand with an average basal area of 106.6 ft^2/ac and has the highest number of trees per acre of any stand at 462 TPA. Like FC5, unit FC6 has a relatively high proportion of Douglas fir and smaller diameter distributions due to its mesic and north-facing site conditions. FC6 has not had any historic management treatments.



FC6 impacts the Sleepy Lion trail draw, which is a potential risk to the Longmont municipal water supply. More so, it is adjacent to active management by Boulder County on Hall Ranch. There is great potential to work in partnership with Boulder County Parks and Open Space to carry out a cross-border project here that further increases the resiliency of this critical draw. **This is therefore one of the priority treatment areas identified by the CO State Forest Service (CSFS), and it is recommended that the southern strip of FC6 be heavily treated in conjunction with work on Hall Ranch**. Collaborative broadcast burning on both properties should also be considered. This section that is proposed for treatment should have a residual basal area of **20 – 40 ft^2/ac**. The steep, northern portion of the FMU should have a residual basal area of **80 ft^2/ac** if treated, although it is low priority.

5.4.7 Front Country FMU 7

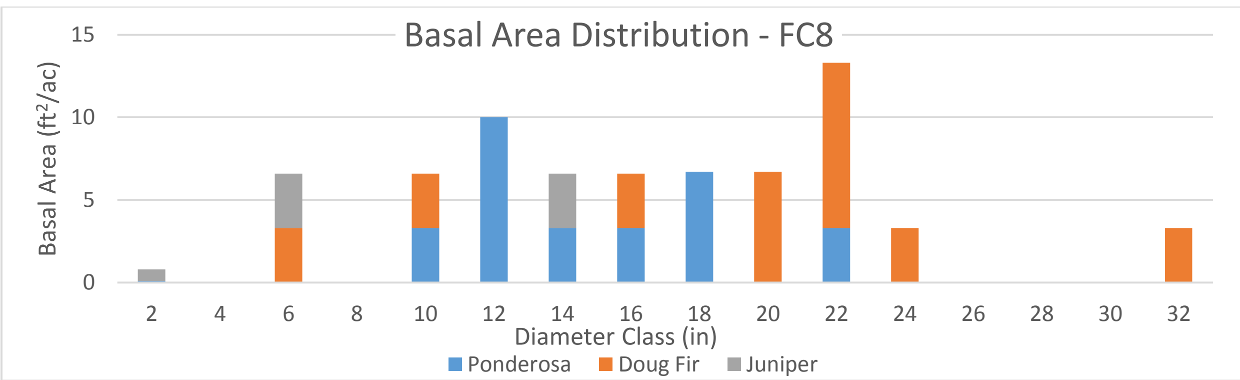
Front Country unit 7 (FC7) is a relatively small unit on the northeast end of the property. It sits on top of the steep slopes north of Longmont Reservoir and is largely surrounded by FC1. It has a somewhat higher basal area but fewer trees per acre than the surround unit FC1. Basal area is 83.1 ft^2/ac and there are an average of 126.1 trees per acre. FC7 is also characterized by a series of meadows within the ponderosa mosaic. FC7 was treated in the 2014 power line cut, which likely accounts in part for the larger diameter distribution and strong dominance of ponderosa pine.



FC7 should continue to have active management to bring the basal area down, but is lower priority than other stands due to its recent management history. Maintenance of the openings (meadows) within FC7 should be the first priority during management treatments. The strong dominance of ponderosa pine shall also be maintained through removal of all juniper and most Douglas fir regeneration. The residual stand should have a density of **20 – 40 ft^2/ac**.

5.4.8 Front Country FMU 8

Front Country unit 8 (FC8) is located within the bottom of Cottonwood Gulch, surrounded by FC1. Although the basal area is slightly less in FC 8 than FC1, there are substantially more trees per acre. Basal area is 70.8 ft^2/ac and there is an average of 226 trees per acre. Given the location of FC8 in the bottom of the drainage the site conditions are relatively mesic and have a higher component of Douglas fir, including large legacy Doug fir. FC8 has not had any management treatments.



Given that FC8 is entirely within the critical Cottonwood Gulch and is relatively dense, it should be prioritized for treatment with the caveat that it may be difficult to operate in. FC8 is immediately upstream of the CSFS recommended priority treatment in FC1. FC8 should therefore be treated in conjunction with that subsection of FC1 as far up valley as is reasonably operable. Since FC8 is naturally mesic, large dominant and co-dominant Douglas fir should be retained in addition to dominant and co-dominant Ponderosa Pine. The remnant stand should have a basal area of **40 – 60 ft^2/ac.**

In order to operate in this FMU and surrounding FMUs, an additional access road should be considered. This road should be built to connect with Longmont Dam Road just upstream from Chimney Rock Dam on the west side of Cottonwood Gulch.

5.5 Backcountry Forest Management Unit Prescriptions

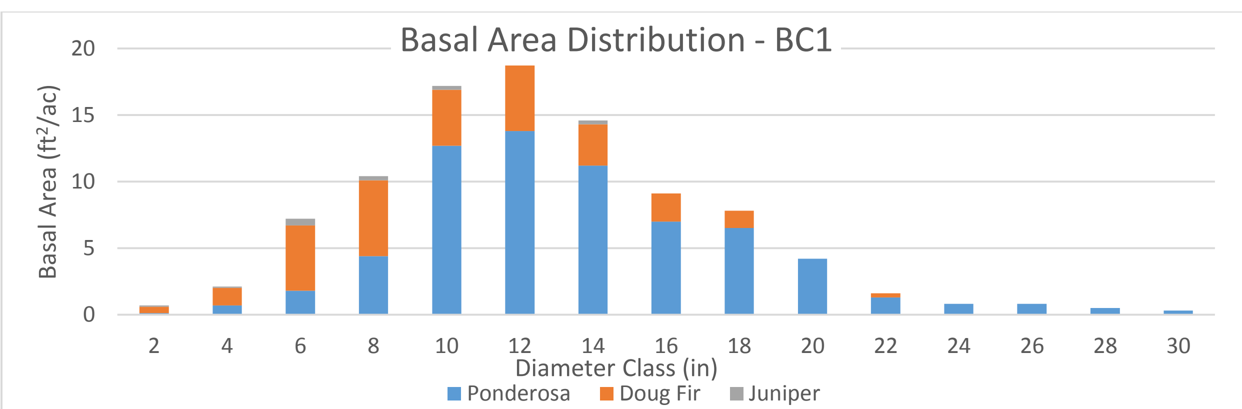
There are six “Backcountry” forest management units. All have been treated in part, but only BC2 has been treated in whole. These stands are more remote than the Front Country management units and interface less directly with infrastructure. These stands also all border on and form a matrix with the “borrow area” and west cove grasslands, which in combination provide important habitat elements and wildfire defensible space. The backcountry forest management units should be primarily managed to improve both of these matrix values through thinning, particularity at the grassland edges.

The backcountry FMUs are only accessible by a steep private road with a couple of steep switchbacks. They are therefore less accessible for removing commercial timber. If a barge is procured for Ralph Price Reservoir, however, commercial removals could be barged to a landing point by the spillway and trucked from there.

All backcountry management units are suitable for, and would benefit from, broadcast burning following mechanical treatment. Broadcast burning is also the most cost efficient way to manage fuels and maintain appropriate stand structure and density in these units long term.

5.5.1 Backcountry FMU 1

Backcountry Forest Management Unit 1 (BC1) is a large unit on the westernmost edge of Button Rock Preserve on the north and west facing slopes of Cook Mountain. Various sections of BC1 have been treated in 2009, 2010, 2011, and 2012 while the higher elevations and western edge have not been treated (See Map 4). BC1 has a very broad diameter class distribution, including some very large ponderosa pine (>26" dbh), and a moderate Douglas fir component. The management unit is relatively dense with an average basal area of 96 ft^2/ac and 285.5 trees per acre.



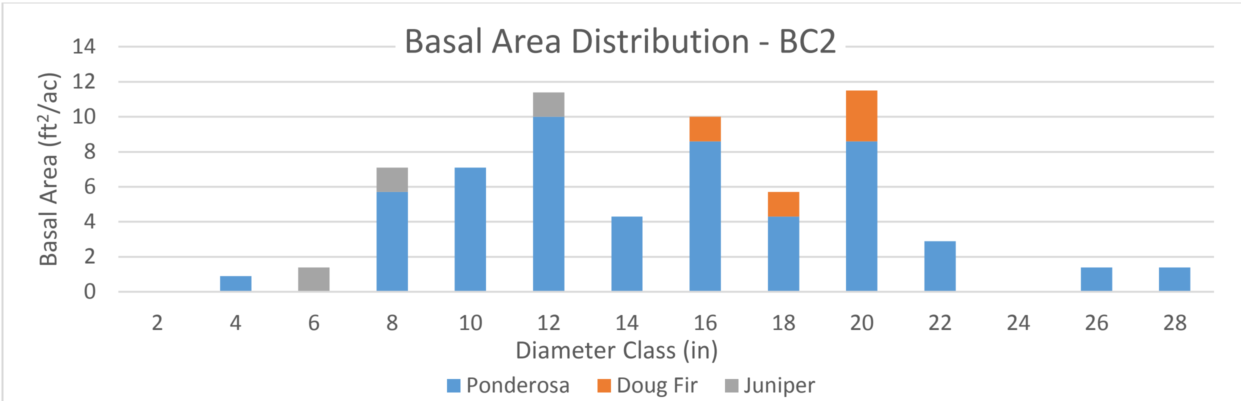
BC1 drains into Coulson Gulch and then into North St. Vrain Creek above Ralph Price Reservoir. As such, any erosion has some opportunity to be ameliorated before entering the water supply, but this unit still has large potential impacts given its size. It is also a reasonably operable unit and can act in conjunction with the other units as a landscape-scale fire break. It is therefore of moderate priority for additional treatment.

A ridgeline treatment to low stand densities (i.e. 30 ft^2/ac) to create a fuel break is recommended, as it could provide defensible space against a fire driven by upslope or downslope winds**.** Improvement of the road on the Cook Mountain ridge could both make this area more operable and enhance the ridgeline fuel break.

Treating areas of this FMU that have not yet been managed should be of secondary priority. The most value will likely be created when areas have already been treated are retreated to bring the basal area diameter distribution closer to that of the original fire-adapted system. Some large, residual Douglas fir should be retained. The residual basal area for the FMU should be **40-60 ft^2/ac**, while the northern border that interfaces with the large meadow should have a residual basal area of **0 – 20 ft^2/ac.**

5.5.2 Backcountry FMU 2

The Backcountry 2 unit (BC2) is comprised of two smaller units that interface with the large “borrow area” grassland complex. As such it is important matrix habitat and it is reasonable to assume is naturally less dense than stands not part of the grassland matrix. Currently BC2 is relatively less dense with a basal area of 65.2 ft^2/ac and 125.9 trees per acre.

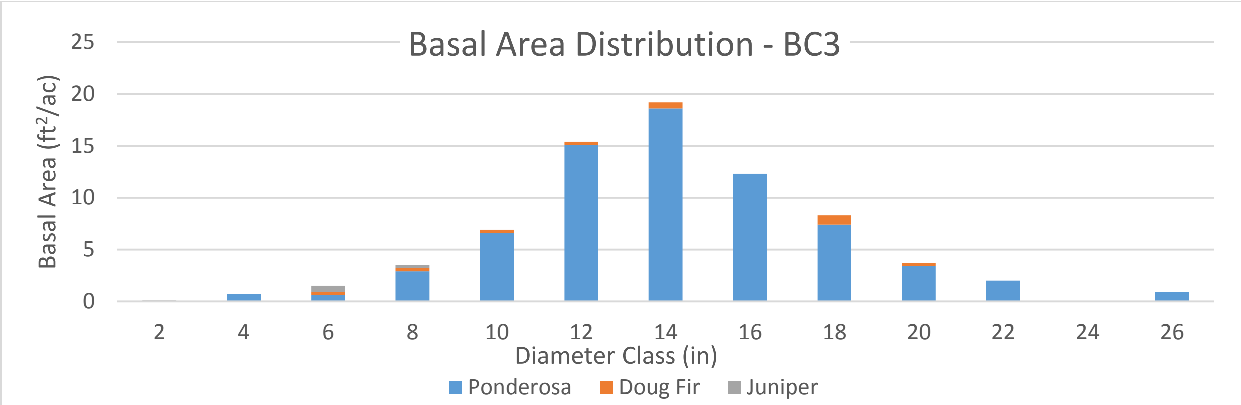


The eastern subunit of BC2 was treated in 2010 and the west subunit was treated as part of the 2013 "two pockets" thinning. The balanced diameter distribution reflects this management history, although the stands should be moved more toward dominance by larger trees. Continued management in BC2 is of moderate priority, and should be managed to provide low density forest-grassland matrix with larger diameter distributions. Some large Douglas fir should be retained, but large Ponderosa Pine retention should be prioritized. There is a higher juniper component in this FMU than others; the vast majority of juniper should be removed. The residual stand should have a basal area of **20 – 40 ft^2/ac**, while edge areas that interface with the "borrows" grassland should have a residual basal area of **0 – 20 ft^2/ac**.

5.5.3 Backcountry FMU 3

Backcountry forest management unit 3 (BC3) is adjacent to BC1 on Cook Mountain at the western end of the Preserve, and covers the east and south facing slopes. The majority of this management unit was treated in 2009 and 2010 while the higher elevations and westernmost portion remains untreated.

