JEFFERSON
COUNTY COLORADO
Open Space

Jefferson County Open Space

Forest Health Plan 2022

The early morning sun melts snow off ponderosa pines at an overlook in White Ranch Park.

Cover: A healthy ponderosa pine forest in Pine Valley Ranch. The Hi Meadow Fire came through this section of the park in 2000 as a low-severity surface fire. The fire resulted in good outcomes for the forest, including a lower fire hazard, higher diversity, and conditions that will likely be more resilient to climate change. This photo is an example of the desired conditions that managers strive to achieve with forest restoration efforts.

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DOCUMENT DELIVERY STATEMENT

The foundation of this Forest Health Plan (Plan) is based on the values and resources important to Jefferson County Open Space (JCOS) and its agency partners, analysis of how those values and resources respond to wildfire, and opportunities for forest management to improve forest resilience and protect vulnerable values and resources. The Colorado Forest Restoration Institute (CFRI) at Colorado State University led a participatory spatial modeling effort that provides a prioritized action plan to inform where and how JCOS can best maximize wildfire risk reduction and enhance ecological resilience through implementing forest thinning and prescribed fire treatments over the next 10 years. Other components of this Plan leverage the strategic planning process to inform forestry program goals, desired conditions, guiding forest management principles, and a collaborative adaptive management framework to guide the JCOS forestry program for the life of this Plan. JCOS hired CFRI through a competitive bid process to lead the development of this Plan in collaboration with JCOS staff. The Forest Stewards Guild (The Guild) was a supporting contractor in the planning process, offering expertise and support in wildfire risk reduction, stakeholder engagement, and document writing. CFRI and The Guild worked in partnership with JCOS staff throughout the process to develop, write, and compile the final Forest Health Plan.

Authorized by Congress through the Southwest Forest Health and Wildfire Prevention Act of 2004, the Colorado Forest Restoration Institute is an application-oriented, science-based outreach and engagement organization hosted at Colorado State University. CFRI strives to earn trust through being rigorous and objective in integrating currently-available scientific information into decision-making through collaborative partnerships involving researchers, land managers, policy makers, interested and affected stakeholders, and communities.

The Forest Stewards Guild is a supporting contractor in this planning process, offering expertise in wildfire risk reduction and assisting in stakeholder engagement and document generation. The Guild is a leader in ecologically, economically, and socially responsible forestry. The Guild has practiced and promoted responsible forestry as a means of sustaining the integrity of forest ecosystems and the human communities dependent upon them for over 20 years.

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LAND ACKNOWLEDGMENT

THE ORIGINAL CARETAKERS OF THE LANDS WE NOW CALL JEFFERSON COUNTY OPEN SPACE PARKS INCLUDE THE TABEGUACHE AND MOGHWACHI BANDS OF THE UTE NATION, THE ARAPAHO AND CHEYENNE TRIBES, AND OTHER INDIGENOUS PEOPLES. THEIR KNOWLEDGE, RESILIENCE, AND CULTURAL AND SPIRITUAL TIES TO THESE LANDS INSPIRE US TO CONTINUE THEIR LEGACY BY PRACTICING INFORMED STEWARDSHIP, PROVIDING EQUITABLE ACCESS, TEACHING SOUND OUTDOOR ETHICS, AND TREATING NATURE AND HUMANITY WITH RESPECT.

SECTION 1: INTRODUCTION

Purpose and Need of the Forest Health Plan

Jefferson County Open Space (JCOS) manages over 25,000 acres of forests along the central Front Range of Colorado that support a wide range of ecosystem services. Like many other organizations in regions across the western United States, JCOS has recognized the need to implement proactive restoration and management of dry coniferous forests to continue contributing to a healthy ecosystem and sustain the services we value from these forested landscapes. The change in fire regimes since Euro-American settlement and over a century of fire suppression has left many ponderosa pine and dry mixed conifer forests overly dense, in a degraded ecological state, and more susceptible to high-severity disturbance. Climate change places added pressure on forests with wider extremes that are more frequent and intense. Human development is rapidly expanding into the wildland-urban interface (WUI) requiring more resources and fragmenting habitats. Additionally, the interaction of these factors has led to increased wildfire activity that poses increasing risk to community safety, water supplies, human infrastructure, wildlife habitat, and forest resilience. To address these concerns, JCOS carefully evaluates the need to carry out forest management and restoration projects using mechanical thinning (forest thinning) and prescribed fire (pile and broadcast burning) treatment methods. JCOS follows a rigorous process of project planning to mitigate negative impacts from treatments, and ensure treatment outcomes progress forest ecosystems towards desired conditions.

The previous forest management plan guiding the JCOS forestry program was developed in 1988, and does not adequately capture the current needs, opportunities, and threats for JCOS, nor does it incorporate the modern breadth of forest ecology or wildfire planning knowledge. Since 1988, 30,000 acres have been added to the park system, and there is growing recognition that park and open space management influences social and ecological values across the surrounding landscape. This Forest Health Plan (Plan) is intended to provide insights into the

current needs of the forested lands and ecosystems currently managed by JCOS. The science-informed process of analysis, prioritization, and strategic planning used to develop this Plan will serve as the basis for a 10-year management plan. This science-informed planning process identifies wildfire risk, highlights degraded ecological conditions, and reveals the most cost-effective acres as the highest priority for active forest management, informing where the JCOS forestry program can gain the biggest 'bang for the buck' implementing forest management. JCOS aims to be a leader of stewarding forests using the latest science-based methods, while recognizing many processes impacting our forests operate at scales larger than any JCOS park. The components of this Plan serve as tools to highlight opportunities where working in a collaborative cross-boundary approach can best achieve JCOS's shared values to sustain healthy forests.

Background

JEFFERSON COUNTY OPEN SPACE

JCOS consists of 56,000 acres of preserved land, with 27 parks and 261 miles of trails open to the public. JCOS is the nation's first sales tax funded county open space organization, with grassroots beginnings as a land conservation organization, dating back to 1972 with PLAN Jeffco and The League of Women Voters of Jefferson County. These organizations proposed a unique concept to the Board of County Commissioners: preserve the scenic vistas and open lands within the county by collecting a one-half of one percent sales tax in Jefferson County. The voters supported this tax, thereby ensuring land conservation and access for public enjoyment.

Stewardship, land acquisition, and other projects are funded through strategic partnerships and invested JCOS sales tax funds to advance the JCOS mission. Preservation Progress is the annual report that details these investments, reflecting the community desire to balance preservation of precious resources with public access to nature.

The JCOS Conservation Greenprint 2020-2025 outlines the overarching strategic framework for JCOS. The Greenprint is a collective call to action to address the challenges JCOS faces, and to find opportunities to work collaboratively for the betterment and health of the environment, public lands, and people. This Plan represents one part of the larger strategic plan and contributes to achieving the JCOS vision, mission, and goals.

JCOS VISION: NATURE, HERITAGE & HUMANITY THRIVING IN WILD HARMONY

JCOS is the front door to the Colorado mountains. On the metro side, society is rapidly evolving, with new challenges associated with a population projected to grow substantially over the next three decades. On the natural side, the plains, foothills, and mountains are a welcomed escape to the wild, natural landscapes of Colorado. It is our collective responsibility to achieve balance between nature and people as parts of our ongoing story.

Nurturing the natural world protects the longevity of land, wildlife, and biodiversity. We seek to provide all ages, abilities, ethnicities, and walks of life access to the outdoors. We plan to empower a new generation of stewards who celebrate the past to build a better future, while creating a culture of visitors who love the parks, are courteous to each other, and respect nature.

This vision is an opportunity to strengthen a healthy Jefferson County community that celebrates the “wild” at the core of who we are, a place where all living things can grow and thrive for generations to come.

The JCOS mission is to preserve open space and parkland, protect park and natural resources, and provide healthy, nature-based experiences.

In the spirit of the JCOS Mission and Vision, the Natural Resources team has three main goals:

PRESERVE NATIVE SPECIES DIVERSITY

PROTECT ECOSYSTEM INTEGRITY

PROVIDE SCIENCE-BASED LAND MANAGEMENT STRATEGIES

Forestry Program Goals

The Conservation Greenprint includes a goal under the Healthy Lands theme to update the Jefferson County Open Space Forest Health Plan and reduce tree density and fuel sources on 1,000 of the 25,000 acres of forested lands. By 2025, the JCOS forestry program plans to treat 1,000 acres of forested land that is strategically located within the park system to have the greatest impact on wildfire risk reduction and ecological benefit. An expanding forestry program will need to hire more staff, and center management and restoration treatments around both mitigating wildfire risk and providing ecological benefit to improve forest health and wildlife habitat. These fundamental goals guide the future direction of the JCOS forestry program; however, to meet the larger JCOS vision, the forestry program includes the following programmatic goals based on community and stakeholder themes in the Conservation Greenprint:

Stewarding Existing Lands - Active management of JCOS forests using thinning and prescribed fire treatments promotes healthy forest ecosystems that comprise a diverse mosaic of vegetation patches across the landscape, contains fine scale heterogeneity in structure and spatial patterns, and sustains a diversity of flora and fauna. Natural forest processes and disturbance regimes are restored and maintained. For example, where appropriate and under the right conditions prescribed fire and wildfire play an important role maintaining overall ecosystem health.

Protection of Resources – Many highly valued resources and assets in Jefferson County are currently threatened by wildfire. Some examples include roads, public buildings, private homes, communication and energy infrastructure, high quality drinking water supplies, and wildlife habitat. Forest management reduces risk and spread of high-severity wildfire within the JCOS park system and across the landscape. In the event of a wildfire, completed forestry projects: contribute to the safety of first responders that protect local communities; mitigate the loss of infrastructure, buildings, and private homes; lower sedimentation and negative impacts to drinking water supplies; and maintain wildlife habitat and diverse vegetation communities.

Providing Assurance That Open Space Will Be There For Future Generations – Forest management strives to create forest conditions that are more resilient to future disturbances and climate change. The goal is to create more open forests, increase tree health and vigor, facilitate climate adaptation, and promote heterogeneity so forests can be sustained into the future.

Diverse Habitat for Wildlife – Management actions create forest gaps that are variable in size and shape to promote a robust understory, and a full range of canopy cover is maintained to allow for diverse light conditions and plant communities. Sensitive habitats are protected from disturbance and other negative impacts, and forest reserves are appropriately identified to maintain areas of closed canopy forest habitat.

Strengthening Partnerships – JCOS is committed to taking an all-hands approach to forest management, and fully recognizes that having an impact at the landscape scale requires coordination with partners to establish cross-boundary management. Forest management involves collaboration with stakeholders to ensure actions are designed based on shared values. Effective collaboration leads to support from local and neighboring communities, and advances adaptive management and research so future actions are based on the best available science.

Information Sharing – The information in this Plan is not confined to the boundaries of JCOS parks, and is available for partners to use in collaborative planning efforts. Data and information on JCOS forest management projects will be available to partners with the goal of advancing shared adaptive learning and cross-boundary efforts.

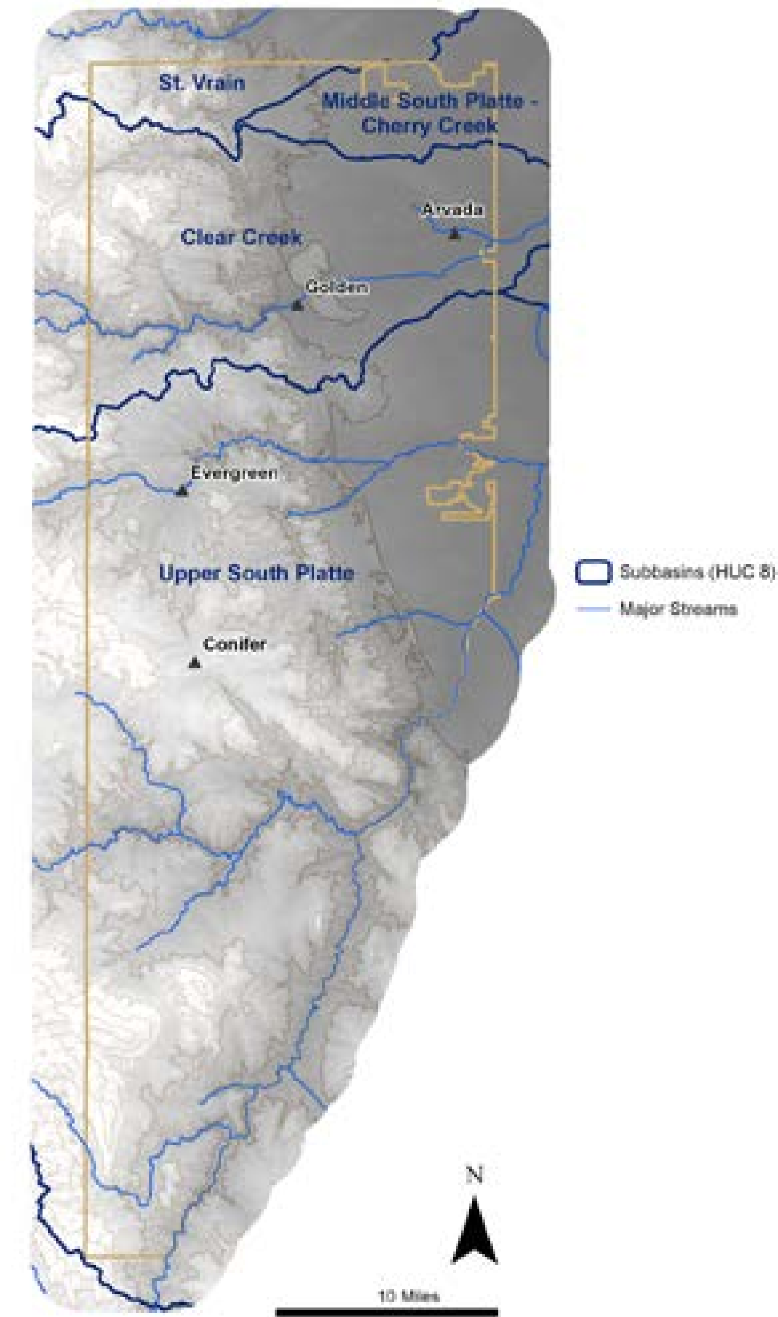
Strategic Planning – Projects are strategically located within the park system to have the greatest impact on shared resources and values. Planning across the JCOS park system leads to a prioritization that is based on shared values, uses limited resources efficiently, and easily communicates future plans to stakeholders.

Area Description and Current Conditions

Jefferson County lies on the western edge of the Denver, Colorado metropolitan area with a land base of 774 square miles. The county has the fourth largest population in the state, currently estimated at 582,881 people with 232,284 estimated households. It is surrounded by Boulder, Gilpin, Clear Creek, Park, Douglas, Teller, Adams, Denver, and Arapahoe Counties. Known as "the gateway to the Rockies," the foothills of the Front Range run the length of the county. Elevation rises rapidly moving from east to west; starting at the lower elevation plains that transition into the foothills and the montane zone, and elevation continues to rise to the subalpine and alpine along the western border of the County. Therefore, Jefferson County has a wide range of topography, vegetation types, and population distribution. The majority of the assessment area can be classified as WUI. The local economy is dictated by the proximity and ease of access to the Denver metro area. Most working residents commute daily to Golden and Denver. There are numerous recreational opportunities on nearby county, state, federal and private lands, and world-class hunting, climbing, cycling, camping, and fishing areas abound throughout the county. (Jefferson County Community Wildfire Protection Plan)

Climate

Jefferson County's climate is relatively dry, with the majority of precipitation occurring in the spring months and late summer monsoons. However, average conditions can vary greatly from one location to another with the highly variable terrain within the county. The area receives 255 days of sunshine per year and an average of 15 inches of annual precipitation. Seasonal weather patterns over the region and topographic effects from the continental divide can generate high winds year-round. (Jefferson County Community Wildfire Protection Plan)



Map of Jefferson County showing terrain and major sub watersheds.