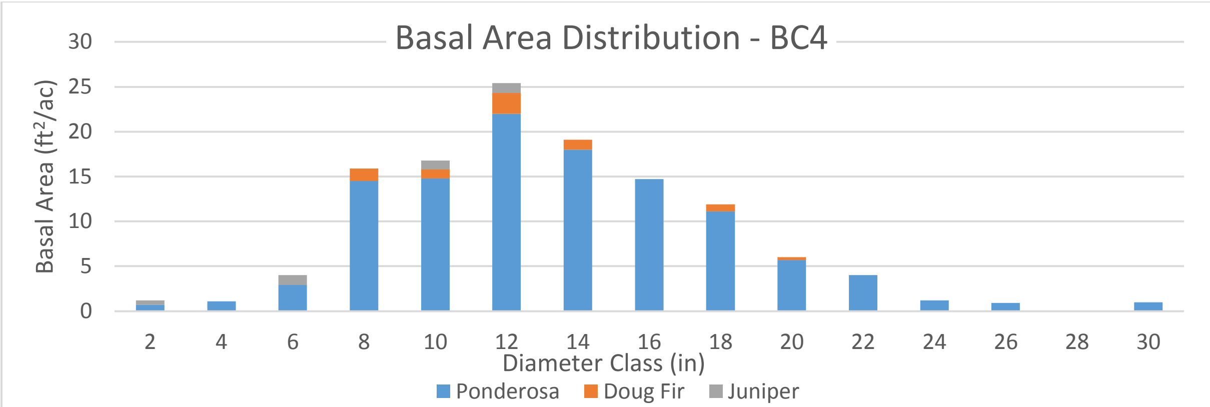
BC3 has a relatively low average basal area of 74.3 ft^2/ac and 134.6 trees per acre. This is a lower density forest than the adjacent BC1, which makes sense given the more xeric southerly aspect. It has a well-balanced diameter distribution dominated by Ponderosa Pine.



BC3 is of moderate priority for restoration. Based on its southerly aspect it should naturally have a low density forest that can act as part of the landscape-scale fuel break. It is also adjacent to the "borrow area" grassland and west cove meadow, making it a good defensible space if managed properly. Despite the well-balanced diameter distribution, it is still overly dense. Ponderosa pine should be removed in all size classes except the largest residual trees. All Douglas fir and juniper should be removed except for a very few large residual Douglas fir. The residual stand should have a basal area of **20 – 40 ft^2/ac.**

5.5.4 Backcountry FMU 4

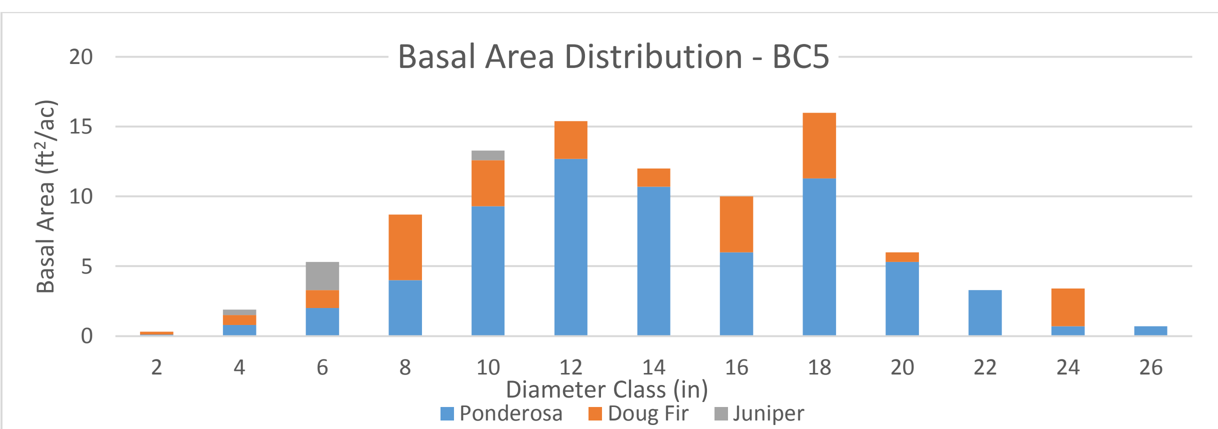
Backcountry unit 4 (BC4) is immediately west and north of the inlet to Ralph Price Reservoir. A strip on the western end of the stand was treated in 2010 but the rest of the unit has not been actively managed. Despite the lack of active management, it is an accessible unit due to an access road that bisects it. BC4 has a relatively high basal area of 104.3 ft^2/ac and a moderate stem density of 261.6 trees per acre. Diameter classes are broadly distributed and dominated by Ponderosa Pine.



The northern half of BC4 is one of the priority treatment areas identified by CSFS. This stand is overly dense and should be treated to move it toward a stand structure more appropriate of the historic structure. Removal of small diameter ponderosa should be prioritized, and all size classes other than the largest should be thinned. All Douglas fir and juniper should be removed with the exception of a very few large residual Douglas fir. The residual stand should have a basal area density of **20 – 40 ft^2/ac**.

5.5.5 Backcountry FMU 5

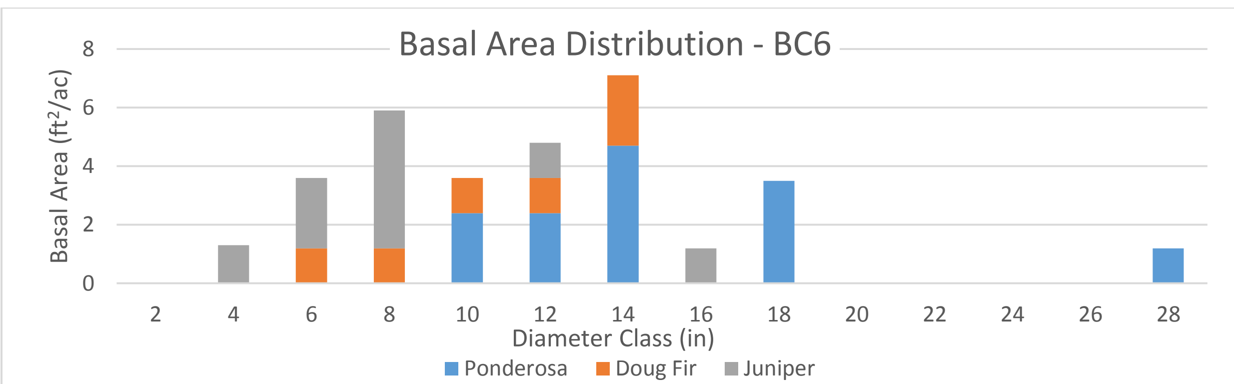
Backcountry unit 5 (BC5) is in a mosaic with BC6 on the north side of the west end of Ralph Price Reservoir. BC5 contains the denser, ponderosa dominant aspects of the mosaic. It has a moderate average tree density of 186.8 trees per acre and an average basal area of 96.2 ft^2/ac. BC5 is also adjacent to and integrates with the "borrow area" grassland matrix. BC5 has a large distribution of age classes, a relatively large Douglas fir component, and a significant component of small-diameter juniper. Portions of BC5 were treated in the 2010, 2011, and 2012 cuts. Other portions were left untreated.



BC5 is of moderate priority for treatment. Removal of small diameter trees should be emphasized, particularly where it interfaces with the grassland matrix. Nearly all juniper and most Douglas fir should be removed. Management should focus both on previously treated areas and untreated areas where operable. Slope and aspect in this FMU are heterogeneous and so treatments should likewise be variable, with an overall average residual stand density of **40 – 60 ft^2/ac**. Where BC5 interfaces with the grasslands on the west side of the FMU the residual stand densities should be closer to **0 – 20 ft^2/ac**.

5.5.6 Backcountry FMU 6

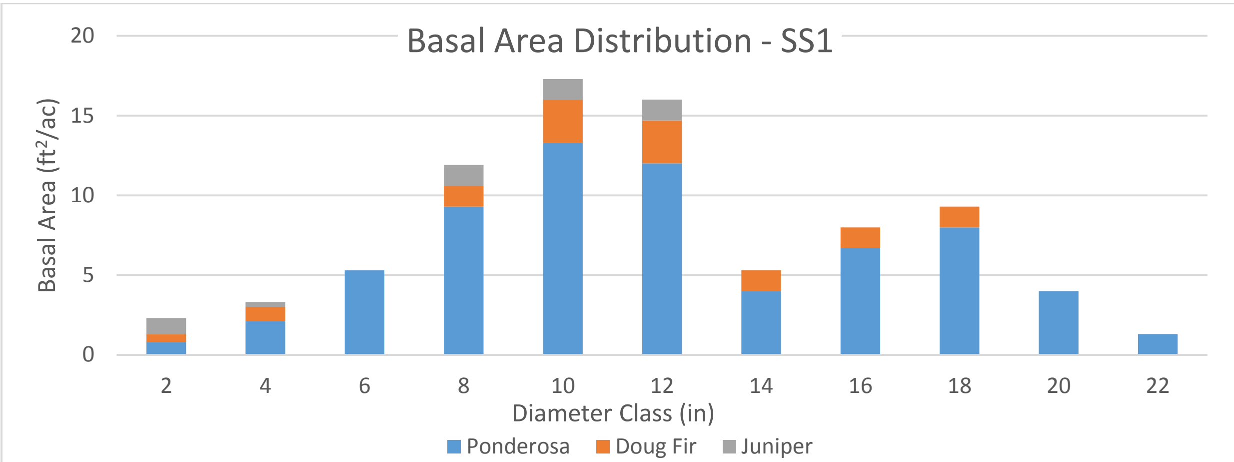
Backcountry unit 6 (BC6) is the least dense stand with an average basal area of 31.9 ft^2/ac and the second lowest stem density at 131.6 trees per acre. This is due in part to the very rocky soils. BC6 occurs in a matrix with BC5, which has deeper, less rocky soils. BC6 has a large juniper component and moderate Douglas fir component. Like BC5, BC6 was treated in portions during the 2010 - 2012 cuts.



BC6 is lower priority for management due to the less dense basal area. That said, the large juniper component is very susceptible to fire, and could provide a strong fuel break if removed. Most of the juniper and most of the Douglas fir should be removed. Ponderosa regeneration should also be removed. Since it is in a matrix with BC5, BC6 should be treated at the same time as BC5. The residual basal area should be **0 – 20 ft^2/ac.**

5.6 Southshore Management Unit Prescription

The Southshore region only includes one large forest management unit, SS1. The Southshore is a remote, inaccessible area to the south of Ralph Price Reservoir that is steep and north-facing. Consequently it is relatively dense with an average basal area of 84.3 ft^2/ac and 425.8 trees per acre. SS1 has a broad diameter distribution and relatively high Douglas fir and juniper component.



Despite being a good candidate for management treatments, the Southshore is difficult to access and operate in. **It is recommended that the City of Longmont purchase a barge that can be used to move equipment to the Southshore and remove fuels.**

If the Southshore becomes operable, the removal of small diameter Ponderosa pine and all small diameter Douglas fir should be prioritized, in addition to the removal of nearly all juniper. The residual stand density should be **80 ft^2/ac** and emphasize the retention of larger trees.

While this large unit would benefit from broadcast burning it is not likely to be logistically feasible. Steep slopes, inaccessibility, and the lack of fuel breaks on all but the northern flank would make a prescribed fire very difficult and expensive to control.

The Southshore contains two subwatersheds that have a large potential to impact Ralph Price Reservoir with sediment, debris, and ash flows after a fire. Button Rock Preserve only encompasses the lower reaches of these two subwatersheds, however, and their overall management is dependent on effective partnerships with Boulder County and the US Forest Service, who manage the majority of the land in these subwatersheds. Successful management of the Southshore will therefore ultimately depend on the nascent *Boulder County Collaborative* discussed in Section 5.3.

When collaborative projects are planned on the southshore, it is recommended that they be guided by watershed-wide fire risk and erosion modeling and should focus on creating ridgeline fuel breaks to a low density (< 30 ft^2/ac) in order to reduce the extent and spread of high-severity wildfire across these subwatersheds.

Ultimately the Southshore forest management unit is difficult to treat, but if those limitations could be overcome, active management of this unit and the larger subwatersheds to the south would potentially provide substantial wildfire mitigation benefits. Management in this forest management unit is therefore low in the short term due to these limitations but high in the long term due to the potential benefits.

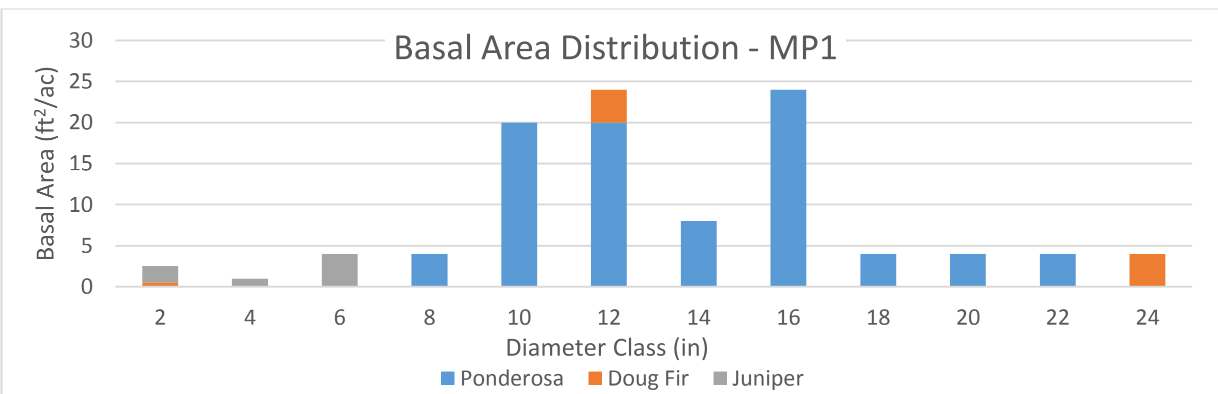
5.7 Mullen Park Management Unit Prescriptions

Mullen Park is a recently acquired section that contains two small management units. Both of these management units are being treated in the winter of 2016, but that treatment was not captured in the 2016 summer forest inventory. Mullen Park is also at the head of Cottonwood Gulch, making it a priority given that it drains directly into North St. Vrain Creek above the municipal water intake at Longmont Reservoir. While Mullen Park would potentially benefit ecologically from broadcast burning, it would require many more resources per acre given that it is surrounded by densely stocked lands with no natural fire breaks or control points and is in close proximity to private residence structures.