Topography, Hydrology, Geology, Soils

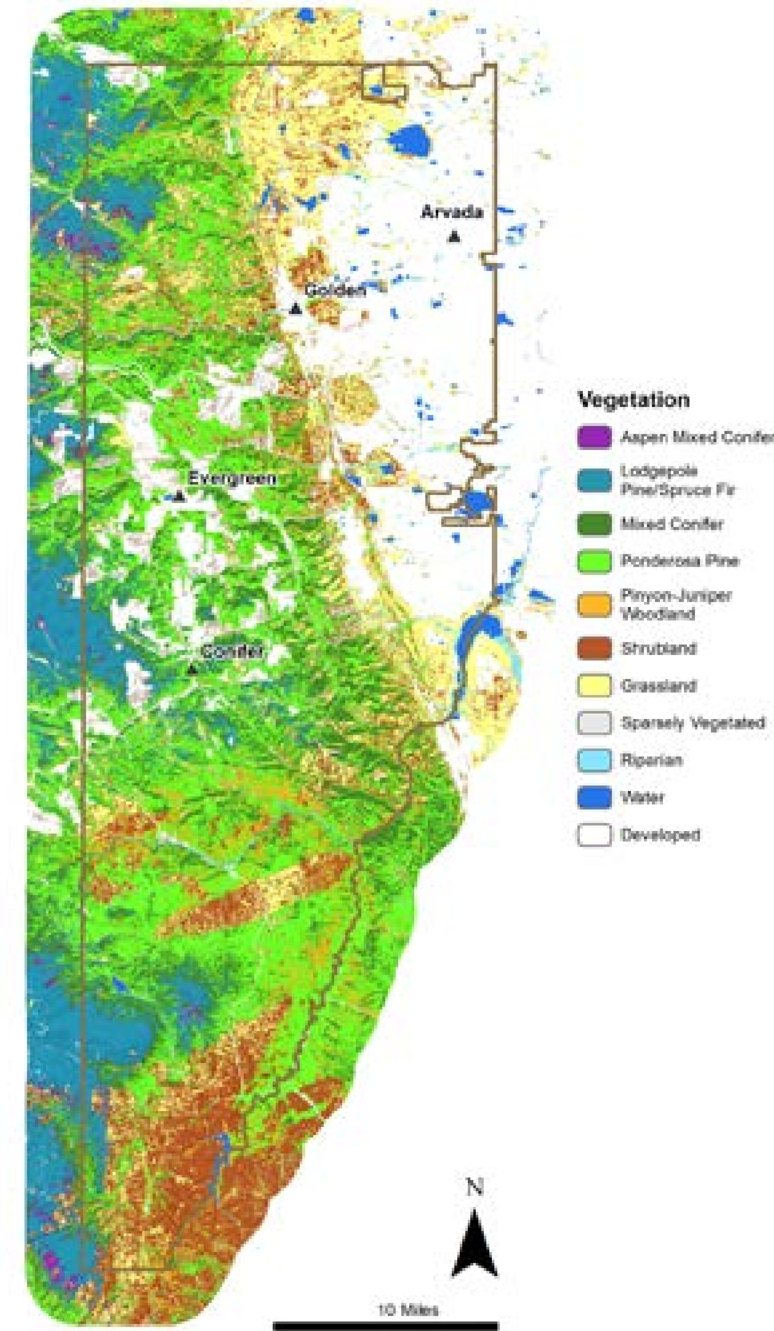
The elevation of Jefferson County ranges from 5,300 to 11,500 feet above sea level. The terrain spans from the rolling plains in the eastern part of the county to steep mountainous terrain. About 28% of the county is covered by plains, and 72% is covered by mountainous terrain. Slopes range from 10 percent to 60 percent or more. (Jefferson County Community Wildfire Protection Plan)

Jefferson County lies within the South Platte River Basin. Four subbasins intersect with Jefferson County. The St. Vrain subbasin covers the northwestern corner of the county, including Coal Creek. The Middle South Platte-Cherry Creek subbasin flows into Jefferson County on a small part of the northeast corner of the county. This includes Big Dry Creek and Standley Lake. The Clear Creek subbasin covers most of the north of the county, basically following I-70. South of I-70, the rest of the county lies within the Upper South Platte subbasin.

Jefferson County hugs the Front Range of the Rocky Mountains as it travels north to south. The dominating geological feature in the County are the foothills of this mountain range. As the Front Range was created through multiple geologic uplifts, eroded material was deposited on low elevations of the new mountain range. This sediment formed what we now identify as the foothills. County soils vary with elevation, and primarily consist of alfisols in the mountainous areas and mollisols in the foothills and the corridor along I-70. (General Soil Map Colorado)

Vegetation, Forest Types, Fire Regimes

"The vegetation in the county is typical of the Rocky Mountain Montane zone, which ranges from 5,600 to 9,500 feet above sea level. The dominant tree species throughout the assessment area are ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). The distribution and density of vegetation species are driven primarily by available soil moisture, which is closely related to elevation and slope aspect. This variability is known as the topographic-moisture gradient (Whittaker 1967), one of the key concepts in forest science. Common species of grass in the Montane zone include prairie Junegrass (*Koeleria macrantha*), blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), little bluestem (*Schizachyrium scoparium*), as well as nonnative species Timothy (*Phleum pretense*), and cheatgrass (*Bromus tectorum*). As elevation and moisture availability increase, ponderosa pine and mixed conifer woodlands with herbaceous and shrub understory are common. North facing slopes throughout the county are characterized by denser stands of ponderosa and mixed conifer forests dominated by Douglas-fir. In the upper montane zone, lodgepole pine (*Pinus contorta*) is prevalent. Quaking aspen (*Populus tremuloides*) occurs intermittently where micro-site conditions provide enough moisture for aspen to thrive in either persistent or seral stands. Deciduous riparian zones along rivers and creek beds are present throughout the area, with occasional stands of cottonwood (*Populus spp.*) and willow (*Salix spp.*). The vegetation in riparian zones is generally not significant carriers of fire, and therefore do not usually require extensive mitigation." (Jefferson County Community Wildfire Protection Plan)



Map of Jefferson County showing major vegetation cover types.

Colorado's Front Range was influenced heavily by fire before the era of fire suppression (Donnegan et al., 2001). Lightning ignited fires were common before European settlement in the 1850s, with low- to mixed-severity fires occurring every 7 to 50 years along with occasional severe, stand-replacing fires. Colorado's Front Range is also the ancestral land of indigenous groups who utilized fire as a land management tool. Fire behavior resulted in a mosaic of widely spaced trees and small tree clumps interwoven with grasslands and shrublands, particularly on drier south-facing slopes. North-facing slopes often supported denser forest stands (Addington et al., 2018). Ponderosa pine and dry mixed-conifer forests were fire-adapted ecosystems and very resilient to lower intensity wildfires. Frequent fires would kill many tree seedlings and saplings, thereby preventing the accumulation of ladder fuels and reducing the potential for surface fires to transition into crown fires. Fire spread was more rapid through understory grasses but released far less heat. These fire effects promoted increased resilience of many larger trees to survive and thrive for centuries. Occasionally dense clumps of trees would experience mortality from passive crown fire, further increasing the diversity of habitat in these ecosystems. Ponderosa pine ecosystems with fewer trees support more abundant and species-diverse understories of grasses, forbs, and shrubs and provide habitat for a variety of wildlife that prefer more open forest structure (Matonis & Binkley, 2018; Kalies et al., 2012; Pilliod et al., 2006).

As the initial ranching and logging activities of Euro-American settlers subsided in the region and government-mandated fire suppression began in the late 1800s, trees grew back in a single age class, resulting in many dense forest stands (Addington et al., 2018, Battaglia et al., 2018). Although many present-day residents consider dense forest to be "natural", these conditions are vastly different from the wildfire-resilient ecosystems that existed before the 1850s. Landscapes of continuous, dense forests are more prone to high-severity fires that are difficult to suppress and can result in catastrophic losses to lives and property (Haas et al., 2014).

Wildlife

"The unique location of Jefferson County at the intersection of the Great Plains and the Rocky Mountain foothills results in a mosaic of ecological communities that are in turn home to a diversity of wildlife. Mule deer (*Odocoileus hemionus*) and Rocky Mountain elk (*Cervus canadensis nelsoni*) are found in all seasons, utilizing the cover of the mixed conifer forests in the summer and the forage of the open plains in winter. Several species of raptors including golden eagles (*Aquila chrysaetos*) and peregrine falcons (*Falco peregrinus*) nest on the steep canyon walls, while Northern goshawks (*Accipiter gentilis*) nest in dense forests. Across the County, well over two hundred different species of migrating and residential songbirds, such as the Woodhouse's scrub-jay (*Aphelocoma woodhouseii*) and grasshopper sparrow (*Ammodramus savannarum*) can be found through the year. The abundance of wildlife habitat throughout the County and Jeffco Open Space supports hundreds of common and special-status species of birds, mammals, reptiles, amphibians, fish, and insects." (JCOS Wildlife Management)

Important species considered in the prioritization analysis for this Plan are Abert's squirrel, bighorn sheep, elk, mule deer, northern goshawk, the Pawnee montane skipper butterfly, and Preble's meadow jumping mouse. These species are indicator species for various desired forest conditions and a high priority for conservation.

WUI, Water Resources, Recreation

Jefferson County encompasses much of the western Denver, Colorado metropolitan area. The communities here occur in the wildland-urban interface (WUI) and intermix. According to the Federal Register, interface is defined as a community that directly abuts wildland fuels. Intermix communities exist where structures are scattered throughout a wildland area. Both interface and intermix areas require fire hazard mitigation. As is typical of Colorado Front Range WUI zones, neighborhoods extend into foothill valleys, canyons, and mountain slopes with restricted access and limited emergency water supplies. These common examples of the WUI each present emergency responders with unique, identifiable, and addressable hazards and risks. Residential neighborhoods oftentimes directly abut JCOS parks, which highlights the need to strategically plan and implement cross-boundary projects to reduce risk to these communities and make it easier for emergency responders to do their job in the event of a wildfire.

A particularly important resource at risk in this County is the Upper South Platte Watershed, which has been impacted from severe erosion and sedimentation following past fire events, and could be further compromised by severe fires in the future. The watershed encompasses approximately 1,000 square miles and supplies the Denver metropolitan area with 80 percent of its water. The Upper South Platte watershed is well known for its recreation opportunities. Cheesman and Strontia Springs Reservoirs, major water sources for the Denver area, are also located in North Fork Fire Protection District in southern Jefferson County. (Jefferson County Community Wildfire Protection Plan)

From rural mountain communities to the western edge of Denver, the population of Jefferson County is rapidly growing. Outdoor attractions are the largest drivers of tourism and inspire many people to move to the Colorado Front Range. In addition to the JCOS park system, there are several other public land management agencies including Denver Mountain Parks, state parks, and national forests.

MANAGEMENT CONCERNS

IMPORTANCE

STRESSORS & THREATS

Wildfire Regimes

Fire plays a critical role in maintaining many Colorado ecosystems. Historically, frequent, low-intensity fires in lower elevation montane forests reduced understory vegetation, while high-intensity fire in high-elevation lodgepole pine forests removed entire tree stands, thereby promoting the regeneration of some native trees and understory plants. Wildfires can benefit ecosystems by releasing nutrients and stimulating regeneration, and reducing the potential for future high-severity wildfires, but they can also deteriorate water quality, alter native vegetation, and threaten human life and property.

Altered fire regimes due to a long legacy of fire suppression have led to an accumulation of fuels in some forests and shrublands, creating the potential for high-severity wildfires.

Climate change and drought are lengthening the fire season and making hot, dry conditions more prevalent.

Human development in the wildland-urban interface is increasing potential losses from wildfires, health impacts from smoke, and decreasing opportunities to use prescribed fire as a management strategy.

Recreation

Residents in Jefferson County value public open space and parkland for recreation opportunities, connected trails, wildlife, and scenic views. Visitors to open spaces maintained by JCOS partake in a variety of outdoor activities, including hiking, mountain biking, picnicking, wildlife viewing, horseback riding, rock climbing, and fishing. Public open spaces can improve people's physical and emotional health, create a sense of community, and foster an appreciation for and understanding of natural resources.

Increasing wildfires and post-fire erosion due to high fuel loads and climate change can damage campgrounds, picnic areas, bridges, and trails and reduce recreation opportunities.

Climate change and drought are altering native plant and animal communities, which can impact wildlife-related recreation.

Negative impacts of recreation on soil, vegetation, wildlife, and water resources require careful planning, mitigation, and consideration.

Human development is increasing demand for recreation opportunities, which can cause crowded trails and campgrounds, reduce visitor enjoyment, result in negative human-wildlife encounters, and exacerbate negative impacts of recreation on natural resources.

Water Resources

Streams, rivers, ponds, and wetlands are critical components of the Front Range landscape. These ecosystems are hotspots of biological diversity, offer important recreation opportunities, and provide water for agriculture, resident drinking water, and downstream municipalities. Riparian and wetland ecosystems provide habitat for many native, rare plant and animal species. Two critical aspects of Colorado's economy—agriculture and outdoor recreation—are highly dependent on water quality and availability.

Altered disturbance regimes impact the structure of native vegetation and increase the risk of high-severity disturbance. This can increase erosion and alter evapotranspiration and snowpack retention.

Climate change and drought are altering the amount, type, and timing of precipitation and snowmelt, and increasing rates of evapotranspiration, stream temperatures, and potential for erosion after vegetation loss.

Human development is increasing demand for water, which can cause downstream water shortages and degrade or eliminate riparian ecosystems.

Motorized and non-motorized recreation can compact soil and cause increased erosion along streams.

Overgrazing in and around riparian corridors can cause bank erosion, channel narrowing, and bacterial contamination from improper waste management.

Wildlife

Hundreds of species of birds, mammals, reptiles, amphibians, fish, and insects occupy the mosaic of Front Range ecosystems. The region is home to federally threatened wildlife species, including the Pawnee montane skipper butterfly and Preble's meadow jumping mouse. Wildlife is ecologically, socially, and economically important; ungulate foraging can shape native plant communities, wildlife species can have cultural significance and provide important food resources, and diverse wildlife provides opportunities for recreational nature photography, birdwatching, and fishing.

Altered disturbance regimes have changed habitat suitability for some wildlife species.

Climate change and drought are reducing the suitable habitat for some species.

Invasive plant species can reduce forage availability, and alter habitat characteristics.

Overgrazing can displace native plants, reduce forage availability, and alter habitats, especially in riparian ecosystems

Human development in the WUI causes habitat loss and fragmentation.

Motorized and non-motorized recreation can alter native vegetation, fragment habitat, and alter wildlife behavior.

Wildlife management and hunting can (re)/ introduce species, or decrease the abundance of certain species.

Forest management can remove habitat features like snags and alter food sources.

Natural Vegetation

The region's diverse range of ecosystems include grasslands, shrublands, savannas, ponderosa pine, aspen, mixed-conifer, riparian forests, and wetlands. These ecosystems provide clean water, recreation opportunities, wildlife habitat, grazing, nutrient cycling, soil retention, improved air quality, and carbon sequestration and storage. They contain cultural significance and offer a sense of place. Rare, native plants increase biodiversity in the region and increase the potential for ecosystems to respond to a changing climate.

Altered disturbance regimes (wildfire, insects, & diseases) have changed the composition and structure of many ecosystems.

Climate change and drought weaken tree resistance to native insects and diseases, increase the severity of wildfires, and reduce regeneration of some native species.

Invasive plant species introduced through grazing, human development, and recreation can out-compete and displace native plants and alter ecosystem processes.

Overgrazing by livestock and native ungulates can compact soil, trample vegetation, reduce plant regeneration, and spread invasive plant species.

Human development in the wildland-urban interface has reduced and fragmented native ecosystems, and created greater pressure to suppress fire in fire-adapted ecosystems.

Motorized and non-motorized recreation can compact soil, trample vegetation, and reduce plant regeneration, and increase risk of fire ignition.

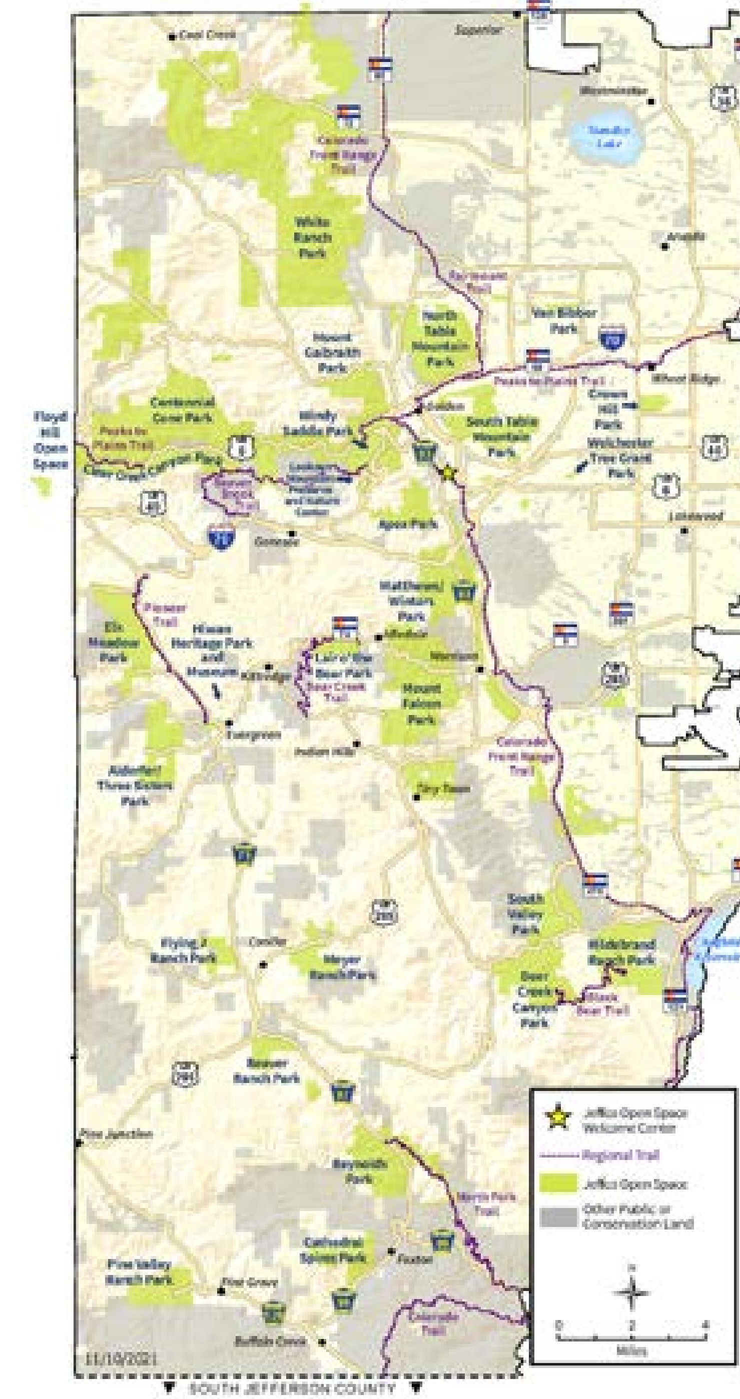
Additional Resources on Management Concerns:

State Wildlife Action Plan, Colorado Forest Action Plan, Colorado Climate Change Vulnerability Study, Conservation Greenprint, Jefferson County Community Wildfire Protection Plan, A Synthesis to Support Water Resources Management and Adaptation

JCOS Parks

The following JCOS parks and properties were considered important for forest management, and include vegetation cover and forest types suitable for the implementation of forest thinning and prescribed fire.

JCOS PARK/PROPERTY	ACRES	BIOGEOGRAPHIC ZONE	COUNTY LOCATION	Local Landscape
Alderfer/Three Sisters Park	1,135	Upper montane	Central	Evergreen
Apex Park	702	Lower montane	North	Golden
Beaver Ranch Park	445	Upper montane	South	Conifer
Cathedral Spires Park	797	Lower montane	South	South Platte
Centennial Cone Park	3,732	Lower montane	North	Clear Creek Canyon
Clear Creek Canyon Park	3,332	Lower montane	North	Clear Creek Canyon
Coal Creek Canyon Study Area	6,204	Lower montane	North	Coal Creek Canyon
Deer Creek Canyon Park	1,637	Lower montane	South	Deer Creek Canyon
Douglas Mountain Study Area	1,828	Upper montane	North	Clear Creek Canyon
Elk Meadow Park	1,658	Upper montane	Central	Evergreen
Flying J Ranch Park	418	Upper montane	South	Conifer
Hildebrand Ranch Park	1,671	Lower montane	South	Deer Creek Canyon
Lair o' the Bear Park	394	Lower montane	Central	Morrison
Lippincott Ranch Property	425	Lower montane	North	Coal Creek Canyon
Lookout Mountain Preserve	100	Lower montane	North	Golden
Matthews/Winters Park	2,461	Lower montane	Central	Morrison
Meyer Ranch Park	667	Upper montane	South	Conifer
Mount Falcon Park	2,252	Lower montane	Central	Morrison
Mount Galbraith Park	800	Lower montane	North	Golden
Mount Lindo	832	Lower montane	Central	Morrison
North Table Mountain Park	1,998	Lower montane	North	Golden
Pine Valley Ranch Park	883	Lower montane	South	South Platte
Reynolds Park	2,050	Lower montane	South	South Platte
South Valley Park	995	Lower montane	South	Deer Creek Canyon
White Ranch Park	3,953	Lower montane	North	Coal Creek Canyon
Windy Saddle Park	792	Lower montane	North	Clear Creek Canyon



Map of Jefferson County Open Space park system.

MEYER RANCH PARK

ALDERFER/THREE SISTERS PARK

FLYING J RANCH PARK

WHITE RANCH PARK

Forest Management History

Forest management was implemented by European settlers on lands that are now JCOS parks as early as the late 1800's. Indigenous peoples used burning as a land management technique long before this. In the late 1800's and early 1900's, forest management was focused on timber production for railroads, mining, and towns. This work was done by local family-owned sawmills who used the timber as a cash crop.

The parks have been subject to forest management by JCOS since 1979. The first timber stand improvement project was a 15-acre cut at Mount Falcon Park in coordination with the Colorado State Forest Service (CSFS), and the timber was sold as firewood to the public. Individual management plans were created for parks as they were acquired, and a comprehensive management plan was written in 1988 for all parks under JCOS management.

In the 1980's forest management was focused on wildfire prevention, timber stand improvement, and pest control. The main goal was to maintain healthy and aesthetically pleasing forests for park visitors. After a large pine beetle outbreak in the 1970's, dwarf mistletoe and mountain pine beetle were considered the biggest threats. Foresters attempted to control the bark beetles through routine cutting, solarization, insecticide, and finally utilizing debarking (in the late 1990's) of infected trees. JCOS foresters also monitored property boundaries to limit spread. Climate change was acknowledged as a long-term threat that was addressed by experimental planting of white fir in Alderfer/Three Sisters, Mount Falcon, and White Ranch Parks. Shaded fuel breaks were cut and cleared every 10 years on average, mainly around roads.

Forest inventories began for every property in the 1990's and data was collected on stands, vegetation, and wildlife. Foresters used plots and aerial photography to document the resources and forest conditions. Management began to integrate wildlife habitat priorities such as leaving snags and down dead woody material where they could provide habitat and increase vertical diversity, but not harm visitors. The pine beetle management plan changed to allow pine beetle activity (10 trees or fewer) to continue in areas that were not visible to

1979

First timber stand improvement project completed at Mount Falcon Park. 15 acres were treated in coordination with Colorado State Forest Service.

1980'S

In line with forest management practices of the time, treatments focused on timber stand improvements, wildfire mitigation, and park aesthetics. Forest pest control was a unifying theme across these focuses.

1988

Jeffco Open Space initial Forest Management Plan adopted, including park-specific recommendations and action plans.

This plan has been in use for over 30 years and is the basis for the updated Forest Health Plan.

1990'S

Following Forest Management Plan recommendations, park property and forest inventories began. Data collection expanded to include fuel loading, understory vegetation, and wildlife indicators.

Forest management focused on managing mountain pine beetle outbreaks, creating shaded fuel breaks, and improving overall forest health.

2000'S

Jeffco Open Space began to incorporate prescribed fire as a management tool, aiming to restore ponderosa pine stands and native meadows.

Prescribed fires were conducted at White Ranch, Elk Meadow, and Mount Falcon Parks.

Additionally, efforts at Meyer Ranch and Flying J Ranch Parks focused on creating one-to-two acre openings by cutting suppressed lodgepole pine stands.

2010-PRESENT

Jeffco Open Space shifts to digital inventory and data collection, increasing partnership collaboration and expanding knowledge sharing.

Forest Health Plan Update begins in 2020 and aims to inform collaborative and strategic forest management in Jefferson County.

the public, and foresters focused efforts on where visitors could see results. In the late 1990's foresters used pheromone packets, debarkers, and tree removal as the primary means of bark beetle control. They focused heavily on the property boundaries to control the spread of the outbreak. As the forestry program continued to grow, so did the threat from invasive species following forest management projects. To address this concern, JCOS used a variety of integrated pest management techniques including herbicide applications and biocontrol releases. In the early 1990s foresters also performed pile burns to remove residual woody biomass following thinning projects at White Ranch, Meyer Ranch, and Pine Valley Ranch Parks.

In the 2000's, prescribed fire became a focus of the agency. JCOS aimed to restore ponderosa pine stands and native meadows at White Ranch, Elk Meadow, and Mount Falcon Parks through low-severity prescribed fires. From 1999 until 2012, prescribed broadcast burns were a standard part of forest management in coordination with CSFS. They treated approximately 1,600 acres with broadcast burns before 2012 when the Lower North Fork Fire, which was an escaped prescribed fire in Jefferson County, caused CSFS to cease broadcast burning. The goal of prescribed fires was to improve vertical and horizontal vegetative diversity, and foresters used avian communities as indicators of ecosystem health. Lodgepole pine stands at Meyer Ranch Park and Flying J Park became a focus for improvement in this decade, and foresters used patch cutting to create one-to two-acre openings to replicate the high-severity fires on a smaller scale to which lodgepole pine stands are adapted. Lodgepole pine was also removed where it was determined to be encroaching on riparian areas. Meadow restoration was also a

focus; JCOS used aerial photography from the 1930's to identify where forests had encroached on meadows and grasslands, and primarily used prescribed fire to restore the meadows to a size approximating their historic norm. Many properties with meadows previously had livestock that prevented trees from encroaching on the meadows. When JCOS purchased the property and removed the livestock, forest encroachment began within a few years and JCOS had to use alternate methods to control it. Technology for GPS, GIS, and forest inventories was rapidly changing in this era, so consistency between old record keeping and new record keeping became challenging due to lack of GIS support and not-yet-developed data management technology.

The mid-2000's through today have been a period of re-entries to enhance past work while restructuring the make-up and focus of the Natural Resources Team and forestry program to meet future needs. For instance, ponderosa pine restoration and lodgepole patch-cuts remain priorities, but more projects are being implemented by contractors than in the past, resulting in a greater number of acres treated each year. Dwarf mistletoe treatments advanced from simple buffer strips of entire areas to including tree climbing so that specific infestations could be targeted. Forest inventories are utilizing historical data and photo-points to initiate surveys, and they now utilize digital data collection and modern modeling technology. Perhaps the most important change was the elevation of forest management as a major priority for Open Space and Jefferson County itself. This can be seen in staff and structuring changes beginning around 2016, which refocused the Natural Resources Team from a group of generalists into a team of specialists, including forestry specialists.

SECTION 2: DESIRED CONDITIONS AND GUIDING PRINCIPLES

This section describes the desired future conditions and guiding principles for the JCOS forest management program. The desired future conditions communicate the intention behind forest management, and describe the outcome for successful management projects and the program as a whole. The guiding principles aid managers with on-the-ground decisions to achieve management goals and are closely linked with the desired future conditions.

Desired Future Conditions

Establishing desired future conditions (DFCs) creates a common vision for success. DFCs can be compared to current conditions to determine whether restorative actions are needed, and can inform treatment prescriptions for individual projects. Desired conditions are also an important component in the adaptive management process, as they provide a benchmark to frame monitoring, determine the success of projects, and make adjustments when needed. Careful consideration of historical range of variability, anticipated future change, and ecosystem process and function is integral to how DFCs are described, and DFCs should not be a static reference condition. To capture these considerations, DFCs need to balance flexibility with clarity about specific conditions that will be used to evaluate project outcomes.

Desired future conditions for forest ecosystems within the JCOS park system can be identified at multiple spatial scales. At the project scale, Managers should develop DFCs during project planning that are unique to each management action. This allows managers to create desired conditions that are relevant to the unique and local context of each project.

Managers can follow a step-by-step process for gathering information that informs project desired conditions, goals, and prescriptions. At the landscape scale, DFCs capture JCOS values, and emphasize a range of diversity, forest complexity, and important ecological processes. The Upper Monument Creek Landscape Restoration Initiative (Lewis and Addington, 2014) inspires how DFCs are framed at the landscape scale and describe general ecological and social conditions relevant across the JCOS park system. Furthermore, landscape scale DFCs are closely tied to the guiding principles described later in this section, and can inform long term program development and resource allocation.

Developing Project Scale Desired Future Conditions

In JCOS park lands, desired future conditions at the project scale are focused on ecological metrics that link projects to scientific research, historical conditions, wildlife habitat, resource protection, and current conditions. All of which are informed by and balanced with societal expectations for high quality outdoor experiences in JCOS parks. Generally, project scale desired conditions will be based on a suite of metrics related to these broad forest management objectives:

1. Reduce risk of catastrophic wildfire
2. Reduce forest densities and canopy cover
3. Increase the presence, size, and diversity of forest openings
4. Restore and maintain a mosaic of ecosystems and vegetation cover across the landscape
5. Promote fine scale heterogeneity in tree spatial patterns
6. Protect and enhance old-growth features
7. Where appropriate, reestablish the use of prescribed fire as a management tool
8. Promote long-term ecosystem resilience to natural disturbance
9. Assist with ecosystem adaptation to climate change
10. Create aesthetically pleasing forest stands

For specific forestry metrics see section 4 on Collaborative Adaptive Management.

Landscape Scale Desired Future Conditions

A diverse landscape mosaic of vegetation cover with structure and composition reflecting variations in biophysical conditions.

- — Open ponderosa pine Douglas-fir woodlands occur at lower elevations and on drier south facing slopes. The forest type transitions into dry mixed conifer, mesic mixed conifer, lodgepole, and subalpine forests on north facing slopes and at higher elevations that support denser forest conditions, correlated with increasing moisture availability.
- — A range of structural and successional conditions exists across forest and vegetation types: Early, mid, and later seral conditions; uneven and even-aged stand structures; open and closed canopy, large and small forest openings/gaps; grassland and shrubland plant communities.
- — Forest openings are reestablished and maintained while supporting natural regeneration.
- — Historically open forest stands and meadows that have been encroached by the surrounding forest are reestablished and openings are maintained while supporting natural regeneration.
- — Old-growth stands are present in all forest types

Fine-scale heterogeneity in forest structure and spatial patterns mimic natural disturbance patterns.