5.7.1 Mullen Park FMU 1

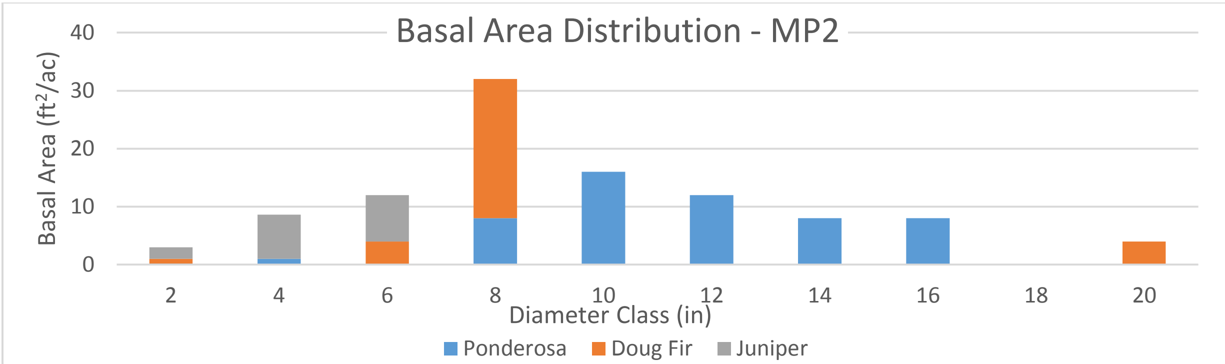
Mullen Park unit 1 (MP1), while less dense than MP2, is one of the most dense stands in Button Rock Preserve with an average basal area of 103.6 ft^2/ac and 414.5 trees per acre. MP1 is mostly smaller diameter classes with substantial small diameter juniper. MP1 should be heavily thinned with juniper and small diameter classes prioritized for removal.

The residual stand should have a basal area of **40 – 60 ft^2/ac.**



5.7.2 Mullen Park FMU 2

Mullen Park 2 (MP2) also has a basal area density of 103.6 ft^2/ac, and a stem density of 698.6 TPA, which is by far the highest in the Preserve. MP2 is also being treated in the winter of 2016, but may require further treatment given the density. Nearly all juniper and small diameter Douglas fir should be prioritized for removal. The residual stand should have a basal area of **40 – 60 ft^2/ac.**



5.8 Modeled Growth and Forest Maintenance Schedule

5.8.1 Forest Vegetation Simulator (FVS) Modeling

Every stand will continue to grow and become more densely stocked in the absence of ongoing active management, and will regrow after treatment as well. Table 5.8.1 below shows the modeled increase in basal area (BA) after a simulated harvest in 2017 down to a BA of approximately 50 ft^2/ac.

After twenty years of regrowth (*see* 2036 Live BA column) all units show substantial increases in basal area while Backcountry unit 2, Front Country unit 4, and the Shouthshore unit are denser in 2036 than in 2016 even with the simulated 2017 harvest. All FMUs continue to have minimal mortality and there is no substantial modeled increase in mortality after ten years (2026) or twenty years (2036). Appendix 4 shows the same modeling results with the addition of trees per acre (TPA) and average height. The table in appendix 4 shows that basal areas increase between 8% and 24% in the ten year period between 2026 and 2036 but there is no increase in the trees per acre. This shows that most of the modeled increases occur in the residual stand. From a fire mitigation perspective this is more resilient than a flush of regeneration after thinning. It should be remembered that this is just a modeled result and the stands should be adaptively managed based on the actual post-thinning regrowth.

TABLE 5.8.1 – Ten-year modeled changes in basal area (BA) in ft^2/ac for all forest management units (FMUs). Inventoried basal area from 2016 inventory. Results show modeled harvest in 2017 that reduces all Stand BAs to approximately 50 ft^2/ac and subsequent regrowth. Modeled using the Forest Vegetation Simulator (FVS). Full results including trees per acre (TPA) and average height shown in Appendix 4.

Stand ID	Inventoried Live BA (2016)	Inventoried Dead BA (2016)	Harvested BA (2017)	2026 Live BA	2026 Dead BA	2036 Live BA	2036 Dead BA
BC 1	88.8	7.2	- 33.6	62.8	0.7	71	0.8
BC 2	63.8	1.4	- 5.2	70	1	80.9	1.1
BC 3	72.9	1.4	- 20.5	56.6	0.9	61.4	0.8
BC 4	103.4	1	- 47.7	67	1	77.5	1
BC 5	94.9	1.3	- 35.9	68	0.8	76.8	0.8
BC 6	31.9	0	- 0	41.3	0.5	51.3	0.6
FC 1	72	0	- 19.4	56.5	0.9	60.9	0.9
FC 2	89.7	0	- 37.3	63.4	1	73.6	1.1
FC 3	112.1	3.2	- 60.5	62.7	0.7	74.1	0.8
FC 4	68.9	1	- 11.4	63.7	0.9	70.4	1
FC 5	110.7	0	- 57.9	63.4	0.6	73.8	0.7
FC 6	104.4	2.2	- 54.4	62.7	0.7	75.2	0.8
FC 7	83.1	0	- 32.3	54.2	0.8	58.3	0.9
FC 8	70.8	0	- 20.8	57.3	0.6	64.6	0.7
MP 1	103.6	0	- 45.6	68.6	0.9	78.5	1.1
MP 2	103.6	4	- 49.6	69.1	0.9	83.7	1.1
SS 1	76.3	8	- 25	64.1	0.9	76.7	1.1

5.8.2 Long Term Maintenance Treatments

Once appropriate stand densities have been achieved through mechanical treatment, broadcast burning is both a cost effective and ecologically effective means of retreatment, as discussed in Section 2.4. If broadcast burning is not feasible, mechanical treatment followed by pile burning or mechanical removal of fuels is an acceptable substitute. In either case, it is necessary to burn or remove the fuels, particularly fine fuels such as branches, so that they are not simply redistributed.

Mechanical retreatments have are potentially very expensive in the long term. **Use of volunteers or youth groups should be implemented wherever feasible** both for economic reasons and to vest the local community in Button Rock Preserve, their water supply, and wildfire resiliency. While volunteers and youth groups cannot generally operate equipment or chainsaws, they can be effective cutting regeneration and limbing using hand tools. Youth groups are currently effectively used in Button Rock Preserve for moving and sorting fuels (slash) as well.

5.8.3 Long Term Maintenance Schedule

It is necessary to regularly maintain all treated units both to ensure they remain within the historic range of variability, and to maintain wildfire resiliency gained through lower stand densities. A roughly fifteen-year rotation of retreatments should be established. In general, FMUs that have least recently been treated should be prioritized for retreatment. Prioritization should also consider if the initial treatment achieved the desired outcomes, wildfire risk, and if there is integration with ongoing partnership projects with other large landholders in the North St. Vrain Creek watershed. Table 5.8.2 below summarizes the treatment priorities discussed in Sections 5.4 – 5.7.

TABLE 5.8.2 – Summary of treatment priorities for forest management units (FMUs) in Button Rock Preserve

FMU	Treatment Priority	Notes
FC 1	High	Includes area prioritized by CSFS. Directly impacts Longmont Reservoir and the municipal water supply.
FC 2	Moderate	Treated twice previously but still too densely stocked.
FC 3	High	Densely stocked and the subwatershed directly impacts Longmont Reservoir and the associated water supply. Areas that have not been previously treated may be difficult to operate in.
FC 4	Moderate	Large stand that has been previously treated but is still too dense.
FC 5	Low	Although it is adjacent to Longmont Reservoir the potential direct impacts are limited. Difficult to operate in.
FC 6	High (southern) & Low (northern)	Prioritized by CSFS on the flat, open, south side where it is adjacent to Hall Ranch. Steep north slopes are inoperable.
FC 7	Moderate	Previously treated but still overly dense.
FC 8	High	Surrounded by FC 1. May be difficult to operate in.
BC 1	Moderate	Remote but large FMU. Most has been previously treated but is still too dense.
BC 2	Moderate	Previously treated. Creates matrix with “borrows” grasslands.
BC 3	Moderate	Large remote unit. Previously treated in part.
BC 4	High	Priority treatment identified by CSFS. Adjacent to Ralph Price Reservoir inlet. Good opportunity to extend landscape-scale fuel break created by Ralph Price Reservoir and grasslands.
BC 5	Moderate	In matrix with BC6. BC5 contains the denser portions of the matrix.
BC 6	Low	Relatively less dense, but large juniper component that could limit effectiveness of fuel break.
SS 1	Moderate	The Southshore unit has good potential for restoration and fire mitigation work, but is difficult to access and operate in. Subwatersheds have large potential impacts, but mostly from other land ownerships south of the Button Rock boundary. “Moderate” priority due to the inaccessibility and greater potential impact of projects on non-City of Longmont land.
MP 1	Low	Mullen Park is being treated in the winter of 2016-2017. Further prioritization depends largely on residual basal areas after treatment.
MP 2	Low	

SECTION 6. Community Wildfire Protection Plan

Button Rock Preserve is addressed in the Community Wildfire Protection Plan (CWPP) developed by the Lyons Fire Protection District (FDP) in 2011[1]. Button Rock Preserve is included as the western portion of the CWPP's North St. Vrain / Longmont Dam Road neighborhood, and many of the prescriptions in the CWPP address the Preserve directly. Figure A-12 from the Lyons CWPP is shown below, and highlights recommended mitigation projects.

6.1 Structures & Defensible Space

The Detailed Community Assessment for the North St. Vrain neighborhood in the Lyons CWPP ranks the overall neighborhood risk assessment as *High*. The high risk in the neighborhood is attributable to 1) the distance from the nearest fire station and corresponding response times greater than 20 minutes, 2) lack of creation of defensible space around many of the homes adjacent to Button Rock Preserve, and 3) the limited availability of water to fight fires other than from the reservoirs. This *High* risk assessment highlights the need for overall wildfire resiliency in Button Rock Preserve and the greater North St. Vrain neighborhood.

The forest management prescriptions detailed in Section 5 will create fuel breaks that will mitigate some of this risk and add to the defensible space in the neighborhood.

6.2 Egress

The primary egress for Button Rock Preserve and the North St. Vrain neighborhood was identified as Longmont Dam Road. There are no good alternate egress points from the neighborhood, so protection of the egress along Longmont Dam Road is a neighborhood priority.

The CWPP highlights the need to identify emergency egress routs in the event that Longmont Dam Road is not safely passable. Emergency egress is discussed in Section 7.1, below**. It is recommended that this additional egress be improved, and better defensible space be created around the existing primary egress along Longmont Dam Road.**

6.3 Collaborative Action

Button Rock Preserve is in the Lyons Fire Protection District, and is accounted for in the Lyons CWPP. Lyons FPD is a primary partner in wildfire mitigation and management in Button Rock Preserve. Lyons FPD is the primary incident response team for Button Rock Preserve.

[1] http://lyonsfire.net/Lyons%20FPD%20CWPP%20Complete.pdf

The Lyons CWPP shows proposed wildfire mitigation projects on US Forest Service land adjacent to Button Rock Preserve (fig. A-12). Collaboration with the US Forest Service on fuel breaks and other wildfire mitigation projects is a keystone of wildfire resiliency in Button Rock Preserve.

6.4 CWPP Identified Priorities

The Lyons CWPP identifies the land north of Ralph Price Reservoir as a prioritized fuel break (p.17), and "Watershed Mitigation" throughout the Button Rock Preserve land base as a proposed mitigation project (Fig. A-8).

The CWPP further highlights mitigation along Longmont Dam Road, identification and creation of safe zones, and identification and improvement of water supply points. In 2014 the forest management treatment ("Powerline Cut") focused on increasing the defensible buffer along Longmont Dam Road and the primary road to the Ranger station and north side of the Preserve.

In 2016 the Colorado National Guard carried out a multi-week exercise using Ralph Price Reservoir as a water source for helicopter firefighting operations. This exercise demonstrated that the reservoir is a great water source for these operations, and training should continue here so that local helicopter firefighting resources are already familiar with the area.

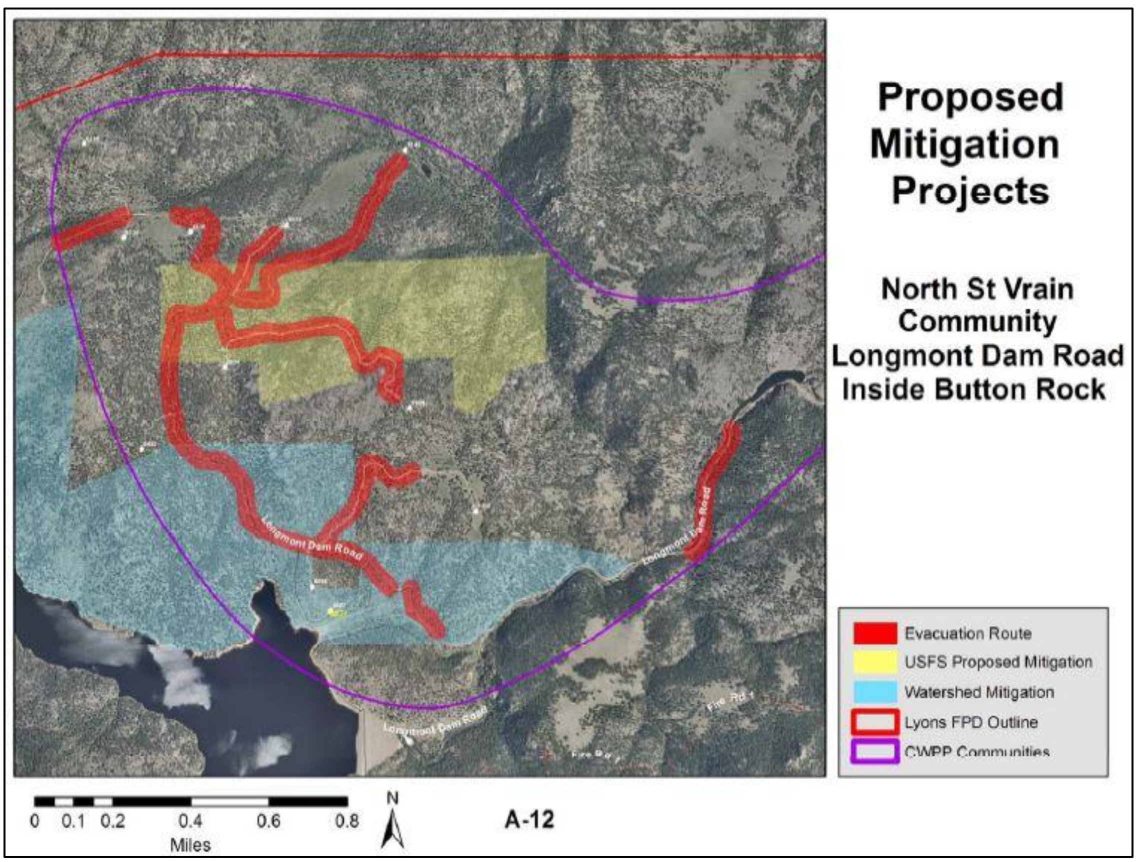


Figure A-12 from Lyons CWPP (2011) showing proposed wildfire mitigation actions in Button Rock Preserve.

SECTION 7. Access and Recreation

The primary access and egress point from Button Rock Preserve is Longmont Dam Road (Boulder County Road 80), which runs 1.75 miles from the Preserve's entrance to the base of Button Rock Dam. Longmont Dam Road has limited access to vehicles beyond the entrance to the Preserve. Only residents, staff, and contractors are generally allowed to drive on the road. There is open pedestrian access however, and it is used heavily as a trail by hikers and anglers.

Internal roads continue from Longmont Dam Road to access the north side of the Preserve and several private homes. Button Rock Preserve also has four trail systems including the North Shore / Fisherman's trail, South Cove Trail, Cook Mountain Trail, and Sleepy Lion trail. The road and trail system of the Preserve is shown in Map 3. Other than along the South Cove Trail, the southwest side of Button Rock Preserve is inaccessible by either road or trail.

It is recommended that a more detailed Access Management Plan be developed and appended to this Forest Stewardship Plan to ensure resilient emergency access and egress, as well as infrastructure for carrying out forest stewardship activities.

7.1 Emergency Egress

Vehicular Egress

Currently the only access point that is accessible by most vehicles is Longmont Dam Road. This single access point is vulnerable to natural disturbances such as fire and flooding, as was demonstrated during the September 2013 floods when the road was largely destroyed. It is therefore necessary to improve and maintain secondary access and emergency egress roads from Button Rock Preserve.

The Sleepy Lion Road that connects with Hall Ranch (Boulder County Open Space) was made passable for four-wheel drive vehicles after the flood and is currently the best emergency egress route. **It is recommended that this road be further discussed with Boulder County Parks and Open Space for improvement in order to provide a more resilient emergency egress route.** Additionally the City of Longmont could partner with Boulder County Parks and Open Space to improve their section of the road. In addition to improved emergency egress, an improved road in this location will greatly aid the ability to conduct forest management prescriptions on the south side of the Preserve. This road is also accessible from the eastern terminus of the Sleepy Lion trail by foot, adding to its value for emergency egress.

An additional emergency egress road runs from the north side of the Preserve through private property, US Forest Service Land, and Boulder County Open Space property to rejoin Longmont Dam Road a mile below the entrance to the Preserve. Currently sections of this road are only passable by small all-terrain vehicles (ATVs). It is also recommended that this emergency egress route be improved sufficiently for passage by at least four-wheel drive vehicles. As the September 2013 flooding event has shown, it is vital to have emergency egress both on the south and north side of the preserve when future natural disasters occur.

Additional Egress

Two trails on the western end of the property can be used for emergency egress by foot traffic. These are the Coulson Gulch trail and an unmaintained trail on the ridgeline between Coulson and Rattlesnake Gulches, both of which lead to the Johnny Park trailhead off of County Road 47. The trail up Rattlesnake Gulch is potentially passable with a four wheel drive vehicle if it receives some improvement**. It is recommended that the City work with the USFS to determine if improving this access road is beneficial to overall resource management including emergency egress.**

Multiple locations are suitable for evacuation by helicopter (helivac) in the event that the other emergency egress routes are not accessible. The primary helivac landing zone is Mullen Park, which is at a high point central to the ranger station and private residences. **The Mullen Park helivac landing zone is shown on the Map 3 and is centered on a point: 40° 14.08'N x 105° 22.60'W** (UTM Zone 13T 467933m E 4453890m N; Military grid 13TDE6793253890)**.** The meadowlands on the western side of the Preserve ("The Borrows") can also be used as a helivac site, are shown on Map 3, and are centered on a point at 40° 13.85'N x 105° 23.78'W. There are also two suitable landing zones near the west end of the reservoir.

7.2 Forest Management and Firefighting Access

The road and trail system in Button Rock Preserve has been used extensively to carry out the forest management goals of the Forest Stewardship Plan and can also provide access for firefighters in the event of a wildfire.

It is recommended that the Sleepy Lion Road be improved in order to allow better access for forest management in addition to the emergency egress discussed above. Currently the road is insufficient to allow the removal of fuels from the forest, which is a key element of the forest management prescriptions. Sufficient access to remove fuels from treatment areas will greatly increase the effectiveness of the entire Forest Stewardship Plan.

In addition to improvements to the road system, forest management and wildfire response will be greatly aided by improvements to the trail system on the south side of the preserve. The portion of the Preserve south of Ralph Price Reservoir is currently largely inaccessible despite the fact that it is at high risk for severe wildfire. It is recommended that the Sleepy Lion trail should continue from where it intersects the Sleepy Lion Road to the top of Button Rock Dam by following the contour of the hillside.

Trail improvements will increase access to the south side of the Preserve, aiding forest management and increasing recreational opportunities in the Preserve.

7.3 Recreation Access

Button Rock Preserve is heavily used by Longmont residents and other communities of the northern Front Range for hiking and angling. The most heavily used areas are along the eastern end of Longmont Dam Road at the entrance to the Preserve, and use decreases with distance west from the entrance gate. Sleepy Lion Trail, which is the easternmost trail, is the most heavily used trail after the road itself. All of the trails on the eastern end of the Preserve are used regularly and link with Hall Ranch so any improvements to the trail system will benefit recreation in the preserve in addition to providing forest management capacity. Angling use is also highest near the eastern entrance and decreases to the west.

Fishing below Button Rock Dam is open to anyone with a Colorado state fishing license, while fishing in and upstream of Ralph Price Reservoir requires a special City permit. This additional requirement reinforces the heavier angling use of the eastern end of the preserve.

There is concern that improving Sleepy Lion Road will reduce the trail-like characteristics that make it appealing to hikers. It is therefore advisable to improve the road in concert with continuing the Sleepy Lion Trail along the contour from where it meets the road to the top of Button Rock Dam. This would allow hikers to continue to enjoy the trail environmental all the way to the reservoir in addition to providing some forest management access by foot.

The trail system on the west end of the Preserve is less heavily used than the east side, but still receives regular use, primarily for angling access. The west side of the Preserve can be accessed either from the east entrance or from the Johnny Park Trailhead off of County Road 47 via the Coulson Gulch or Rattlesnake Gulch trails.

SECTION 8. Post-Wildfire Mitigation Planning

Proper planning for post wildfire response will allow the City of Longmont to respond quickly and effectively to the effects of wildfire, which will in turn help maintain the high quality water supply (Objective 1), maintain resiliency in the face of natural disaster (Objective 2), and maintain a healthy forest matrix ecosystem (Objective 3).

There are many post-wildfire mitigation strategies that include contour felling trees, creation of sedimentation basins, seeding, and mulching (Napper 2006). Many of these have limited demonstrated success, however. From consultation with John Moody and Deborah Martin at the USGS (personal communication, August 3, 2016) and City of Longmont natural resources staff, **the following mitigation strategies were prioritized and are hereby recommended for Button Rock Preserve in the event of a wildfire:**

- Leverage the ability of Ralph Price Reservoir to act as a sedimentation basin to manage debris flows
  - ✓ Deploy floating booms to capture debris flows as soon after a fire as feasible
  - ✓ Develop a barging system to excavate and remove those debris when the reservoir is lowered

- Develop a strategy for wood strand mulching
  - ✓ Respond to burn scar areas with wood strand mulching as soon after a fire as feasible
  - ✓ Work with US Forest Service's BAER and NRCS's EWP programs to fund mulching program
  - ✓ Identify appropriate weed-free wood strand sources ahead of time
  - ✓ Consider producing wood straw on-site from burned materials after fire

Given that the erosion impacts on a burned hillside are greatest in the first season after a fire, by an order of magnitude (Robichaud et. al. 2013 a), it is imperative that these post-fire mitigation measures are implemented in as timely as a manner as possible. The greatest risk is from thunderstorm rain events that occur in the same year as the fire. The City of Longmont should therefore plan ahead for post-fire mitigation as much as possible in order to ensure a timely implementation. An emergency wildfire response plan is included in this Forest Stewardship Plan as Appendix 3**. It is recommended that this plan be kept up to date so that it can guide the immediate post-fire response.**

8.1 Managing Debris Flows

As discussed in Section 2.3, a primary impact of wildfire on a watershed is the post-fire increase in runoff, sediment, debris, and ash flows. For the majority of the municipal watershed that is above Button Rock Dam, this increased runoff will be intercepted by Ralph Price Reservoir. The reservoir will store sediments and debris, and the residency time of water in the reservoir may help to mitigate some of the impacts of ash and other increases in nutrient load.

In order to effectively isolate sediment, debris, and ash so that they can then be removed it is recommended that the City of Longmont pre-purchase debris and sediment booms similar to the boom already installed at the inlet to Ralph Price Reservoir. These booms can then be deployed to the affected drainages after a fire. **Anchors for these booms should be pre-installed in all of the major side**

drainages to flow into Ralph Price Reservoir to further aid quicker deployment. Given that the greatest impacts to a watershed often occur in during summer thunderstorms in the months following a fire, quick deployment of these measures is vital. A two-stage boom system is recommended. The first stage should be a large boom capable of intercepting large woody debris. The second stage should be designed to capture floating ash and other debris, and should not have any gaps in the boom. A quote for a potential boom system is included in Appendix 3.

In order to remove sediment, debris, and ash that accumulates in Ralph Price Reservoir, the City of Longmont should purchase or pre-plan for a barge and excavator that is capable of removing the sediments captured behind these booms. This reservoir level can be lowered to make these debris accessible for removal. By planning to capture and then remove as much of the sediment, debris, and ash that will occur as part of the post wildfire runoff, impact to the Longmont municipal water supply can be partially mitigated.

8.2 Wood Strand Mulching

Of the many methods employed to mitigate post-wildfire erosion, mulching with wood strands (also known as wood shreds or Wood Straw ®) has been the most relatively successful (John Moody and Deborah Martin, USGS, personal communication August 3, 2016). Mulch reduces the impact of rain water drops on the soil surface, slows runoff so that it has time to absorb into soils, and has potential to slow the erosive process by creating small scale barriers to sediment movement. There are multiple types of mulch including hydromulch, straw mulch, and wood strand mulch. While all of these are initially effective, wood strand mulch has vastly superior residence time on the ground since it is much less susceptible to both wind and water displacement (Robichaud et. al. 2013 a). This is a key consideration given the high winds and steep slopes in Button Rock Preserve.