- Unique forest structure features are present and persist following disturbance and management.
- Standing dead trees and large downed logs are present. Standing dead trees will encompass a range of decay and size classes sufficient to support the full suite of cavity nesting, drilling, and excavating bird and mammal species present in the area.
- Large, old trees with unique habitat features such as fire scars, cavities, and complex crown structure (e.g. broken tops, split stems) are present.
- Individual trees and smaller tree groups (<~16 trees) are unevenly spaced and a full range of canopy cover (0-100%) is present across scales to create variable light conditions on the forest floor.
- Forest gaps are variable in size and shape.
- A wide range of vegetation plant communities are present, and rare or endemic species are not vulnerable to extirpation.
- Spatially heterogeneous patterns of forest gaps and tree groups limit the spread of high-severity disturbance.

Northern goshawk on nest, Photo: Joanne King

Pawnee Montane skipper, Photo: USFWS

Landscape scale, and fine scale heterogeneity provide a diversity of wildlife habitat.

- Healthy wildlife populations are maintained.
- All wildlife species have sufficient and available habitat.
- A mosaic of canopy cover provides a continuum of open to closed canopy cover occurring at multiple canopy heights.
- Forest habitats are connected and allow for species movement across the landscape.
- Rare, endemic and desired species are fully supported, and not rendered vulnerable to extirpation.

Natural disturbances take place in forest stands, are recognized as an important ecological process, and contribute to healthy ecosystems.

- Disturbances that are high-severity and have a negative impact on ecosystem services are minimized across the landscape.
- Fire occurs within the natural range of variability and is socially acceptable. Low-severity fire behavior occurs in lower elevations and kept safely away from highly valued resources and assets. Pockets of moderate-to high-severity fire occur at more productive sites, away from highly valued resources and assets, and are generally small in extent (<10 acres).
- The spread of insect and disease related mortality is limited, closely monitored, and occurs on a small scale, affecting individual tress to small tree groups.

Where deemed safe and responsible, prescribed fire is used across the JCOS park system.

— Pile and broadcast burning are used as a cost-effective tools to reduce surface fuel loading, access challenging terrain, and build off forest thinning projects.

— Numerous stands are ready for prescribed fire to increase opportunities and capitalize on highly variable burn windows.

Watersheds support functioning hydrologic processes; erosion is limited following disturbance and drinking water supplies are maintained.

— High quality water supplies are maintained

— Erosion and sedimentation are limited following wildfire and forest management implementation, and do not harm access to drinking water or create unsafe runoff and flooding events.

— Riparian areas support a wide range of native species, provide cover for terrestrial wildlife, and support a high diversity of vegetation.

— Cooler and wetter areas of the landscape provide refugia from disturbances, drought and climate change.

A diversity of forest conditions enhances recreation experiences, and recreation opportunities are sustained into the future.

- — Access to recreation opportunities within the JCOS park system is minimally disrupted during forest management projects and wildfire events.
- — Forest management works to enhance recreation opportunities and perceived quality of experience while protecting sensitive areas from unauthorized use.
- — Education and outreach on forest ecology and restoration topics are part of the recreational experience.

Forest conditions facilitate a safe and effective fire response.

- — Evacuation routes remain clear during wildfire and other emergencies so people have safe egress and emergency response is quick and effective.

JCOS parks strengthen fire adapted communities in Jefferson County.

- — The public is aware of, engaged with, and supports JCOS goals for forest management and restoration.
- — Local communities can coexist with fire, receive the benefits from a healthy and intact fire regime, and negative impacts are minimized.

Ecosystems are able to adapt to climate change and maintain ecosystem services in the future.

- — Where appropriate, forests and vegetation communities are able to resist, be resilient to, and/or transition in response to changes in the climate and associated impacts from disturbances.
- — Ecosystem services are maintained when ecosystems experience assisted and unassisted transitions.

Together the desired future conditions support a landscape that is more resilient to disturbance and adapted to climate change, with critical forest processes sustaining a wide array of ecosystem functions and services into the future, and where ecological values coexist with human populations.

Guiding Principles

When JCOS natural resource managers are planning individual forestry projects, it can be difficult to translate broad program goals to on-the-ground decisions. This Sectionprovides guiding principles designed to aid managers with making decisions at the project scale, and to be integrated into forest management planning. When a project is being developed, laid out, and implemented, these science-based principles can help managers place projects into the broader context of the landscape. The RMRS-GTR-373 (Addington et al. 2018) provides the foundation for many of these principles and serves as an additional resource to aid with on-the-ground decisions in the JCOS park system.

1) Scale

Guiding Principle: Individual projects are planned with consideration of the larger landscape context – how treating individual stands contributes to forest structure patterns, a landscape mosaic of vegetation, ecosystems services, and socio-economic factors across spatial and temporal scales.

— Project planning and implementation follows a hierarchal process across both spatial scales and institutional divisions with partners and within JCOS. Distinct and connected planning processes happen from landscapes to stands and from leadership to implementers.

— Management at the project scale recognizes and attempts to facilitate important interactions and effects across larger spatial scales.

— Desired vegetation cover types are represented at broader scales, individual projects contribute towards enhancing and maintaining a landscape mosaic of vegetative patch types.

— A range of structural and successional conditions exists across forest and vegetation types, including: early-, mid-, and late-seral conditions; uneven and even aged stand structures; open and closed canopy, large and small forest openings/gaps; and grassland and shrubland plant communities.

— In addition to ecological effects from treatments, management also considers impacts to neighboring communities, park visitors, and the local and regional economy.

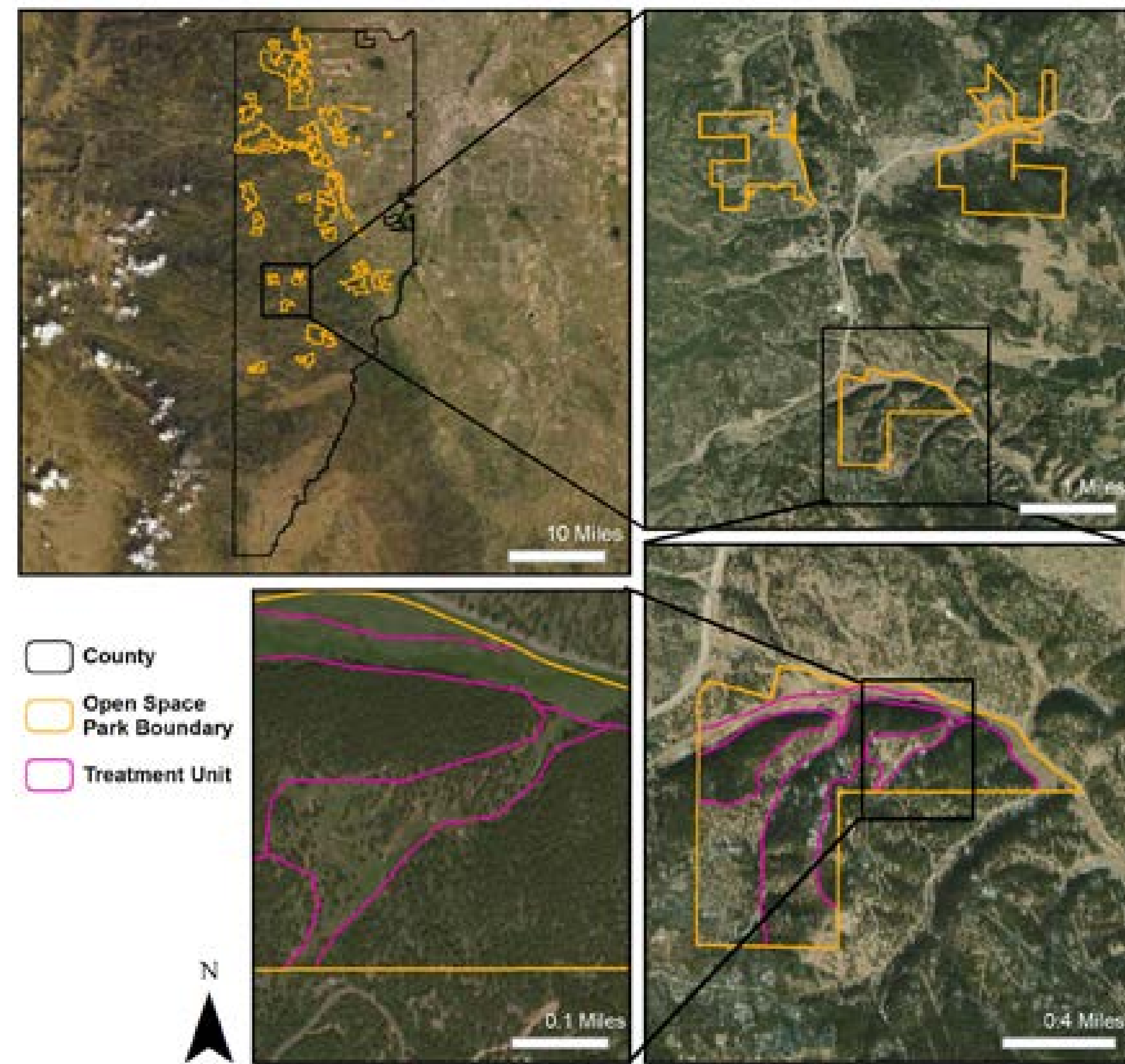
Planning and Implementation Across Spatial Scales

Broad Landscape: 100,000-1,000,000+ acres—equivalent to National Forest or large watershed. Jefferson County, the entire JCOS Park system, the Upper South Platte Watershed, and the Central Front Range are broad landscapes relevant to JCOS. Strategic planning begins at this scale, where JCOS works internally and with partners to identify areas at smaller scales where management efforts should be focused.

Examples: JCOS park system prioritization modeling (Section3) identifies local landscapes and project areas where management efforts should be focused. County wide prioritization modeling (Appendix A) provides tools for JCOS to strategically plan and coordinate cross-boundary projects with partners across Jefferson County. The USPP follows an informal process to identify

focus areas within the Upper South Platte Watershed to target funding and coordinate implementation. The Colorado Forest Action Plan provides a planning framework starting on page 63 that can help JCOS managers connect both to projects to the larger state-wide context for prioritization, and to the 6 themes for Colorado forest management goals: forest conditions, living with wildfire, watershed protection, forest wildlife, urban and community forestry, and forest products.

Local Landscape: 1,000-100,000+ acres—equivalent to sub watersheds. One or multiple JCOS parks within an area of similar vegetative cover and conditions, USPP focus areas, and priority sub watersheds are local landscapes. Strategic planning continues to prioritize and coordinate projects at smaller scales so management is impactful and treatments build off one another. Some local landscapes identified in



Going clockwise add Broad Lanscape, Local Landscape, Project Area, Treatment Unit and Stand.

the JCOS park system prioritization modeling include the parks surrounding Conifer, Evergreen, and Coal Creek Canyon.

> **Examples**: JCOS prioritization modeling (Section3) helps JCOS staff prioritize areas, parks, and management units within the JCOS park system where treatments designed to reduce wildfire risk and provide ecological benefit will have the greatest impact relative to cost. In the USPP, partners develop strategies within focus areas that connect management projects and create contiguous areas of treatment.

Project Area: 100-1,000+ acres—containing multiple treatment units. Individual JCOS parks and/or large sections of bigger parks are considered project areas. In project areas, managers gather detailed information on current conditions, desired future conditions, treatment prescriptions, and a timeline of treatment implementation and monitoring.

> **Examples**: JCOS project planning documents or forest management plan.

Treatment Unit and Stand: The smallest scale for forest management planning and implementation. Equivalent to JCOS management units within individual parks. The end-point for planning, informed by detailed project plans, and where implementation begins. Treatment or management units are constrained to similar forest stand conditions. Each unit is given a specific prescription, treatment method, and plan for operations. Some management units may contain multiple stands or vegetation types, where further stratification is required so prescriptions and treatment plans are precise. Treatment unit information will include fine scale features such as forest openings, reserves, tree groups, and individual trees and snags.

> **Example**: Detailed prescription for an individual stand, or a prescribed fire burn plan for an individual burn unit.

Additional Resources: GTR-373 Section3.2 (Addington et al., 2018); Hessburg et al., 2015; Lindenmayer et al., 2008

2) Historical Conditions as a Guide

Historical conditions describe the range of conditions and processes that characterized ecosystems historically, and are often called the historical range of variability (HRV) in the scientific literature. HRV typically describes conditions that existed prior to Euro-American settlement in the 19th century and before new land use (e.g., logging and grazing), human development, and land management policy substantially altered conditions and disturbance regimes.

The concept of HRV has long provided an important foundation for framing desired conditions and setting goals and targets for restoration work. It is widely accepted along the Front Range that historical conditions were more resilient to natural disturbances and fluctuations in climate, and restoring these conditions should improve the resiliency in contemporary forests. However, managers should be careful to not let HRV constrain management decisions. Like forests, our understanding of HRV is always changing as we gather more information about the range of conditions from further back in time (>200 years), or the anticipated range of future conditions, including increased development and novel climate change scenarios. JCOS forest managers will also take into account climate projections, habitat needs of key wildlife species, human-caused stressors, and park visitor expectations when planning treatments; no one of these factors will dictate JCOS forest management to the detriment of the others.

Guiding principle: Management decisions should be informed but not constrained by historical conditions and the historical range of variability (HRV).

— HRV records demonstrate that forests were dynamic, included a complex range of conditions that varied over space and time, and were self-sustaining at a broad landscape scale. When considered along with other relevant factors, HRV often provides a foundation upon which to begin planning projects.

— For a project area, gather historical information, reconstruct locally relevant changes over time and use this information to help inform management decisions. Historical information can include photos (Veblen & Lorenz 1991), historical written accounts, and aerial imagery (University of Colorado; Arthur Lakes Library, Colorado School of Mines).

— On the ground, use forensic forestry techniques to document and gather data identifying legacy structural features that are often still present and provide clues about what forests looked like historically. Legacy features are often large trees and snags that persist on the landscape for decades because these features resist or avoid disturbances that would remove them (Brown et al. 2019). The lack of legacy features can also provide important information about historical disturbances.

— Restoration should not strictly recreate historical conditions, but also consider the future range of variability (FRV) based on the current understanding of how climate change, social factors, and disturbance may influence the range of future forest conditions. See Section3.9 of the GTR-373, and the Conservation Greenprint to help frame FRV.

Additional resources to help determine HRV: Battaglia et al. 2018; Brown et al. 2015; GTR-373 (Addington et al., 2018); Veblen & Donnegan 2005; Veblen 2003; Graham 2003

3) Natural Variation of Environmental Gradients

Guiding principle: Natural environmental gradients that influence site productivity, forest structure, and vegetation composition should guide management decisions.

— Physical environmental gradients are closely linked to moisture and productivity gradients, and help determine the appropriate stand structure and composition. In general, drier and less productive sites should support lower tree density and cover, more isolated and individual trees, smaller tree groups, and drought resistant trees (Figures 2.1 & 2.2).

— Recognizing and responding to the variability in environmental conditions across the landscape can help create more heterogeneity and diversity across spatial scales.

— Managers should develop an understanding of environmental gradients at different scales for individual projects. Information such as latitude and elevation can help managers place individual projects into the context of the broader landscape. Within a project area, mapping tools that show slope, aspect, and soil type (if available) can help foresters identify and create variability in prescriptions. Lastly, simple documentation and mapping of topographic features (e.g., ridgelines, swales, watercourses, rocky outcroppings, etc.), soils, and vegetation, can further aid managers in understanding local environmental gradients.