A significant risk in mulching is the introduction of non-native plants, particularly noxious weeds. Even mulches that are 99% weed free have the potential to spread weeds on the scale of post-fire watershed mulching. It is therefore strongly recommended that very high quality sources of wood strand mulch are identified ahead of time before a wildfire occurs. Local sources have a much lower chance of introducing non-native invasive plants (Robichaud et. al. 2013 b), therefore production of wood strand mulch from Button Rock Preserve or adjacent properties is preferred. This also serves a logistical benefit of not having to haul wood or mulch long distances. Either green trees or wood from within the burn area can be used to create wood strand mulch. Standing dead trees from within the burn are drier and therefore produce lighter mulch than green trees, but the charcoal component of these tress can be a potential nuisance. If green trees are harvested for mulching purposes, that harvest should follow the forest management prescriptions laid out in this document. The USDA Forest Service Rocky Mountain Research Station General Technical Report 307 (RMRS-GTR-307) has information on the production of wood shreds (Robichaud et. al. 2013 a).

Funding is a major constraint to the effective implementation of a wood strand mulch emergency response program. Given it's heavier weight, wood strand mulch is much more expensive to spread using helicopters than wheat straw ($2,000 per acre vs. $500 per acre). This cost comes from the need to spread at least 6 tons of wood strand mulch per acre to achieve the 60% ground coverage that is recommended as a minimum to effectively mitigate runoff effects (Robichaud et. al. 2013 b). In the event of a large fire, much of this cost burden on US Forest Service property in the North St. Vrain Watershed will be managed by the Burned Area Emergency Response (BAER) that is part and parcel of the federal fire response. Good cost share funding for Button Rock Preserve, private lands, and Boulder County lands is likely available through the NRCS Emergency Watershed Protection (EWP) program.

In the event of a fire, City of Longmont staff and municipal leaders should reach out to and work directly with the BAER and EWP post-fire emergency response teams. Current contact information for the BAER and EWP leads and other relevant information regarding the programs are contained in Appendix 3, the Post-Fire Emergency Response Plan.

SECTION 9. River System Prescriptions & Implementation

9.1 Flood Recovery

In September 2013 North St. Vrain Creek experienced an approximately 500-year flood event, as discussed above in Section 2.5. Since the flood, the damaged infrastructure of Button Rock Preserve was repaired and a river restoration process started. The river restoration process in Button Rock Preserve focuses on aiding the natural recovery process by recreating naturalistic channels using the tenants of natural channel design, and replanting the riparian plant corridor.

In March 2016, Boulder County in partnership with the City of Longmont implemented a river restoration project along 1,600 linear feet of North St. Vrain Creek on the eastern edge of the Preserve. This is considered Phase 1 of the river restoration program in Button Rock Preserve, and was completed using flood recovery funding from CDBG-DR.

Phase 2 of the river restoration program was designed in the summer of 2016 and covers the 1.5 miles of river between the inlet of Longmont Reservoir on the downstream end and the confluence with the Ralph Price Reservoir spillway on the upper end. This Initial (30%) Design demonstrates the need for extensive in-channel and riparian restoration in this reach, as well as addressing fish passage issues.

The most significant barrier to fish passage is at Chimney Rock Dam, which was scoured during the 2013 flood. This barrier was passable before the flood but is not passable as of August 2016. Other potential barriers to fish passage may exist at the box culvert immediately upstream of Chimney Rock Dam, and at the secondary / bypass diversion structure 0.4 miles upstream of Longmont Dam.

The first stage of Phase 2 will focus on the uppermost and downstream most subreaches in this reach. A second stage to be completed will focus on the middle subreach that contains Chimney Rock Dam. In addition to in-channel and riparian restoration, this middle subreach will focus on providing fish passage past Chimney Rock Dam and the box culvert upsteam.

While these two stages go a long way toward restoring the river from the effects of the September 2013 floods and subsequent emergency infrastructure recovery, they are still insufficient to recover the river fully. **It is recommended that the City of Longmont continue to develop funding for the river restoration program so that the design created in 2016 can be carried to completion.**

North St. Vrain Creek on the west end of the Preserve upstream of Ralph Price Reservoir (the “inlet”) was also impacted by the September 2013 floods. **Given the wilderness character of this reach, and given that there was no infrastructure in place or infrastructure repair to affect the natural recovery of this reach, it is recommended that this reach be allowed to recover naturally.** It is believed that the large amount of fresh sediment in this reach has aided hyporheic flow and other habitat features such that it currently provides high-quality cold water fishery habitats.

9.2 Riparian Restoration

Restoration of the riparian plant community is an integral and essential part of the ongoing flood recovery process. While natural riparian recovery is ongoing throughout entire reach of North St. Vrain

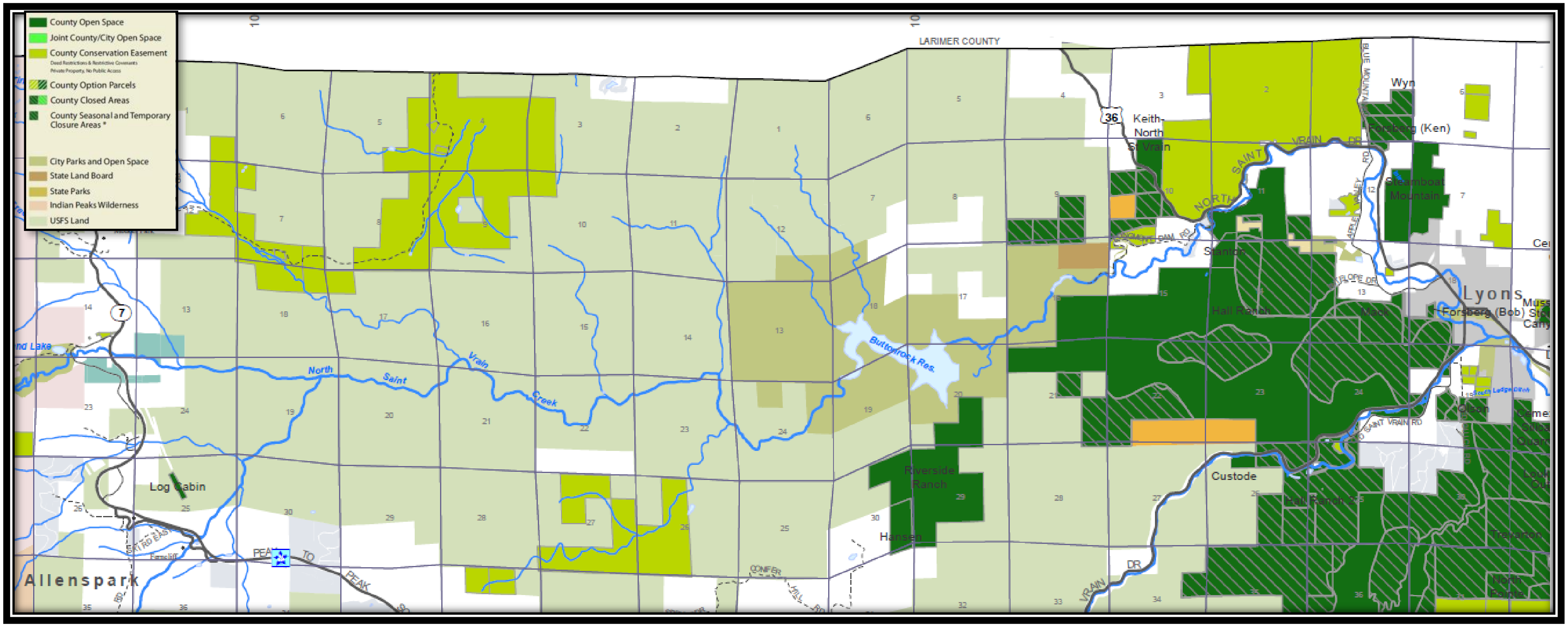
Creek in Button Rock Preserve, progress is slow and active riparian restoration will help the process substantially.

The Initial 30% Design that was created in 2016 highlights the need to use native plant species and diversity, particularly those ecotypes sourced from within the Preserve, when restoring riparian areas. This more closely mimics the natural recovery process, aids that natural recovery process, and provides for a diverse and resilient riparian corridor once reestablished. Some of the riparian restoration that occurred during the emergency infrastructure repairs overemphasized the use of willow, particularly coyote willow (*Salix exigua*), which may ultimately reduce the diversity and resiliency of the riparian corridor. **It is recommended that riparian restoration moving forward emphasizes the diversity described in the Initial 30% Design.**

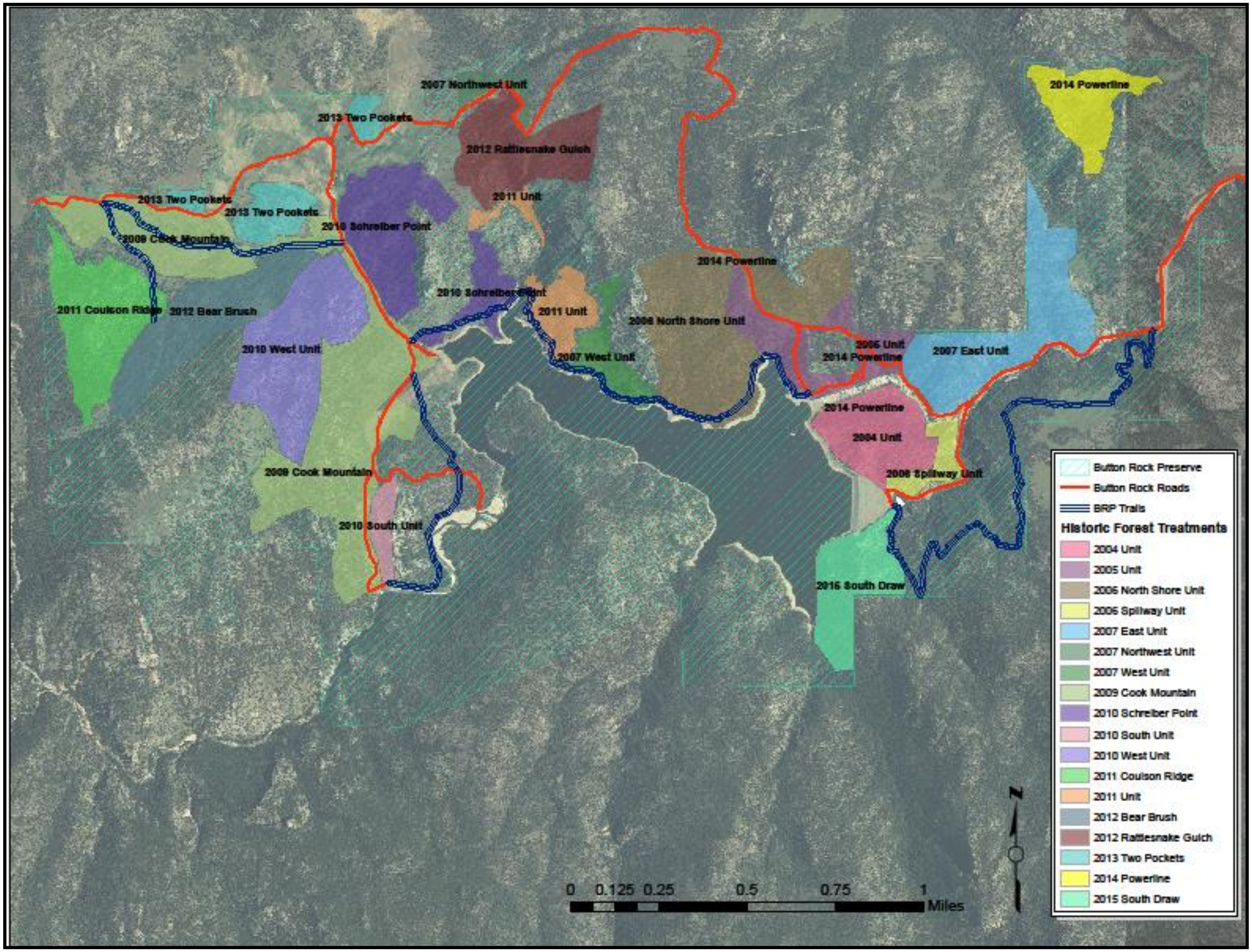
The purpose of riparian restoration is to speed up and compliment the natural recovery that occurs after disturbance events such as the September 2013 event. Active riparian restoration work should therefore not compete with the natural restoration process. That is, riparian plantings should not be made that directly compete with natural regeneration. Instead riparian plantings should occur in areas where natural riparian recovery has not yet taken hold three or more years after the flood.

Using plant materials sourced from within Button Rock Preserve (i.e. local ecotypes) most closely mimics the natural recovery process. Collecting and growing seed from sources within Button Rock Preserve is a time-consuming process, and therefore the riparian restoration plan should account for at least five years of ongoing restoration work. This extended riparian restoration timeframe will also allow gaps in the natural recovery to continually be filled with active restoration while not infringing upon the natural recovery.