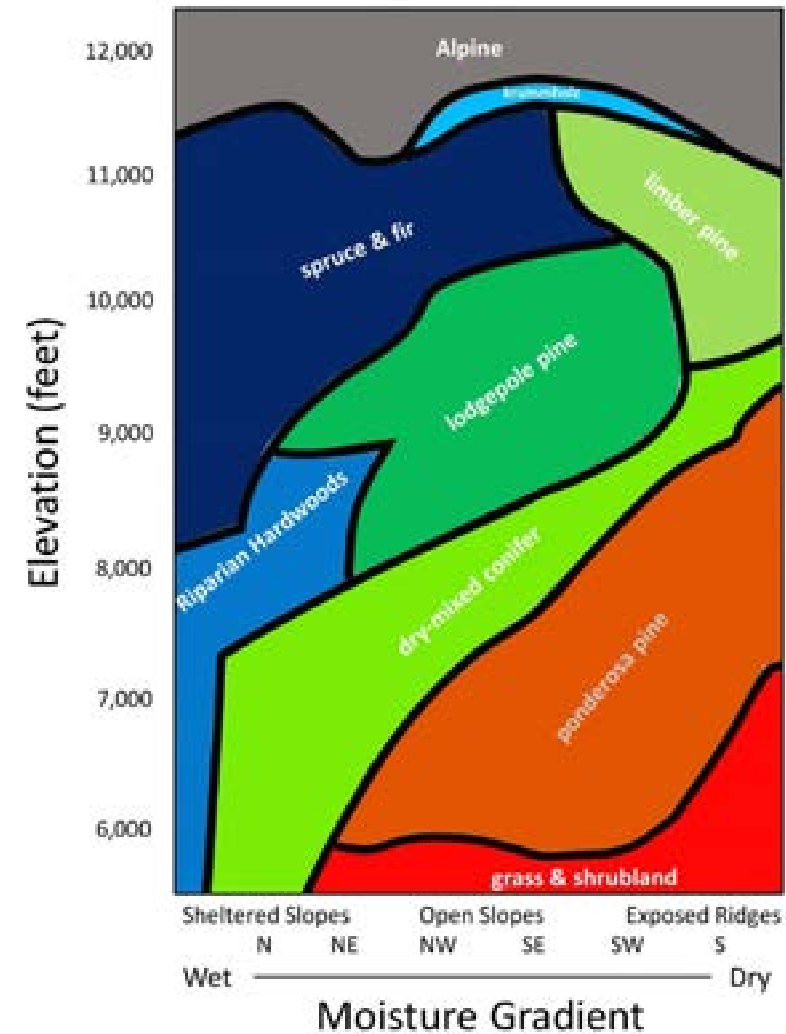


Figure 2.1 Dominant forest and vegetation type by elevation and moisture gradient (from Addington et al., 2018; and adapted from Peet 1981).

Environmental Gradients

Latitude – Climate varies from south to north at a broad scale along the Front Range; however, changes related to latitude are small within Jefferson County. In general, southern parks may be slightly warmer and drier than parks further north. Jefferson County lies at the transition between the northern and southern Front Range climate zones; in the north, precipitation regimes peak during the spring, and in the south, mid-to-late summer monsoons bring more precipitation later in the growing season. JCOS parks could exhibit a mixture of both precipitation regimes with a proportion of the annual precipitation falling during the summer at parks further south.

Elevation – Vegetation can change dramatically over elevational gradients along the Front Range, mostly in response to substantial changes in precipitation and temperature. From the plains (<6,000 feet above sea level) to the subalpine forest, (>9,200 feet above sea level) average temperatures can drop by 15 F° and precipitation can increase by more than 50%. These changes in temperature and precipitation lead to a shorter growing season, higher moisture availability, and a less frequent fire regime at higher elevations. Nearly all forest management within the JCOS park system falls within the upper montane (~8,000-9,200 feet) and the lower montane (~6,000-8,000 feet) zones. Tree cover, productivity, and surface fuel accumulation typically increase with elevation within the montane zone.

Aspect – Due to higher solar radiation, south-facing slopes tend to have lower soil moisture than north-facing slopes. Forests tend to be more open on south-facing slopes, and they support more frequent low-severity fire regimes. On north-facing slopes lower temperatures and evapotranspiration rates create conditions allowing deep snow packs to persist later into the year. The conditions on north-facing slopes are generally more productive and can support higher tree densities and cover. However, forest structure patterns can be highly variable, and include openings and closed canopy patches. Fire behavior is also more variable on north-facing slopes, and historically sustained variable forest structure. North-facing slopes may provide some mitigation to the effects of climate change, and create refugia for certain forest types as warmer and drier climate conditions push vegetation to new areas of the landscape.

Slope and Slope Position – At the local scale and within project areas, slope position can influence moisture gradients. Productivity and tree density regularly decrease from the bottom of slopes up to mid-slope and to ridges. Slope steepness can also influence moisture availability, as soil moisture decreases with increasing slope. Gentle slopes below 20 percent tend to develop deeper soils that retain more water, and steep slopes are often prone to soil loss.

Soils – Soil along the Front Range is generally rocky, shallow, coarse, and slightly acidic, which leads to lower productivity when compared to other regions in the western United States. Soils can vary broadly with latitude; granitic soils associated with the Pike Peak Batholith are widely present in the southern Front Range. These soils have a low water holding capacity, and potentially make forests more prone to drought stress. The southern parks within the JCOS system are on the northern edge of the Pike Peak Batholith, and could exhibit soil types associated with the southern Front Range. Soil formation can also be influenced by aspect and slope, where south-facing and steep slopes often lack an organic matter O-horizon. However, soils can vary on a fine scale, and managers can note vegetation productivity patterns in the field to gain an understanding of how soils change within a project area. Soils that are less productive and have a lower water holding capacity should support less tree cover and more drought resistant species.

Topographic Wetness Index – Many of the underlying topographic gradients described above can be summarized using metrics such as the topographic wetness index (TWI). TWI can help managers discern fine scale moisture gradients within a project area, and identify dry areas where there is opportunity to create forest openings and low-density forest structure. TWI can be derived using a digital elevation model that calculates topographic and hydrologic elements (e.g., slope, flow direction) to determine where water availability may be higher (Sörensen et al., 2006; Beven & Kirby, 1979). However, TWI does not incorporate information on precipitation and soils, and should only be used as a tool to help managers make on-the-ground decisions about forest structure and composition.

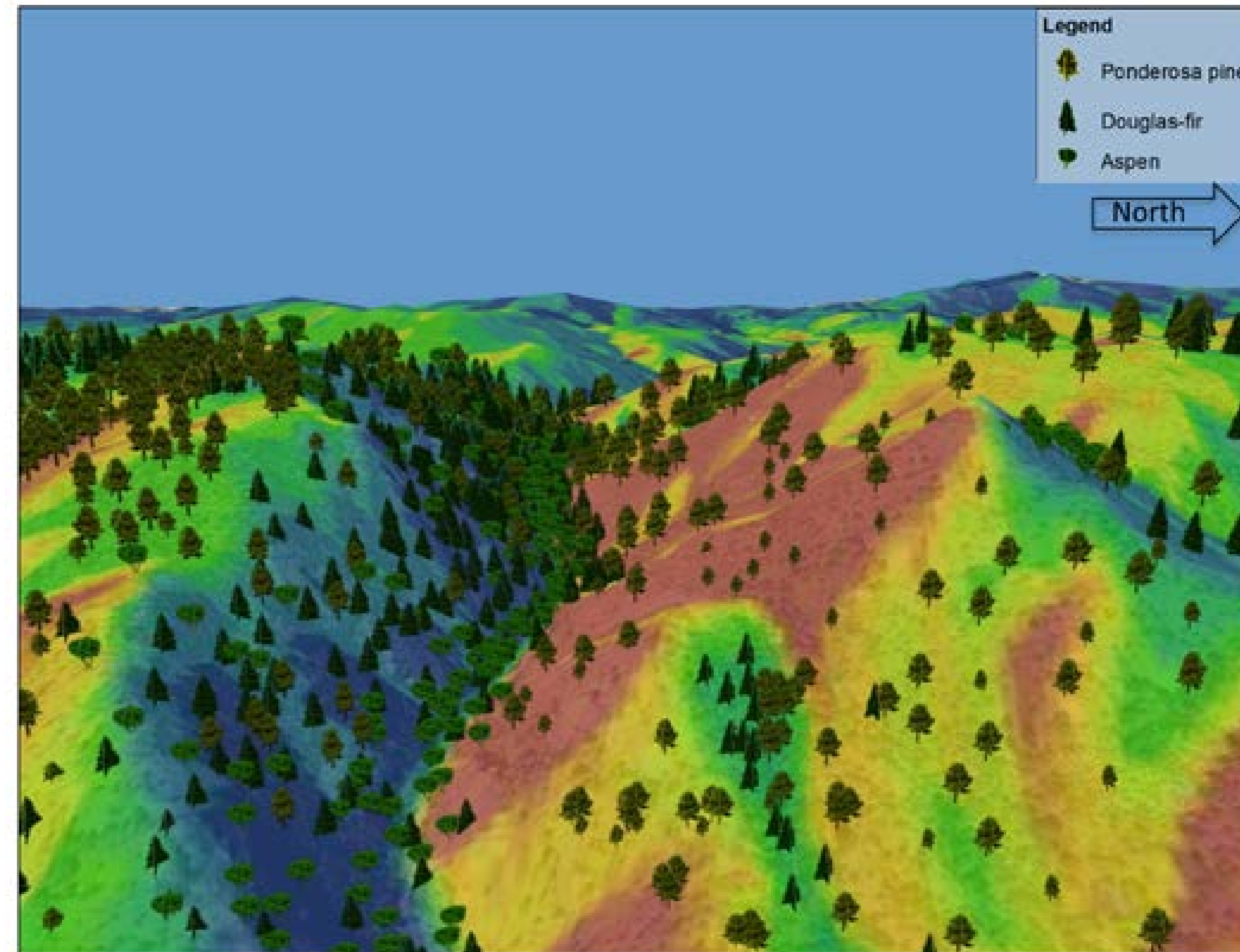


Figure 2.2 Image showing how topography, moisture gradients and forest structure correlate. Warmer colors represent more exposed topography, less moisture availability and lower forest cover. (from Addington et al., 2018)

Climate Change – Expected changes in future temperature and precipitation in Jefferson County present new stresses that will vary over time and space. The environmental gradients described earlier will remain relatively constant over the next several decades; however, warmer temperatures and decreasing precipitation will impact moisture availability and site productivity on shorter time scales that necessitate consideration when planning projects. Managers should keep climate change in the forefront of their thoughts as they gather information about environmental gradients related to topography and soils, and when determining desired conditions. Future climate conditions may require managers to plan for creating forest structure and composition that will be better adapted to less moisture availability, or plan for multiple treatments to facilitate adaptation to a changing climate over time. Some areas will likely change faster than others, and the same topographic variables described above can help managers determine areas that will be more or less vulnerable to climate change. In general, drier sites at lower elevations and with higher solar radiation will likely see more climate stress over time, with higher tree mortality and less recruitment (Rodman et al., 2020); wetter sites stand a better chance of maintaining desired conditions under the current and future climate.

Additional resources: GTR-373 Section3.4 (Addington et al., 2018); Peet 1981

4) Rare and Desired Elements

Guiding principle: Forest Management protects and promotes desired features at the stand and landscape scale that are underrepresented, support desirable wildlife and non-woody vegetation, provide important ecological services, and/or contribute to heterogeneity.

- Identify the structural and floristic components and features that make up the desired conditions of a stand or landscape. This includes vegetation patches, openings, randomly spaced tree groups and individual trees, snags, downed woody debris, old growth, rare and threatened plants, riparian zones, aspen stands, specific components of wildlife habitat, desired understory plants, and other highly valued resources and assets.
- Rare and desired elements can help guide treatment prescriptions and stand marking by focusing on what should remain or be created following treatment.
- Fine-scale heterogeneity in forest structure and spatial patterns mimic –to a degree- natural disturbance patterns, contribute to limiting the spread of high-severity disturbance, and increase wildlife habitat diversity.

Forest Elements

Vegetation Patches – A vegetation patch is a contiguous area of similar forest type or understory plant community. At the landscape scale, vegetation patches are primarily described in terms of composition. Figure 2.1 shows how vegetation types vary across environmental gradients. General vegetation cover types are also used in Section3 to model wildfire risk and ecological benefit. Different vegetation cover types should make up a mosaic of patches that contribute to overall diversity across the landscape. At larger scales management should identify patches that are underrepresented and take actions to restore or promote those patches. Within a vegetation cover type, smaller patches can be identified and described by composition, structure, connectivity, and successional stages. Smaller-scale patches that are common to forest ecosystems in the JCOS park system are described below.

Openings – Forest openings are characterized by an understory vegetation layer made up of grasses, sedges, forbs, and shrubs. Trees may still exist in openings but canopy cover is typically lower than 10%, and the size of openings can vary greatly from gaps smaller than an acre to large areas of grasslands and shrublands. Openings provide important ecosystem services including wildlife habitat and forage, pollen, nectar, and breeding sites for insects, mitigation from high-severity wildfire, and increase overall biodiversity. Historically, forest openings were more prevalent across the landscape, and changing land use patterns, particularly fire suppression, has led to a loss of this important and desired element. Persistent openings are often sustained by biophysical factors (e.g., soils) that lead to poor

site productivity. However, disturbance plays an important role in creating and maintaining transient openings, and many openings become encroached by trees or are not created in the first place when disturbance is removed. Post-disturbance and early successional stages often establish openings that can promote regeneration. Over time these transient and early successional openings can be allowed to transition into forest as long as management or disturbance is allowed to create new openings and restore the overall coverage of openings that resembles historical conditions.

Open Forests – Open forest conditions with an average canopy cover generally ranging from 10-40% should be predominate across the JCOS Park system. However, similar to openings, fire suppression over the last century has led to a loss of open forest conditions. Open forests are found in relatively drier sites, and are maintained by a frequent, low-severity fire regime.

Closed Forests – As moisture availability increases, open forests transition into closed canopy forests where canopy cover is typically greater than 40%. Closed forests were historically less common than openings and open-canopy forests. Mixed-severity fire regimes are expected to occur in closed forests, and management may need to remove cover in order to protect highly valued resources and assets. Closed canopy still provides important wildlife habitat and cover in riparian areas; management actions should identify areas that should be maintained as a closed forest, and where there are appropriate opportunities to restore more open forest conditions.

Tree Groups – Disturbance and tree regeneration patterns create a "groupy-clumpy" and uneven-aged forest structure within JCOS parks, and lead to the formation of tree groups. Tree groups include two or more individual trees with interlocking crowns. A canopy of irregularly spaced tree groups provides wildlife habitat and reduces the potential for active crown fire. The proportion of trees in tree groups and the size or number of trees in a group are determined based on existing and desired site conditions. Drier sites have mostly individual trees with some small tree groups, and the proportion of trees in groups and size of groups increases with higher moisture availability. Large tree groups containing more than approximately 20 trees can be considered continuous canopy and are commonly maintained in closed canopy forest reserves or riparian areas as a separate element or patch type.

Individual Trees – Managers should consider species composition, age class distribution, and unique habitat features (e.g., complex crowns and fire scars) when identifying individual trees to retain following treatment. In general, large mature trees are often underrepresented and, in most cases, should be favored for retention; however, selectively removing overstory trees may be necessary to reach desired canopy cover or tree group conditions.

Snags and Downed Logs – Standing dead trees and downed logs are created during mortality events and provide important ecosystem services for many years after the tree dies. These structures cycle nutrients, create microclimates, and provide wildlife habitat and food sources. The intensity and spread of fire are influenced more by small woody debris less than 3 inches in diameter than large down wood, and leaving large logs does not necessarily create a fire hazard. When snags and downed logs are lacking at a site, managers can create these structures by leaving the occasional cut tree on site, girdling a standing live tree, expecting windthrow following thinning, and/or through the use of prescribed fire.