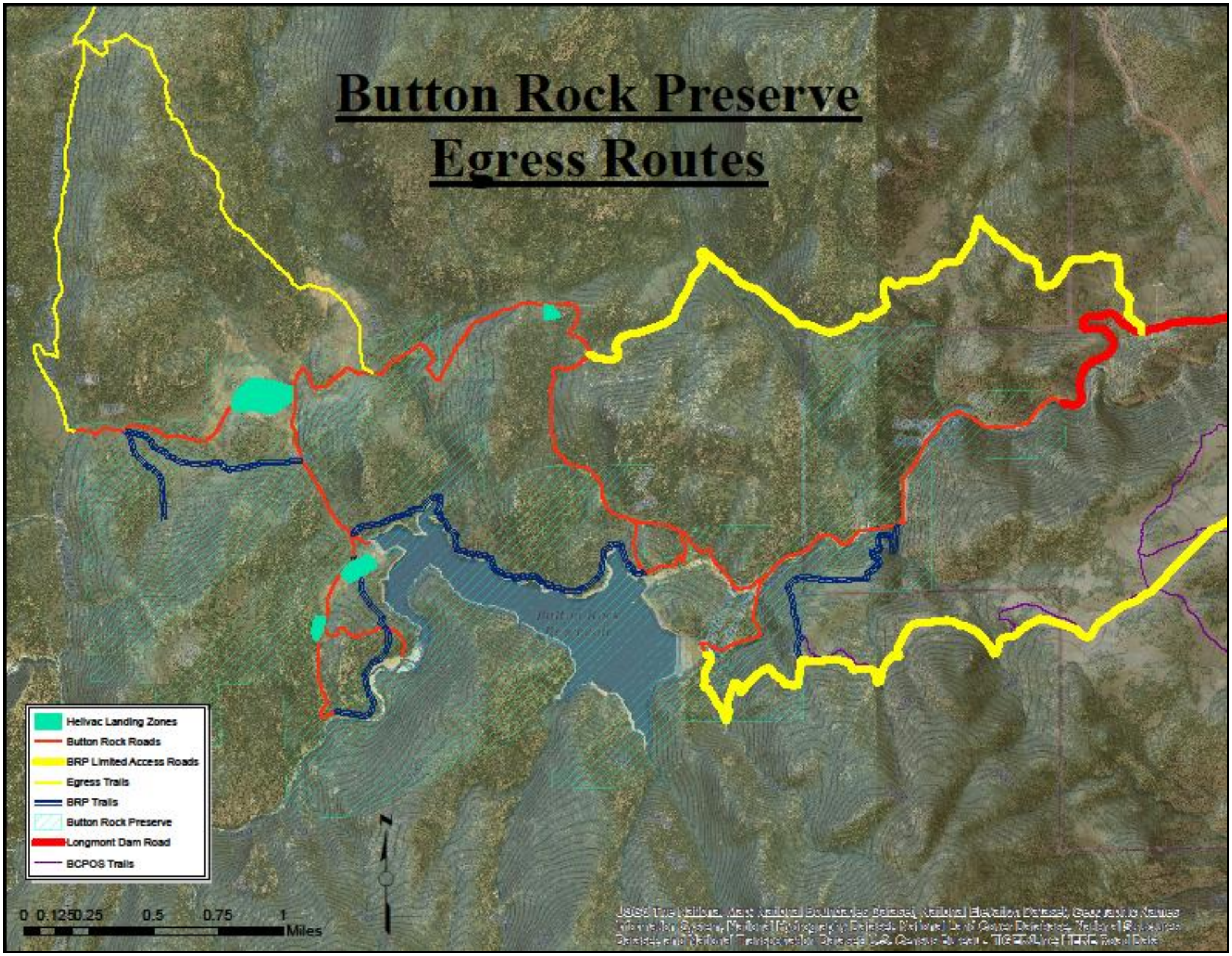
SECTION 10. Maps & Figures



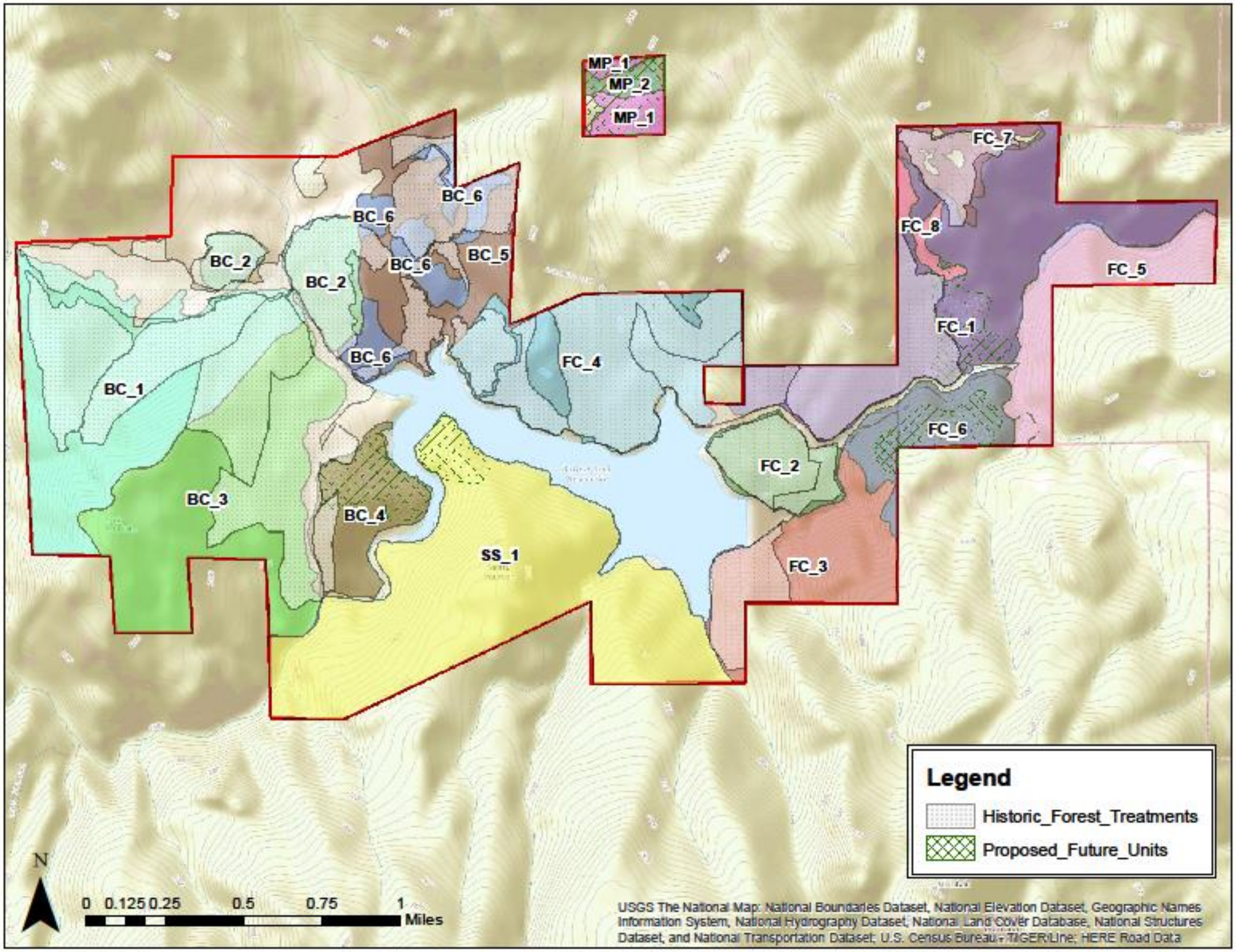
MAP 1. A section of the Boulder County Parks and Open Space Map showing land ownership around Button Rock Preserve. Blank (white) parcels represent private land. Up is north. Ralph Price Reservoir (mislabeled "Buttonrock Res.") is in the center.



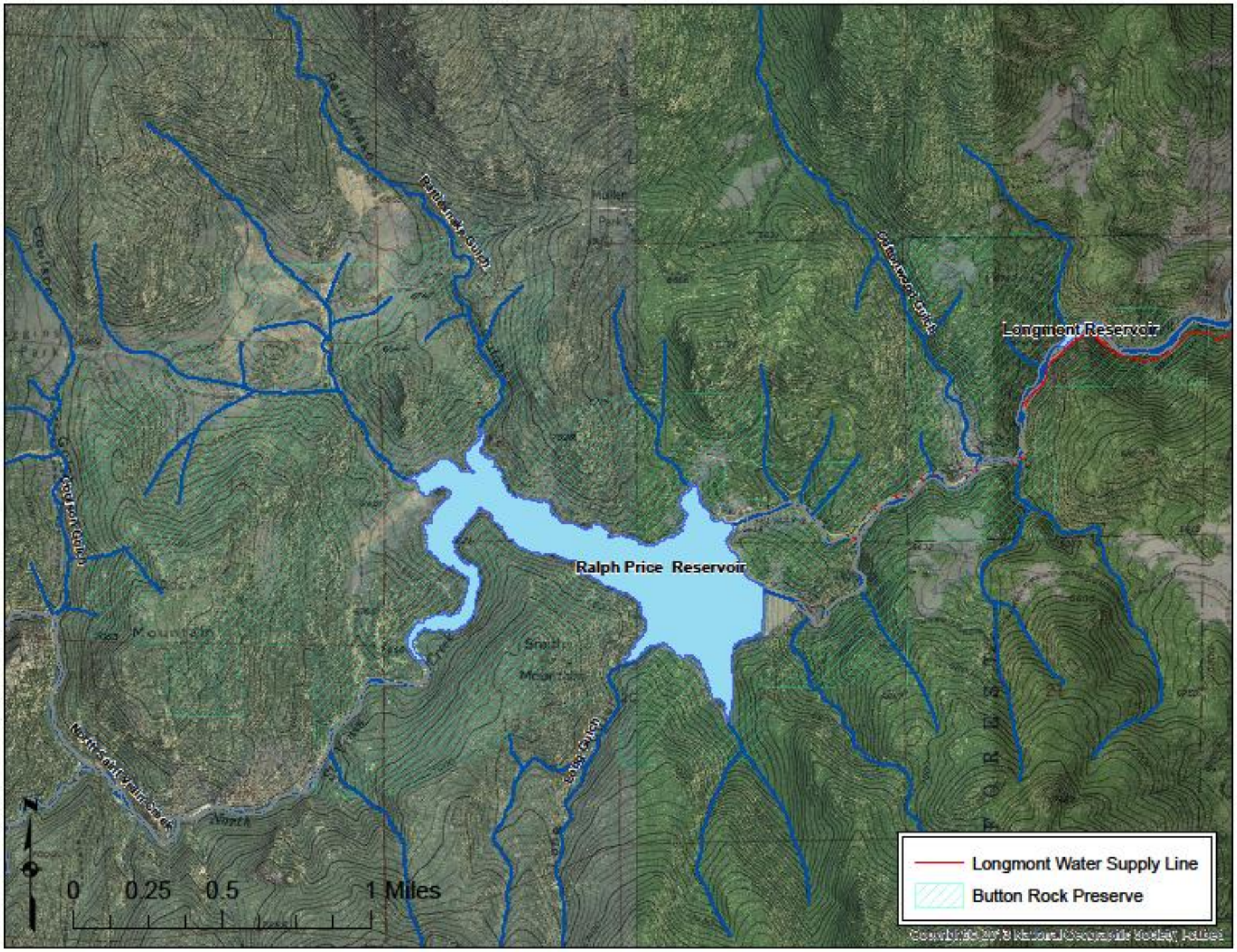
MAP 2. Forest Management Thinning Treatments implemented under the 2003 Forest Stewardship Plan. The "2014 Powerline" treatment occurred along the road / powerline in the eastern part of the Preserve in addition to the larger treatment in the northeast corner.



MAP 3. Current egress routes from Button Rock Preserve, including trails, roads, limited access roads, and helivac zones. See Section 7.1 for details.



MAP 4. Forest Management Units (FMUs) as defined during the 2016 forest inventory. These management units are the basis of prescriptions contained within this Forest Stewardship Plan. Overlay shows areas treated to date (see Map 2 for additional detail) and recommended priorities provided by CSFS.



MAP 5. Major drainages affecting Button Rock Preserve and the Longmont municipal water supply from North St. Vrain Creek.

Literature Cited

Addington, R.N., G. H. Aplet, M. A. Battaglia, J. S. Briggs, P. M. Brown, A. S. Cheng, Y. Dickinson, J. A. Feinstein, P. J. Fornwalt, B. Gannon, C. W. Julian, K. A. Pelz, C. M. Regan, J. Thinnes, R. Truex, J. L. Underhill, and B. Wolk. *In prep*. 2016. Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range.

Baker, M. B. 1988. Hydrologic and water quality effects of fire. Presented at Effects of Fire in Management of Southwestern Natural Resources. Tucson, AZ

Benavides-Solorio, J. B., and L. H. MacDonald. 2001. Post-fire runoff and erosion from simulated rainfall on small plots, Colorado Front Range. Hydrological Processes **15**: 2931-2952

Boyden, S., D. Binkley, and W. Shepperd. 2005. Spatial and temporal patterns in structure, regeneration, and mortality of old-growth ponderosa pine forest in the Colorado Front Range. Forest Ecology and Management **219**: 43-55

Brown R. T., J. K. Agee, and J. F. Franklin. 2004. Forest restoration and fire: Principles in the context of place. Conservation Biology **18**: 903-912

Brown, P. M., M. A. Battaglia, P. J. Fornwalt, B. Gannon, L. S. Huckaby, C. Julian, and A. S. Cheng. 2015. Historic (1860) forest structure in ponderosa pine forests of the northern Front Range, Colorado. Canadian Journal of Forest Restoration **45**: 1462-1473

Brown, P. M., D. R. D'Amico, A. T. Carpenter, and D. Andrews. 2001. Restoration of montane ponderosa pine forests in the Colorado Front Range: a forest ecosystem management plan for the City of Boulder. Ecological Restoration **19**: 19-26

Brown, D. G., K. M Johnson, T. R. Loveland, and D. M. Theobald. 2005. Rural land-use trends in the conterminous United States, 1950-2000. Ecological Applications **15**: 1851-1863

Churchill, D. J., M. C. Dalhgreen, A. J. Larson, and J. F. Franklin. 2013. The ICO approach to restoring spatial pattern in dry forests: Implementation guide. Version 1.0. Stewardship Forestry, Vashon, Washington, USA.