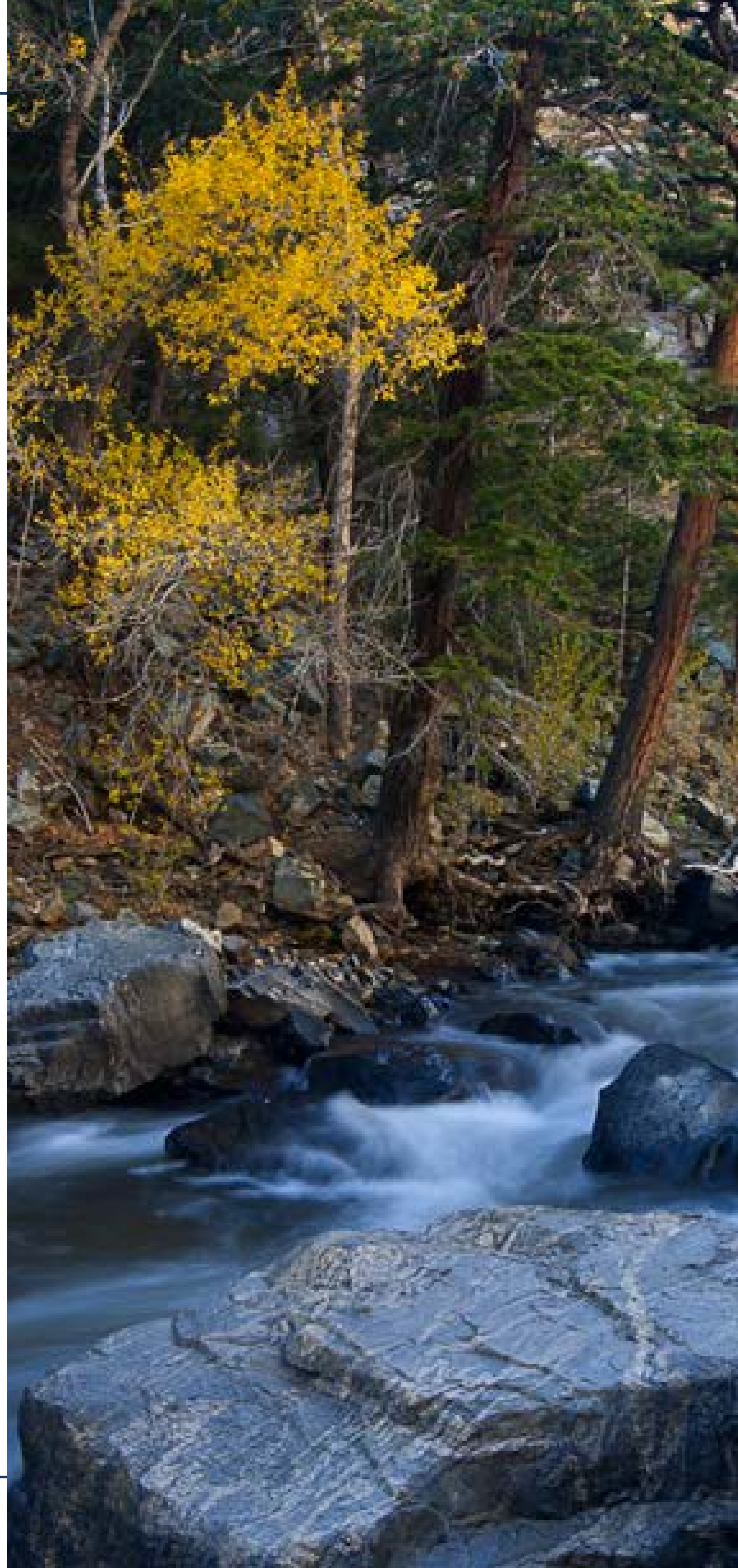
Aspen Stands – Aspen trees are often a desirable feature to maintain or restore with management, as they provide wildlife habitat, overstory diversity, beauty, and natural fire mitigation. It could be difficult to perpetuate aspen stands at drier sites where higher water stress is expected in the future due to climate change. At lower elevations, wetter conditions in riparian corridors and swales could provide refugia for aspen. Thinning can be used to restore aspen stands encroached by conifers, and prescribed fire can be used to promote aspen regeneration and expand stands. Early successional aspen stands can be heavily browsed by ungulates, and managers should consider mitigation strategies to reduce browsing when necessary.

Riparian Corridors – Hydrology and wetter site conditions in riparian areas typically add to overall structural and species diversity by supporting higher canopy cover and riparian vegetation. Management should protect these areas by treating only the surrounding landscape, adhering to Stream Management Zone (CSFS 2010) guidelines, and promoting connectivity of riparian corridors. Treatments may be needed to promote aspen stands and regeneration in riparian areas.

UNDERSTORY PLANTS

Desired - The JCOS park system contains many plant species that are rare, threatened, or important food sources for wildlife. Depending on the species, restoration treatments may be needed to promote desired understory plants, or it may be necessary to exclude areas from treatment where plants are sensitive to the impacts of implementation. When present, desired understory plant species should guide decisions about prescriptions, operational methods, and monitoring.

Undesired - The JCOS park system contains numerous invasive species that are a priority for management. These species (e.g., cheatgrass, yellow toadflax, and musk thistle) have a high potential to displace rare, threatened, or desirable plant species that might otherwise be enhanced following restoration treatments. Special care needs to be taken when implementing a restoration project to ensure that invasive species do not establish



themselves following the disturbance caused by the project itself. Project sites should be monitored for several years after completion, until native vegetation covers the forest understory. When necessary, appropriate management actions should be taken to prevent establishment of non-native invasive plants.

Additional resources: Brown et al., 2019; GTR-373 Section3.3 (Addington et al., 2018), Hessburg et al., 2015; GTR-310 (Reynolds et al., 2013); Lindenmayer et al. 2008; Franklin et al. 2007; Kaufmann et al. 2003

5) Ecosystem Processes

Guiding Principle: Forest management supports and in some cases mimics ecosystem processes so ecosystem services are sustained and resilient to future disturbances.

- Fine-scale heterogeneity in forest structure and spatial patterns mimic natural disturbance patterns, contribute to limiting the spread of high-severity disturbance, increase wildlife habitat diversity, and promote stand regeneration.
- Forest stands are able to withstand natural disturbance without significantly impacting ecosystem services. Low-severity fire is used to maintain desired conditions, and limit the frequency and extent of high-severity wildfire.
  - Promote larger diameter and fire-resistant trees such as ponderosa pine, and seed trees that provide regeneration following wildfire.
- Limit increases in surface fuel loading following thinning treatments, and maintain lower surface fuel loading with slash management, prescribed fire, and other tools.
- Reduce forest density to mitigate the spread of insect and disease related mortality.

Additional Resources: GTR-373 Section3.5 & 3.8 (Addington et al., 2018); Turner et al. 2012, Schoennagel et al. 2011

6) Climate Change Adaptation

Guiding Principle: Management identifies the climate change adaptation strategy that complements other management goals at the stand scale and watershed scale.

At the highest level, climate change adaptation strategies fall under four broad categories:

Resistance – Actions that improve the defenses of the forest against anticipated change or directly defend the forest against disturbance to maintain relatively unchanged conditions over time.

> **Example** – Thinning dense tree stands reduces physical stress on remaining trees, allowing them to better resist attack by mountain pine beetles and other forest insects.

Resilience – Actions that accommodate some degree of change, but encourage a return to a prior condition or desired reference condition after disturbance.

> **Example** – Restoring forest structure, composition, and a frequent low-severity fire regime in ponderosa pine forests based on historical reference conditions.

Transition – Actions that intentionally accommodate change and enable ecosystems to adaptively respond to changing and new conditions.

> **Example** – Planting ponderosa pine at higher elevations or planting novel tree species that are adapted to future climate conditions.

No Action – forests respond to climate change in the absence of direct intervention.

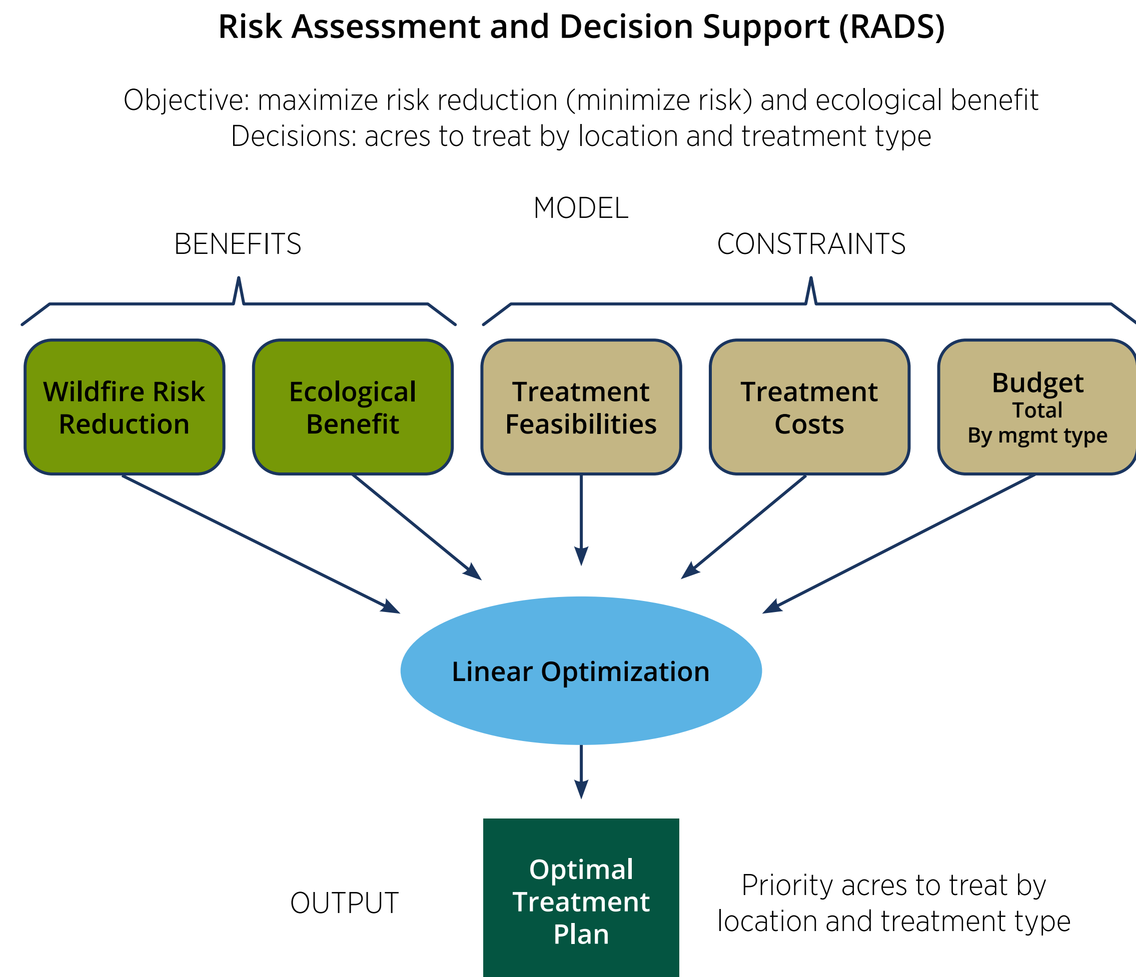
> **Example** – Allowing an open forest to convert into a grassland or shrubland following a large high-severity wildfire.

Additional Resources: Halofsky et al. 2018; Janowiak et al. 2014; Stephens et al. 2013; Millar et al. 2007

The Forest Health Plan used the Colorado Forest Restoration Institute's Risk Assessment Decision Support (RADS) tool to inform management planning (Gannon et al., 2019). RADS expands on the risk assessment and planning framework developed by Scott et al., (2013) and followed a similar collaborative process to identify Highly Valued Resources and Assets (HVRAs), evaluate HVRA wildfire risk and ecological benefit, and prioritize areas where forest management will have the biggest impact on reducing catastrophic wildfire risk and enhancing ecological integrity for the lowest cost. This collaborative planning process and the RADS tool have been used for other planning efforts in Colorado, including the Chaffee County Community Wildfire Protection Plan, the Lake County Community Wildfire Protection Plan, and the Peaks to People Water Fund Watershed Investment Tool, among others.

The purpose of the strategic planning process was three-fold: 1) establish a landscape-scale snapshot of current condition of resources and assets that are relevant to JCOS park management and surrounding communities in Jefferson County; 2) serve as a tool to assess change in resource condition in response to wildfire and management actions; and 3) evaluate trade-offs among different potential management actions to maintain and improve the safety and condition of HVRAs. The assessment model incorporated local spatial data on HVRAs, best available science and expert opinion regarding HRVA response to wildfire and forest management, and the relative importance of values based on stakeholder input. The prioritization model leveraged these assessments to estimate the change in wildfire risk and ecological benefit in response to forest management options such as forest thinning and prescribed fire. The prioritization model combined these effects estimates with management constraints, including feasibility and cost, to identify where forest management has the largest relative benefit to protect and enhance HVRAs compared to the cost of management actions. This trade-off analysis informed the Forest Health Plan by helping JCOS staff and their partners identify optimal locations and forest management strategies to protect the suite of resources and assets within JCOS parks (Figure 3.1).

Figure 3.1. Conceptual diagram of the Risk Assessment and Decision Support (RADS) fuel treatment optimization model. Fuel treatment benefits and constraints are summarized for the feasible treatment area in each treatment unit. Modeling outputs can then demonstrate where treatments will either maximize risk reduction or maximize ecological benefit for the available budget.



Collaborative Modeling Effort

RADS is a structured decision-making framework designed to bring the technical and social aspects of forest and vegetation management together. The JCOS planning and prioritization modeling effort was informed by the contributions of individuals from JCOS, CFRI, and The Guild. Twenty-seven employees from these three organizations participated in at least one of 14 virtual large-group meetings, including fifteen people from JCOS, nine from CFRI, and three from The Guild. The large-group meetings occurred approximately every other week beginning in September 2020. The last of the model-focused meetings was in March 2021, when modeling was finalized. In addition to the formal large-group meetings there were many small-group meetings between participants. These meetings were primarily virtual, but some took place over the telephone and JCOS staff met in-person. Smaller groups met to prepare for the large-group meetings, complete assigned tasks, and have other FHP-related discussions.

In addition to the JCOS, CFRI, and The Guild participants, a variety of external stakeholders shared their expertise to inform our model values. A total of fifteen external stakeholders were involved, including stakeholders from the Bird Conservancy of the Rockies, Colorado State Forest Service, Colorado Natural Heritage Program, Colorado Parks and Wildlife, Denver Mountain Parks, Elk Creek Fire Protection District, Golden Gate Fire Protection District, Evergreen Fire Protection District, Jefferson Conservation District, Inter-Canyon Wildfire Protection District, and US Forest Service South Platte Ranger District – Pike National Forest. There were five fire professionals, two wildlife experts, three botanists, and five foresters.

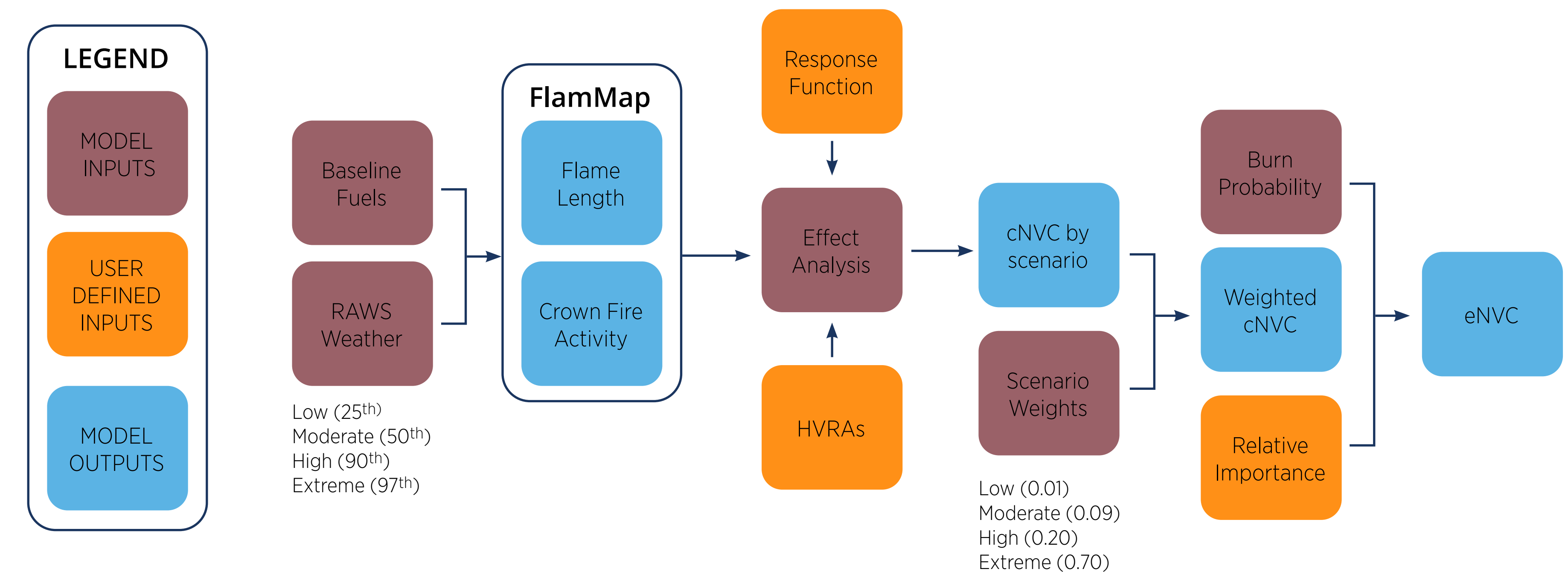
Three virtual focused HVRA meetings were devoted to gather stakeholder's input. Each meeting had a focused discussion on: 1) wildfire risk to life safety, infrastructure, and WUI; 2) wildfire risk and ecological benefit to vegetation cover and forest structure; and 3) wildfire risk and ecological benefit to wildlife. Each stakeholder attended at least one of these three meetings depending on their area(s) of expertise. Many stakeholders also completed a worksheet after attending a meeting. The worksheets allowed them to spend more time considering their answers and documenting their reasoning than during the meetings. Through these meetings and worksheets, stakeholders provided feedback on the relative importance of HVRAs and HVRA categories, HVRA response to a range of wildfire intensities, and HVRA response to three forest management treatments.

The contributions of all 42 individuals were used to guide our modeling effort. As more people became involved and shared their expertise, the modeling evolved. There were six major iterations of the model, where substantial changes were made to model inputs, HVRA relative importance, and/or HVRA response to wildfire or management. There were several other iterations where small improvements and/or value adjustments were made. With each iteration the model became more closely aligned with JCOS needs and values, expert opinion, and scientific research. After 7 months of work, our model was finalized. A total of 30 values were selected as inputs into the model, with relative importance and responses based on expert feedback. There were a variety of products generated at each step in the model, including more than 125 maps, 10 tables, and 15 graphs produced for JCOS planning consideration.

Wildfire Risk Assessment

The JCOS Wildfire Risk Assessment followed the framework described in Scott et al., (2013), A Wildfire Risk Assessment Framework for Land and Resource Management. This framework has been widely used in other prioritization efforts in Colorado and across the Western US, including the Colorado Wildfire Risk Assessment (Technosylva, 2018). CFRI worked with JCOS and their partners to gather data that was relevant within the local landscape and context to inform fire simulation products, HVRA spatial data and response functions, and relative importance weights within the risk assessment framework (Figure 3.2). Fire behavior metrics, including flame lengths and crown fire activity were modeled in FlamMap 5 (Finney et al., 2015) for low, moderate, high, and extreme fire weather scenarios. The burn probability product used for this assessment came from the National FSim burn probability (Short et al., 2020). See Appendix B (Jefferson County Open Space

Figure 3.2. The Jefferson County Open Space Wildfire Risk Assessment framework.



Wildfire Hazard Modeling) for a more detailed description of methods. Fire behavior outputs were then combined with data on HVRA extent and science-informed responses of HVRAs to wildfire or forest management to calculate conditional Net Value Change (cNVC) for each HVRA and fire weather scenario. The multiple cNVC measures for each HVRA were combined with a weighted averaging that favored the high and extreme fire behavior weather scenarios (Technosylva, 2018). Lastly, the cNVC measures for each HVRA were combined with burn probability and relative importance weights to compute a composite expected Net Value Change (eNVC; "risk") map for Jefferson County.

Throughout this Plan, the terms conditional and expected net value change (cNVC and eNVC), wildfire risk, and risk reduction are used. These metrics are unitless, and are relative measures of whole actuarial risk that combine and index fire intensity (flame length and crown fire activity), numbers associated with wildfire and treatment response for each HVRA, and the probability of fire occurrence (eNVC only). Wildfire risk is synonymous with cNVC and eNVC, and risk reduction is the difference between eNVC before and after simulated treatments.

HVRAs and Relative Importance Weights

In order to model risk across the landscape, JCOS and stakeholders determined which geospatial HVRAs to include in the assessment and prioritized the importance of HVRAs relative to each other. HVRA selection involved extensive stakeholder engagement and consensus among agency partners, resulting in a list of shared values that drove the forest health planning process. We defined an asset as a human-made thing—a building, communication

Table 3.1. Relative importance weights used for combining HVRA categories into a composite risk map.

CATEGORY	RELATIVE IMPORTANCE
Life Safety	100
Infrastructure	90
Water	90
Vegetation Cover	90
WUI	50
Wildlife	50
Recreation	50

The following examples will help illustrate how decisions were made to identify HVRAs and define the buffer and relative importance for each HVRA (Table 3.2). Stakeholders identified evacuation routes important for egress and wildfire response and divided the routes between first and second priority. First priority evacuation routes included roads that were the only egress option for a particular area and would prevent evacuation if the road became impassable. The 200m buffer was established around evacuation routes to match the fuel break guidelines from the Colorado State Forest Service. The buffer around campgrounds was initially 100m but was increased to 400m to encompass the surrounding area of use. JCOS leaned on the knowledge of fire professionals for the HVRA relative importance values in the life safety and infrastructure categories.

Parks within the JCOS system are dominated by ponderosa pine and dry mixed conifer forest types, and these forest types were given higher priority amongst vegetation cover types. Lodgepole pine and spruce-fir forest types were lumped together because it was determined management planning would not significantly differ between the two forest types, and JCOS staff only manages these forest types in one of their parks. The Pawnee montane skipper butterfly was the most important HVRA in the wildlife category because it was the only federally listed species on JCOS property, and influences management decisions over other values when present. Lastly, the relative importance values for recreation HVRAs were assigned based on the difficulty of replacing those values. After a fire, a trail is easier to reconstruct than a picnic area, so the picnic areas, bridges, and stairs were given a higher relative importance.

tower, road, etc.—of use or value to its owner and/or the general public. By contrast, we defined resources as naturally occurring—wildlife habitat, vegetation, water, etc. Primary HVRA categories and the related spatial HVRAs within each category were determined by JCOS and stakeholders throughout a series of collaborative meetings and workshops. An optional buffer distance was added to some HVRAs to define a greater zone of influence to represent the area in which an HVRA was expected to influence management actions beyond the spatially mapped extent. Then, relative importance weights were defined at two levels. Each HVRA was placed under a category, and each category was assigned a relative importance value used to weight the contribution of each HVRA category to the composite risk map (Table 3.1). For each HVRA, a relative importance weight was assigned to reflect its proportional contribution to an HVRA category (Table 3.2).

Exposure and Effects to HVRAs

The process of defining HVRA response to wildfire was a science-informed process. Where JCOS HVRAs aligned with previous efforts, we started the process using values from the Colorado Wildfire Risk Assessment (Technosylva, 2018) and the CFRI-led collaborative effort in Chaffee County (Chaffee County Community Wildfire Protection Plan; Next Generation Community Wildfire Protection

Research shows that aspen regeneration increased with fire intensity so that aspen would benefit from moderately higher intensity fire. However, the highest fire intensity could have negative impacts when the fire is intense enough to kill the root system and prevent suckers from resprouting or result in even-aged aspen stands that are less desirable to JCOS (Porter, 2019, Keyser et al., 2005). To accommodate the possible range of responses, we used a bell-shaped response function for Aspen/Aspen Mixed Conifer. Bighorn sheep, elk, and mule deer winter ranges have been shown to benefit from high intensity fire in the long term, but the short-term impacts may not be as positive (Greene et al., 2012). We weighted the response functions for these HVRAs towards the long-term impacts because management decisions would not focus on mitigating the short-term impacts on ungulates. The northern goshawk has been shown to require a mixture of open meadows mixed with patches of relatively higher tree cover when compared to other wildlife species, so high-intensity fires were scored to have a more negative impact for this species.

Table 3.2. HVRAs included in the risk assessment by category. The buffer distance used to define an influence zone for wildfire around the HVRA, the HVRA relative importance (%) to the category, and the relative wildfire response functions by intensity level are specified. All inputs were defined through a collaborative process using stakeholder input informed by expert opinion and data resources.

CATEGORY	HVRA	BUFFER (M)	RELATIVE IMPORTANCE	WILDFIRE RESPONSE - FLAME LENGTH (feet)					
				0-2	2-4	4-6	6-8	8-12	> 12
Life Safety	Evacuation Routes – First Priority	200	60	-20	-40	-80	-100	-100	-100
	Evacuation Routes – Second Priority	200	40	-20	-40	-80	-100	-100	-100
Infrastructure	Electrical Power Lines	200	25	-10	-20	-30	-50	-60	-80
	Communication Points	200	20	-10	-20	-30	-50	-60	-80
	Occupied Buildings	200	30	-20	-40	-80	-100	-100	-100
	Structures	200	25	-20	-40	-80	-100	-100	-100
Water	Drinking Water Protection	0	100	-20	-40	-80	-100	-100	-100
Vegetation Cover	Aspen/Aspen Mixed Conifer	0	5	30	40	60	60	40	30
	Lodgepole Pine/ Spruce-fir	0	15	25	25	50	25	-25	-50
	Mixed Conifer	0	30	25	50	50	25	-25	-50
	Ponderosa Pine	0	35	100	75	50	25	-25	-80
	Shrubland	0	10	50	50	25	-25	-75	-100
	Grassland	0	5	50	50	25	20	0	-10
WUI	Adjacent Private Property	0	100	-20	-40	-80	-100	-100	-100
Wildlife	Abert's Squirrel	0	5	100	75	0	0	-50	-100
	Bighorn Sheep Winter Range	0	15	100	100	100	50	0	-50
	Elk Winter Range	0	15	100	100	50	50	0	-100
	Mule Deer Winter Range	0	10	100	100	50	50	0	-100
	Northern Goshawk	0	15	100	100	50	0	-50	-100
	Pawnee Montane Skipper	0	25	100	80	30	20	10	0
	Preble's Jumping Mouse	0	15	70	40	0	-50	-75	-100
Recreation	Campgrounds	400	20	0	-10	-10	-20	-50	-70
	Trails	100	15	0	-10	-10	-20	-30	-30
	Picnic areas, Bridges, Stairs	100	35	0	-10	-10	-20	-50	-70
	Turnpikes/Trail Features	100	30	0	-10	-10	-20	-50	-70

[Plan](); [Gannon, 2019]()). Where HVRAs could not be matched with previous work, CFRI and JCOS staff reviewed scientific research to inform responses. Local resource experts then provided additional input on each HVRA's response to wildfire by intensity level (Table 3.2). Relative HVRA response was quantified on a scale from -100 for total loss to +100 for complete restoration to allow for both negative and beneficial effects of fire. Methods to delineate the wildland-urban-interface-adjacent private property response are described in Appendix C. The response of the drinking water protection HVRA was quantified with a separate process described in Appendix D.

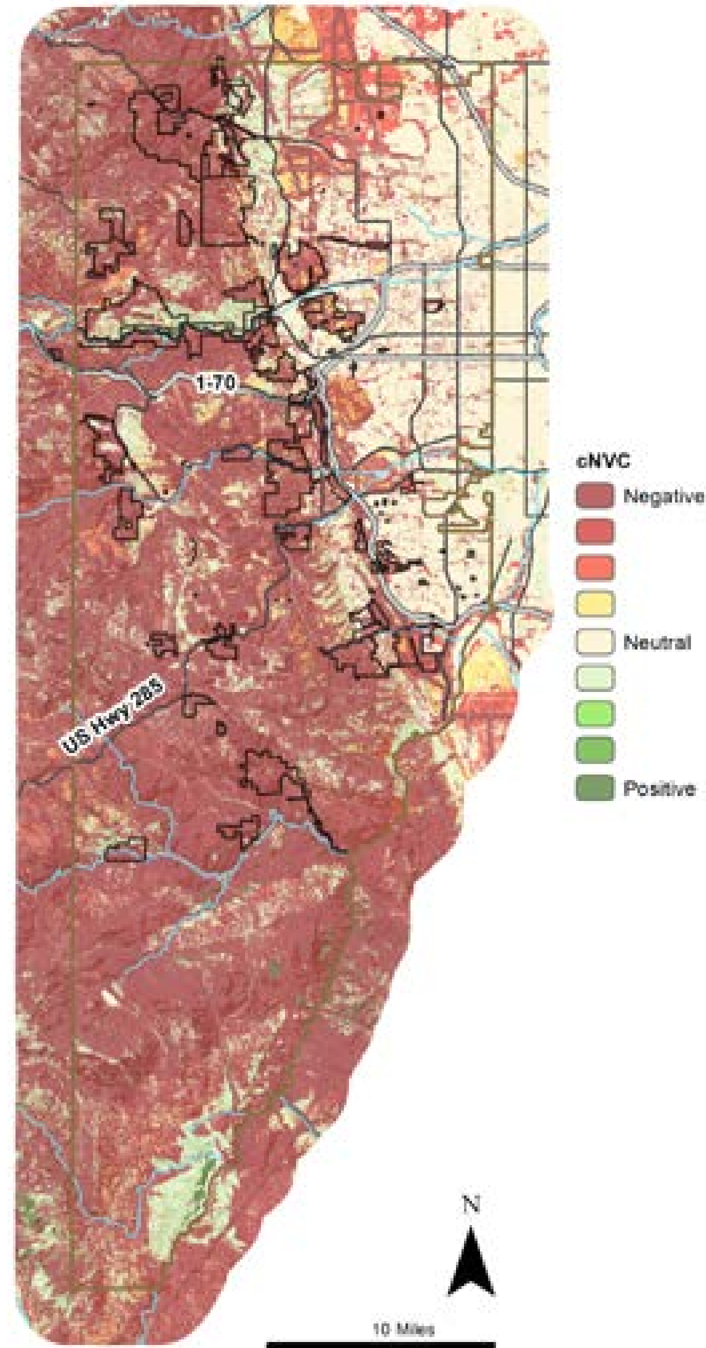
Once all stakeholder inputs were determined, the RADS model generated cNVC raster outputs for each HVRA by applying the response function to the predicted fire behavior within each HVRA's extent. This was done first by fire weather scenario, and then scenarios were combined into a single cNVC raster per HVRA with weighted averaging (Figure 3.3). We used the same scenario weighting scheme as CO-WRA ([Technosylva 2018]()), which reflects that the most area was expected to burn under high and extreme fire weather scenarios (Table 3.3), consistent with recent wildfire activity in Colorado ([Haas et al. 2015](), [Graham et al. 2003]()).

Table 3.3. Probabilities for weighting cNVC calculated for each fire weather scenario.