City of Longmont. 2003. Button Rock forest stewardship Plan. City of Longmont, Longmont, CO US 131 p.

Colburn K., Integrating recreational boating considerations into stream channel modification & design projects. American Whitewater

Collins B. M., and S. L. Stephens. 2010. Stand-replacing patches within a 'mixed severity' fire regime: quantitative characterization using recent fires in a long-established natural fire area. Landscape Ecology **25**: 927-939

Front Range Watershed Protection Data Refinement Work Group. 2009. Protecting critical watersheds in Colorado from wildfire: A technical approach to watershed assessment and prioritization.

Hansen, W. R., J. Chronic, and J. Matelock. 1978. Climatography of the Front Range urban corridor and vicinity, Colorado. Geological Survey Professional Paper 1019. US Dept. of the Interior, Geological Survey. Washington, DC, USA.

Hessburg, P.F., J. K. Agee, and J. F. Franklin. 2005. Dry forests and wildland fires of the inland northwest USA: Contrasting the landscape ecology of the pre-settlement and modern eras. Forest Ecology and Management **211**: 117-139

Hester, E. T., and M. N. Gooseff. 2010. Moving beyond the banks: hyporheic restoration is fundamental to restoring ecological services and functions of streams. Environ. Sci. Technol. **44**: 1521-1525

Houck, K. 2014. CDOT/CWCB hydrology investigation phase one - 2013 flood peak flow determination. Colorado Water Conservation Board, Dept. of Natural Resources. State of Colorado.

Huffman E.L., L. H. MacDonald, and J. D. Stednick. 2001. Strength and persistence of fire-induced soil hydrophobicity under ponderosa and lodgepole pine, Colorado Front Range. Hydrological Processes **15**: 2877-2892

Hunter, M.E., W. D. Shepperd, J. E. Lentile, J. E. Lundquist, M. G. Andreu, J. L. Butler, and F. W. Smith. 2007. A comprehensive guide to fuels treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest. General Technical Report RMRS-GTR-198. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins Colorado, USA.

Kaufmann, M.R., P. J. Fornwalt, L. S. Huckaby, and J. M. Stoker. 2001. Cheesman Lake – a historical ponderosa pine landscape guiding restoration in the South Platte watershed of the Colorado Front Range. Pages 9-18 in Vance, R . K., C. B. Edminster, W. W. Covington, and J.A. Blake. Ponderosa pine ecosystems restoration and conservation: steps toward stewardship. Proceedings of RMRS-P-22. US Department of Agriculture Forest Service, Rocky Mountain Research Station, Ogden, UT, USA

Kauffmann, M. R., T. T. Veblen, and W. H. Romme. 2006. Historical fire regimes in Ponderosa Pine forests of the Colorado front range, and recommendations for ecological restoration. Front Range Fuel Treatment Partnership Roundtable, findings of the Ecology Workgroup. http://www.frftp.org/roundtable/pipo.pdf

Kondolf, G. M., A. J. Boulton, S. O'Daniel, G. C. Poole, F. J. Rahel, E. H. Stanley, E. Wohl, A. Bang, J. Carlstrom, C. Cristoni, H. Huber, S. Koljonen, P. Louhi, and K. Nakamura 2006. Process-based ecological river restoration: visualizing three-dimensional connectivity and dynamic vectors to recover lost linkages. Ecology and Society **11**: 5

Kondolf, G. M. 2006. River restoration and meanders. Ecology and Society **11**: 42

LeMaster, D. C., G. Shao, and J. Donnay. 2007. Protecting Front Range forest watersheds from high-severity wildfires. Pinchot Institute for Conservation. http://www.pinchot.org/gp/Colorado_watersheds

Longmont Ledger. 1947, July 18. Water in your faucet didn't 'just happen'. Longmont Ledger.

Lyons Fire Protection District. 2011. Community wildfire protection plan. Lyons FPD. Lyons, CO USA 125 p.

Lytle, D. A. and N. L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution. **19**: 94-100

Marr, J. W. 1961. Ecosystems of the east slope of the Front Range in Colorado. Series in Biology, Paper 21. University of Colorado, Boulder, CO, USA

Moody, J. A., and D. A. Martin. 2001. Initial hydrologic and geomorphic response following a wildfire in the Colorado Front Range. Earth Surf. Process. Landforms **26**: 1049-1070

Moody, J. A., D. A. Martin, S. L. Haire, and D. A. Kinner. 2008. Linking runoff response to burn severity after a wildfire. Hydrological Processes **22**: 2063-2074

Napper, C. 2006. Burned area emergency response treatment catalog. Watershed, Soil, Air Management 0625 1801-SDTDC. U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center, San Dimas, CA.

Palmer, M. A., E. S. Bernhardt, J. D. Allan, P. S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C. N. Dahm, J. Follstad Shah, D. L. Galat, S. G. Loss, P. Goodwin, D. D. Hart, B. Hassett, R. Jenkinson, G. M. Kondolf, R. Lave, J. L. Meyer, T. K. O'Donnell, L. Pagano and E. Sudduth. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology **42**: 208-217

Reeves, T. 1965, July 1. Longmont Times-Call

Reynolds, R. T., A. J. Sanchez Meador, J. A. Youtz, T. Nicolet, M. S. Matonis, P. L. Jackson, D. G. DeLorenzo, and A. D. Graves. 2013. Resorting composition and structure in southwestern frequent-fire forests: A science-based framework for improving ecosystem resiliency. General Technical Report RMRS-GTR-310. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Fort Collins Colorado, USA

Richer, E. E., M. C. Kondratieff, and B. D. Swigle. 2015. Post-flood recovery assessment and stream restoration guidelines for the Colorado front range. Colorado Parks and Wildlife.

Robichaud, P. R., L. E. Ashmun, R. B. Foltz, C. G. Showers, J. S. Groenier, J. Kesler, C. DeLeo, M. Moore. 2013 (a). Production and aerial application of wood shreds as a post-fire hillslope erosion mitigation treatment. Gen. Tech. Rep. RMRS-GTR-307. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 31 p.

Robichaud, P. R., S. A. Lewis, J. W. Wagenbrenner, L. E. Ashmun, R. E. Brown. 2013 (b). Post-fire mulching for runoff and erosion mitigation part 1: Effectiveness at reducing hilllslope erosion rates. Catena **105**: 75-92

Robichaud, P., L. MacDonald, J. Freeouf, D. Neary, D. Martin, L. Ashmun. 2003. Post fire rehabilitation of the Hayman Fire. USDA Forest Service Gen Tech Rep. RMRS-GTR-114

Rosgen D.L. 1994. A classification of natural rivers. Catena **22**: 169-199

Schultz C. A., T. Jedd, and R. D. Beam. 2012. The collaborative forest landscape restoration program: A history and overview of the first projects. Journal of Forestry. **110**: 381-391

Sherriff, R. L. and T. T. Veblen. 2007. A spatially-explicit reconstruction of historical fire occurrence in the ponderosa pine zone of the Colorado Front Range. Ecosystems **10**: 311-323

Smith H. G., G. J. Sheridan, P. N. J. Lane, P. Nyman, and S. Haydon. 2011. Wildfire effects on water quality in forest catchments: A review with implications for water supply. Journal of Hydrology **396**:1–2:170.

Stephens S. L., J. D. McIver, R. E. J. Boerner, C. J. Fettig, H. B. Fontaine, B. R. Hartsough, P. L. Kennedy, and D. W. Schwilk. 2012. The effects of forest fuel-reduction treatments in the United States. BioScience **62**: 549-560

Stephens, S. L., and L. W. Ruth. 2005. Federal forest-fire policy in the United States. Ecological Applications **15**: 532-542

Swanson, F. J., S. L. Johnson, S. V. Gregory, and S. A. Acker. 1998. Flood disturbance in a forested mountain landscape. BioScience **48**: 681-689

Thompson, M. P., J. Scott, P. G. Langowski, J. W. Gilbertson-Day, J. R. Haas, and E. M. Bowne. 2013. Assessing watershed-wildfire risks on national forest system lands in the rocky mountain region of the United States. Water **5**: 945-971

USGS. 2012. Wildfire effects on source-water quality – lessons from four mile canyon fire, Colorado, and implications for drinking water treatment. USGS Fact Sheet 2012-3095

Veblen, T. T., T. Kitzberger, and J. Donnegan. 2000. Climatic and human influences on fire regimes in Ponderosa Pine forests in the Colorado Front Range. Ecological Applications **10**: 1178-1195

Wohl, E. 2005. Compromised rivers: understanding historical human impacts on rivers in context of restoration. Ecology and Society **10**: 2

Writer, J. H., A. Hohner, J. Oropeza, A. Schmidt, K. M. Cawley, and F. L. Rosario-Ortiz. 2014. Water treatment implications after the High Park wildfire, Colorado. Journal AWWA. **106**:4 189-199

Appendices

APPENDIX 1. Individual-Clump-Opening (ICO) Ratios

Historic stand reconstruction data developed from historic stand maps provided by the authors of Brown et. al. 2015 for Hall Ranch (HA) and Heil Ranch (HE) sites. These data were used to develop the “Individual, Clump, and Opening” (ICO) ratios used and referenced in Section 5.1.3.

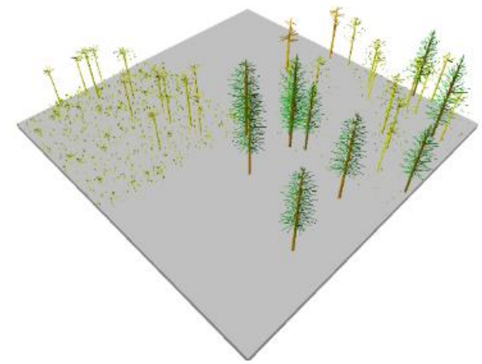
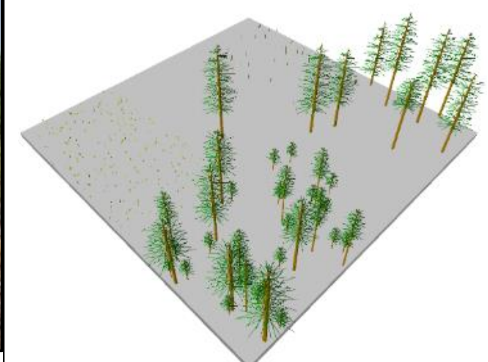
Number of Groups per Class columns reference the number of groups per stem map for each group size, defined by the number of trees. *Proportion of Trees in Group Class* columns reference the percentage of trees in a given group class, developed from the number of groups per class multiplied by the average number of trees in that group and divided by the total number of trees per site.

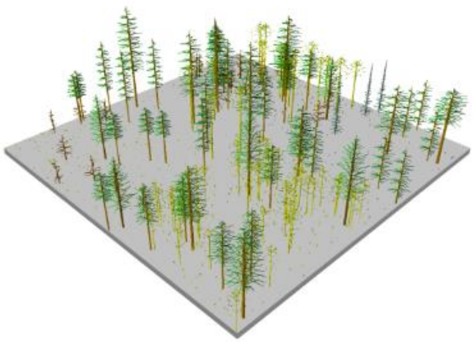
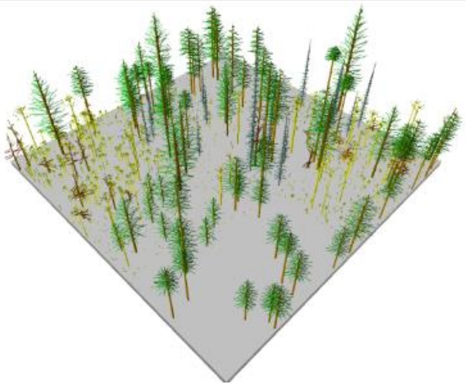
The green columns represent Basal Area and tree density data converted from metric to imperial units. Rows in red only had individual trees and small groups, and the small group percentages were adjusted to more accurately reflect the average group size for those site maps. Percentages are based on average group size and do not equal 100% across all groups for a given site.

PLOT	Elevation (ft)	Aspect	Slope (%)	TPH	Trees per Acre	BA (m^2/ha)	BA (ft^2/ac)	Number of Groups per Class					Proportion of Trees in Group Class				
								1	2-5	6-10	11-15	16+	1	2-5	6-10	11-15	16+
HA18	6,237	NE	18	25	10	0.3	1.3	10	3				63%	37%	0%	0%	0%
HE06	6,250	W	26	35	14	2.3	10.0	21	3				75%	25%	0%	0%	0%
HE18	6,359	SE	31	320	130	7.0	30.5	11	7	2	2	2	8%	22%	15%	24%	29%
HA17	6,408	N	40	145	59	10.8	47.0	7	8	3	1		12%	39%	33%	18%	0%
HE22	6,431	ENE	12	90	36	0.5	2.2	14	3	1			47%	32%	25%	0%	0%
HA01	6,516	W	18	170	69	17.1	74.5	9	5	4	1		13%	24%	45%	18%	0%
HE13	6,529	ENE	16	100	40	3.7	16.1	10	15	1			16%	74%	11%	0%	0%
HA05	6,546	SE	15	20	8	5.2	22.7	14	3				70%	30%	0%	0%	0%
HA16	6,588	NE	21	165	67	14.7	64.0	19	13			1	26%	57%	0%	0%	20%
HE20	6,680	NNW	36	110	45	12.5	54.5	9	7	1	2		14%	36%	12%	39%	0%
HE19	6,792	NE	9	25	10	0.8	3.5	13	6				41%	62%	0%	0%	0%
HA24	6,857	E	20	90	36	4.2	18.3	11	8	1			26%	60%	17%	0%	0%
HE21	6,864	ENE	18	50	20	2.9	12.6	13	9	1			31%	60%	15%	0%	0%
		AVERAGE:		95.8	38.8	6.0	26.2	12.6	6.3	1.9	1.5	1.5	34.0%	45.7%	13.3%	7.6%	3.8%

APPENDIX 2. Stand Density Matrix from Addington et. al. 2016

The stand density matrix included in Addington et. al. (2016) as Appendix B is shown below. These are the primary basal area targets used in Scn. 5.

Structure	BA*	Description	Example Photo	Stand visualization
Openings	0-20	Openings ranging in size from 0.25 to tens of acres are appropriate in low-productivity settings within the treatment unit. Openings may contain small amounts of residual tree cover. Openings are expected to stimulate understory vegetation growth, and may result in the establishment of conifer seedlings and aspen sprouts as well.		
Low-density matrix	20-40	A low-density woodland matrix is appropriate along ridges, south-facing slopes, and other low productivity areas within the treatment area. Ponderosa pine will likely dominate these areas and the desired structure is open woodland characterized by tree groups, scattered individual trees, and openings. Residual trees should be variably spaced. Existing tree groups (i.e. trees having interlocking crowns) should be enhanced by clearing around them. Tree groups may contain anywhere from 2 to 10+ trees, but most likely contain around 2-5 trees.		

Medium-density matrix	40-60	A medium-density woodland matrix is appropriate for mid-slopes and other areas of intermediate productivity. Enhance spatial structure by focusing on tree groups, individual scattered trees, and openings. Average distance between tree groups may be less in this case (around 1 tree length), and the proportion of trees that occur in groups versus scattered individual trees should increase as well. Approximately 70-90% of trees may occur in groups and group size may be larger as well, on the order of 5-9 trees per group typically.		
High-density matrix	80+	A high-density forest matrix is appropriate on north-facing slopes and other moist, higher-productivity areas. Douglas fir is naturally more prevalent in these areas. The characteristic structure of lower-density settings (i.e. tree groups, individual scattered trees, and openings) may be less evident at this density as most trees occur in groups (90+ percent) and fewer as scattered individuals. Treatments in this setting may involve mild reductions in density by thinning from below or hand-felling of small diameter stems and ladder fuels.		

APPENDIX 3. Post-Wildfire Emergency Response Plan

This appendix outlines steps that can and should be taken in the immediate aftermath of a major fire with significant areas of high-severity burn in the North St. Vrain watershed that will affect the Longmont municipal water supply.

For background on post-fire impacts please see Section 2.3 and Section 8 of this Forest Stewardship Plan. The greatest risk to water quality is from a thunderstorm that occurs in the first year after a fire. Therefore quick deployment of these emergency response items is of the essence. The erosion risk remains high for up to about 5 years after a fire.

Initiate Burned Area Emergency Response (BAER) process with US Forest Service

- **The BAER process will address post-wildfire mitigation on USFS lands** that surround Button Rock Preserve. The City of Longmont should work directly with the BAER Process after a fire. A BAER Information Brief is attached below in this appendix.
- **BAER includes a prioritization process for areas to treat** that will also inform where the NRCS EWP program prioritizes funding. This prioritization process also recommends which post-wildfire treatments are most appropriate.
- **BAER in the Button Rock Preserve area will be managed by the Boulder Ranger District**
  - **Contact:** Eric Schroder
    BAER Programs Coordinator
    Arapahoe and Roosevelt National Forests
    P: (303) 541 – 2538
    E: eschroder@fs.fed.us

Initiate an Emergency Watershed Protection (EWP) process with NRCS

- **The EWP program provides emergency assistance to protect watersheds,** including emergency wildfire response. EWP responds to emergencies from natural disasters, but does not require an official disaster declaration to go into effect. EWP is a funding source specific to non-federal lands and is the best potential funder for post wildfire emergency response on Button Rock Preserve, private lands, and Boulder County properties.
- **EWP requires a local sponsor and 25% match.** It is recommended that the City of Longmont take on the sponsor role to ensure quick and timely funding. Match can be provided via cash or in-kind, but cash match is much easier and quicker to demonstrate. The City should also work with Boulder County Parks and Open Space on the EWP process and match funding since it is likely that in the event of a major fire assistance will also be needed on Riverside Ranch, Hall Ranch, or both.

- **To initiate the EWP process the City of Longmont should submit an Application for Assistance letter *as soon as possible.*** The EWP Application for Assistance letter is the formal step that starts the EWP process.

- **EWP funding is based on a return on investment model that is assessed using their Damage Survey Report (DSR) process.** The City of Longmont should work to develop an assessment of the dollar value of values at risk *as soon as possible*. In the case of Button lost due to Rock Preserve, this value is the cost of treating or replacing municipal water supply from North St. Vrain creek that is damaged or lost due to the potential fire impacts. This should include
  - Additional anticipated water treatment costs
  - Cost to replace the water supply 1) for five years due to potential severe water quality issues from runoff while the watershed recovers and 2) cost to permanently replace lost reservoir capacity in Ralph Price Reservoir from post-wildfire sedimentation.

- **EWP requires environmental and cultural clearances on land treated through their funding process.** In order to ensure timely funding, the environmental and cultural clearance processes should be started by the City of Longmont *as soon as possible*.

- **EWP in the Button Rock area will be managed by the NRCS Fort Collins, CO office.**
  - **Contact:** Todd Bolt
EWP Specialist
USDA Natural Resources Conservation Service
P: (970) 215 – 9897
E: todd.boldt@co.usda.gov

Install Debris and Silt Barriers in Ralph Price Reservoir

Debris and silt barriers will capture large debris (e.g. trees) and small debris (e.g. sediment and ash) that erode off of burned hillslopes into Ralph Price Reservoir. The greatest risk is from debris flow down the North St. Vrain into the inlet, or into one of the five side drainage that wash directly into the reservoir. A barrier system can also be installed in Longmont Reservoir.

- **All barrier systems should consist of two parallel booms**: a robust barrier to catch large debris ("debris boom") placed immediately in front of another boom ("silt boom") to catch floating ash and sediment that will escape the larger boom. The inlet already has a debris boom in place from the 2013 floods.
  - A quote for a 300-foot barrier system is included at the end of this appendix as FIGURE 1.

- For all embayment, including the inlet, south cove, and long gulch a **250 foot long boom should suffice.** For Longmont Reservoir or the south cove of Ralph Price Reservoir, a shorter 150 foot boom is sufficient. The quote included in this appendix is for a 300-foot boom system.

- **Anchors with eye bolts** should be pre-established in all embayments to make deployment of booms quicker.

- **A reservoir management plan** should be established to lower the reservoir after the summer thunderstorm season to dredge and remove the debris and ash caught behind the barriers.

<u>Source and Deploy Wood Stand Mulch</u>

A literature review and consultation with experts at the USGS in Boulder, as discussed in Sections 2 and 8 of this Forest Stewardship Plan, affirms that the most effective post-fire mitigation strategy is likely to be extensive mulching with wood strands. Given the expense associated with wood strand mulching, initial efforts should focus on the most severely burned and high-risk areas.

- **Wood strand mulch can be made on-site or purchased commercially**. It is much less expensive to make wood strand mulch on site, it requires less transportation, and there is less risk of introducing weeds. That said, it requires a large drum chipper and special process to create long and narrow “strands.”
  - Standard chippers produce a shorter, wider mulch that is too easily washed off the soil because it does not create an interlocking “matrix.”
  - On-site wood strand mulch can be made from either green trees or dead (burned) trees.
    - *Any green trees harvested for mulch should follow prescriptions outlined in this Forest Stewardship Plan.*

- **Instructions for producing wood strand mulch on-site** are contained in the USDA Forest Service Rocky Mountain Research Station General Technical Report 307 (RMRS-GTR-307), which is also cited in this Forest Stewardship Plan as Robichaud et. al. (2013 a).

- **WoodStraw ®** is a commercially available manufactured wood strand mulch (www.woodstraw.com). Manufactured wood strands are much more expensive and have transportation costs, but are readily available and effective.
  - WoodStraw ® is locally manufactured and available from Mountain Pine Manufacturing in Steamboat Springs (www.mpinem.com 970-367-6111). This manufacturer uses beetle-kill lodgepole pine to create wood strand mulch.

- **Deploying wood strands via helicopter** is expensive, but the most expedient way to mulch severely-burned, high-risk areas. Mulch can also be deployed via a straw blower attached to a vehicle, or by hand.
  - Mountain West Helicopters is one company recommended by the WoodStraw ® company as an operation with experience in deploying wood strand mulch (www.mwheli.com 801.216.4001).
  - Other helicopter operations with external-load and firefighting experience should also be able to successfully deploy wood strands.

ATTACHMENT 1 – Button Rock Preserve Emergency Response Plan **ATTACH**

ATTACHMENT 2 - Quote from GEI Works for 300-foot containment boom system (2 booms). **ATTACH**

ATTACHMENT 3 - BAER Information Brief **ATTACH**

APPENDIX 4. Forest Vegetation Simulator (FVS) Modeling Results

Table showing full modeling results of FVS run with inventory data (2016) and simulated harvest in 2017 that reduced all stands to a basal area (BA) of 50 ft^2/ac.

	Inventory (2016)					Modeled Harvest (2017)			2026 Modeled Stand					2036 Modeled Stand					Growth Projection		
Stand ID	Live TPA	Live Avg Ht	Live BA	Dead TPA	Dead BA	TPA	Avg Ht	BA	Live TPA	Live Avg Ht	Live BA	Dead TPA	Dead BA	Live TPA	Live Avg Ht	Live BA	Dead TPA	Dead BA	2026-2036 TPA	2026-2036 BA	10-yr BA % Growth
BC 1	270.1	21.6	88.8	15.3	7.2	211.1	16.9	33.6	58.1	44.2	62.8	0.8	0.7	57.2	49.5	71	0.8	0.8	-0.9	8.2	13%
BC 2	124.3	18.8	63.8	1.6	1.4	63.1	6.4	5.2	59.9	37.6	70	1.2	1	58.8	41.9	80.9	1.2	1.1	-1.1	10.9	16%
BC 3	131.6	28	72.9	3	1.4	86.2	18.9	20.5	44.6	50	56.6	0.8	0.9	43.7	54.3	61.4	0.7	0.8	-0.9	4.8	8%
BC 4	260.2	25	103.4	1.4	1	205.2	21.1	47.7	53.9	45	67	1.1	1	52.8	50	77.5	1	1	-1.1	10.5	16%
BC 5	186	26.4	94.9	0.8	1.3	138.7	21.7	35.9	46.6	45.7	68	0.8	0.8	45.8	50	76.8	0.7	0.8	-0.8	8.8	13%
BC 6	131.6	14.7	31.9	0	0	0	0	0	128.5	17.7	41.3	3.1	0.5	125.4	20.7	51.3	3.1	0.6	-3.1	10	24%
FC 1	177.8	20.4	72	0	0	127.5	13.5	19.4	49.2	43.2	56.5	1	0.9	48.3	48.3	60.9	0.9	0.9	-0.9	4.4	8%
FC 2	195.9	25.7	89.7	0	0	146.8	21.2	37.3	48.1	44.7	63.4	1	1	47.2	49.8	73.6	0.9	1.1	-0.9	10.2	16%
FC 3	352.9	22.6	112.1	4.7	3.2	291.8	20.1	60.5	60.2	41	62.7	0.9	0.7	59.3	46.9	74.1	0.8	0.8	-0.9	11.4	18%
FC 4	98.5	31.3	68.9	0.9	1	49.3	21.6	11.4	48.2	46.5	63.7	0.9	0.9	47.2	51.3	70.4	0.9	1	-1	6.7	11%
FC 5	431.8	25.6	110.7	0	0	375.7	23.5	57.9	55.3	45.4	63.4	0.7	0.6	54.6	50.9	73.8	0.7	0.7	-0.7	10.4	16%
FC 6	452.5	20.6	104.4	9.5	2.2	380.3	17.8	54.4	71.2	41.5	62.7	1	0.7	70.1	47.4	75.2	0.9	0.8	-1.1	12.5	20%
FC 7	126.1	37.7	83.1	0	0	81.6	34.5	32.3	43.7	49.1	54.2	0.9	0.8	42.8	54	58.3	0.9	0.9	-0.9	4.1	8%
FC 8	226	17.4	70.8	0	0	188	12.2	20.8	37.4	47.5	57.3	0.6	0.6	36.8	51.2	64.6	0.6	0.7	-0.6	7.3	13%
MP 1	414.5	15.6	103.6	0	0	355.6	12.6	45.6	57.7	38.7	68.6	1.2	0.9	56.5	43.4	78.5	1.2	1.1	-1.2	9.9	14%
MP 2	698.6	15.7	103.6	13.8	4	597.9	12.6	49.6	98.9	39.2	69.1	1.8	0.9	97.1	44.1	83.7	1.7	1.1	-1.8	14.6	21%
SS 1	420.5	15.6	76.3	5.3	8	343.5	11.6	25	75.6	38.8	64.1	1.3	0.9	74.2	43.8	76.7	1.3	1.1	-1.4	12.6	20%