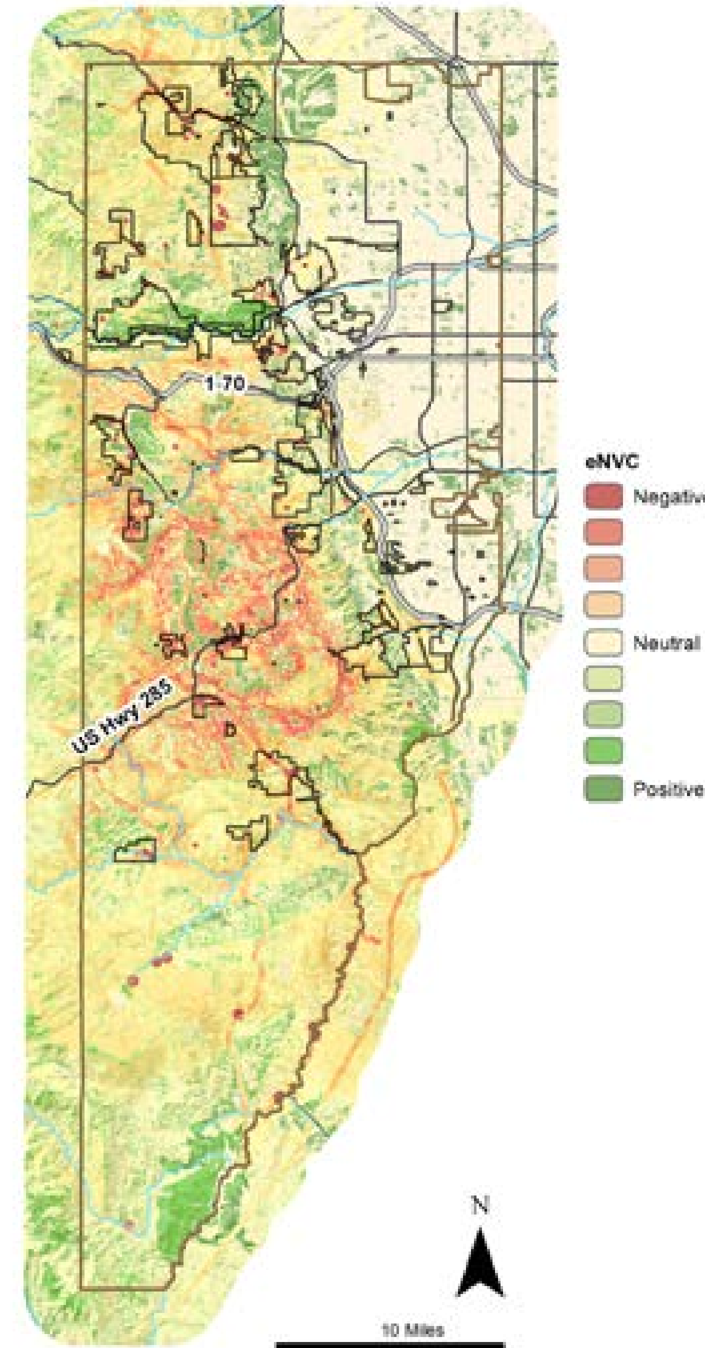
SCENARIO	PERCENTILE	PROBABILITY
LOW	25th	0.01
MODERATE	50th	0.09
HIGH	90th	0.20
EXTREME	97th	0.70

Figure 3.3. Composite conditional net value change (cNVC) wildfire risk map for Jefferson County. Negative cNVC means high risk. Positive cNVC means there is an expected benefit from wildfire.

COMPOSITE CONDITIONAL NET VALUE CHANGE



COMPOSITE WILDFIRE RISK



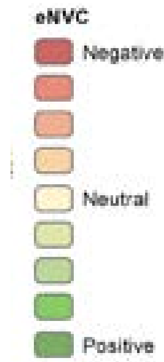
Wildfire Risk Within the JCOS Park System

Composite wildfire risk maps were generated at the county level (Figure 3.4, Figures 3.4a-3.4g). The more negative the eNVC, the greater the risk to HVRAs from wildfire, while a positive eNVC means there was an expected benefit from wildfire. Within Jefferson County, the greatest risk from wildfire was concentrated around the central part of the county. Wildfire risk was highest in JCOS parks Beaver Ranch, Flying J Ranch, and Meyer Ranch along the US Hwy 285 corridor and, to the north, Alderfer/Three Sisters Park. All these parks had high potential for fire spread into the WUI (Figure 3.4g), and also a high concentration of trails (Figure 3.4c) and infrastructure (Figure 3.4a) that overlaps with high fuel loads. There were also several high priority evacuation routes (Figure 3.4b) between these parks. Localized wildfire risk around park structures and occupied buildings was noticeable in several other parks as well.

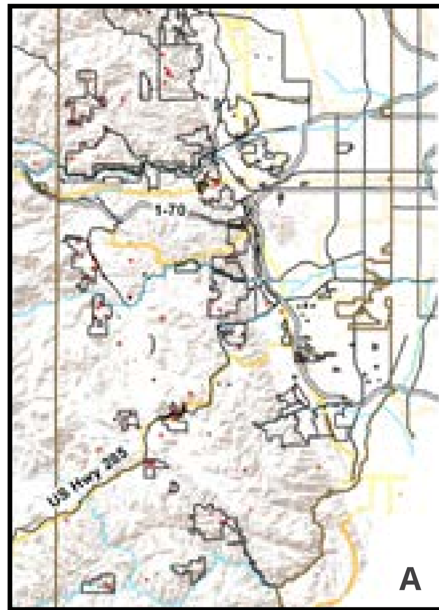
Expected positive benefits from wildfire were concentrated within the Centennial Cone and Clear Creek Canyon Parks. This was being driven by the positive effects expected from wildfire on bighorn sheep habitat (Figure 3.4f) along the canyon. The eastern portions of Coal Creek Canyon Study Area and Lippincott Ranch were also expected to receive positive benefit from wildfire. This area is located in mainly shrubland and grassland vegetation types (Figure 3.4d), which generally benefit from exposure to wildfire.

Figure 3.4. Composite wildfire risk map for Jefferson County. Negative eNVC means high risk. Positive eNVC means there is an expected benefit from wildfire.

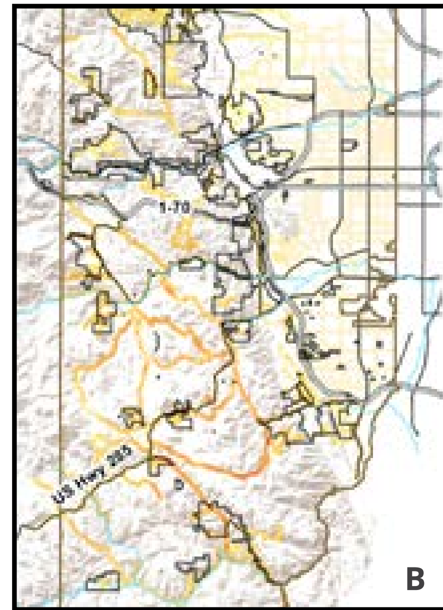
Figure 3.4a-g. Composite wildfire risk map for each HVRA category. Negative eNVC means high risk. Positive eNVC means there is an expected benefit from wildfire.



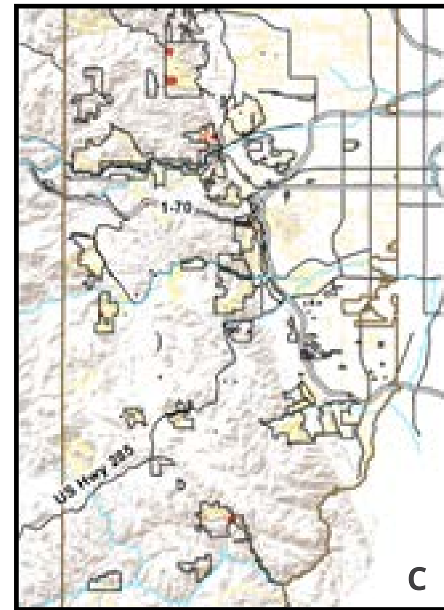
INFRASTRUCTURE



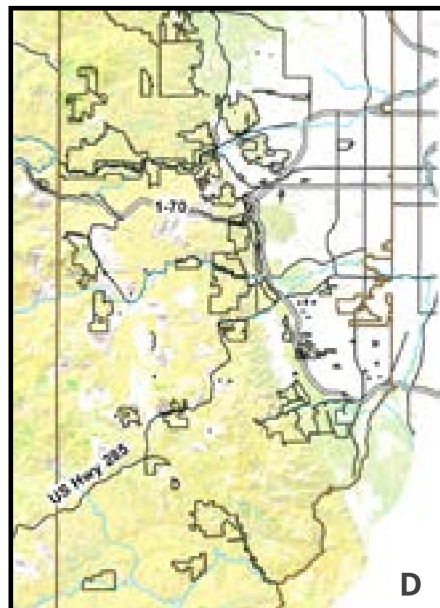
LIFE SAFETY



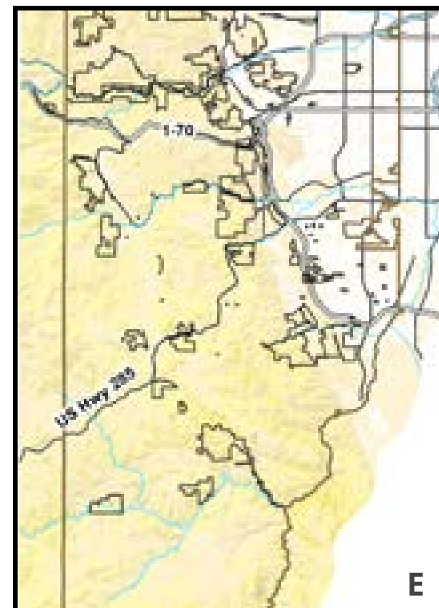
RECREATION



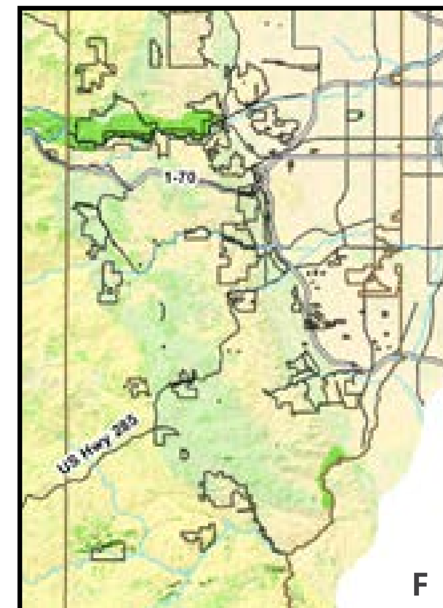
VEGETATION COVER



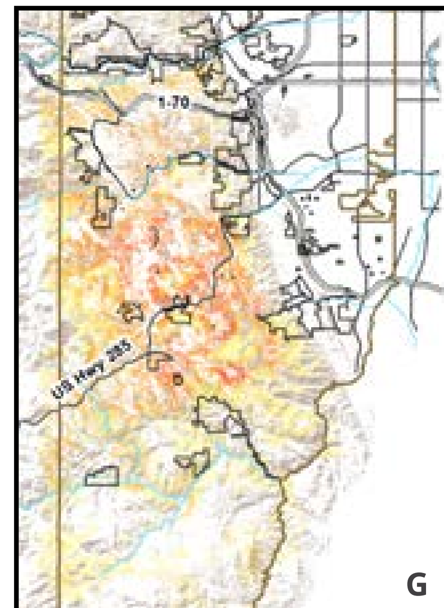
WATER



WILDLIFE



WUI

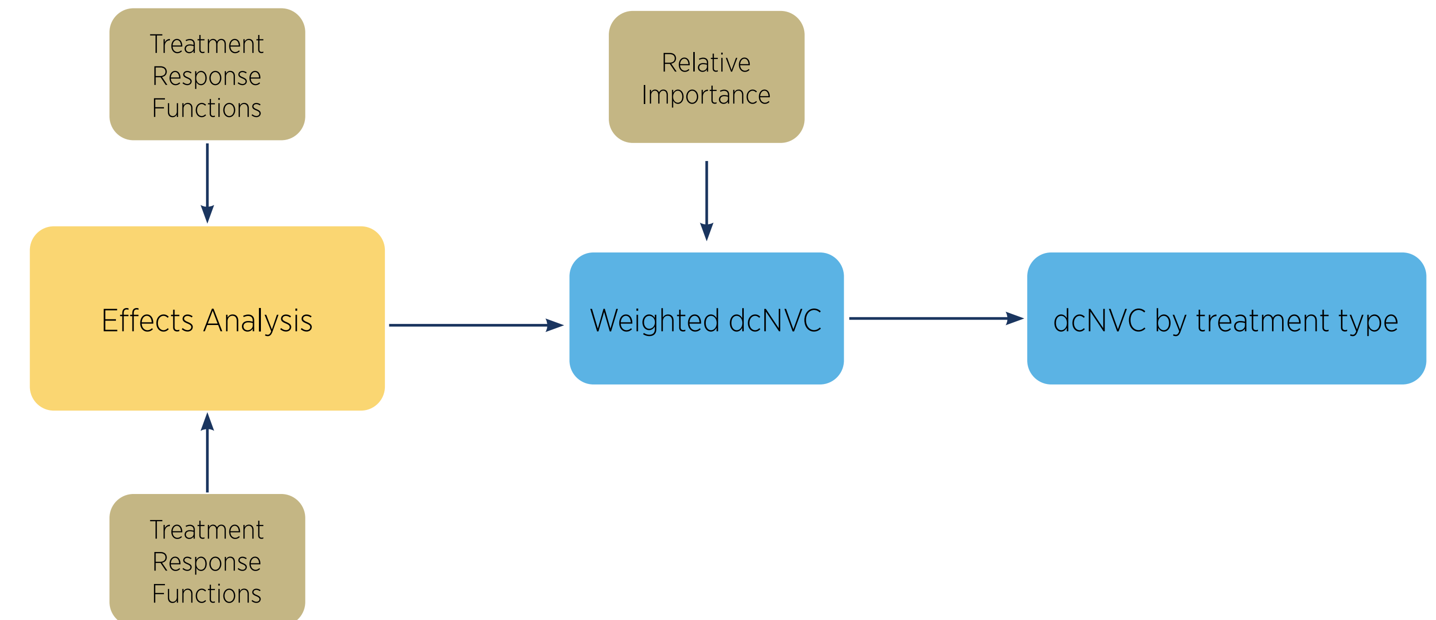


Ecological Benefits Assessment

In addition to designing this Plan to be framed around improving outcomes from wildfire, forest management is often aimed at enhancing the function of forest systems through ecological restoration (Addington et al., 2018). In order to develop this Plan to consider forest management impacts for both changing wildfire outcomes and enhancing ecological function in the absence of wildfire, CFRI worked with the Guild and JCOS staff to develop a new analysis that directly accounts for responses of HVRAs to different forest management techniques. JCOS staff and stakeholders identified key values of interest where forest management activities were intended to provide direct ecological benefit to the resources. Ecological benefit was defined for this assessment as the estimated change in resource value as a result of forest management given the current resource condition.

The Ecological Benefits Assessment produced an equivalent measure of pre- versus post-treatment difference. However, instead of evaluating wildfire risk, the Ecological Benefits Assessment directly

Figure 3.5. The Ecological Benefits Assessment framework.



evaluated the total benefit that was gained or lost as a result of management actions. Using spatial data on the location of highly valued ecological resources and assets, we evaluated how each resource was expected to respond when exposed to forest management activities, such as thinning and prescribed fire.

Similar to the Wildfire Risk Assessment framework, local data on ecological HVRA extent and science-informed treatment response functions were combined to calculate the delta conditional Net Value Change (dcNVC) for each HVRA and treatment type (Figure 3.5). The multiple dcNVC measures for each HVRA were combined via the relative importance weights to compute a composite dcNVC for each treatment type.

HVRAs and Relative Importance Weights

A different set of HVRAs and relative importance weights were selected for the Ecological Benefits Assessment through a similar process as the Wildfire Risk Assessment, although some of the same HVRAs were evaluated in both assessments. Ecological Benefit HVRAs only included ecological values, or resources, not human-made assets (e.g., infrastructure or WUI assets). HVRA categories, the related spatial HVRAs within each category, buffer distances, and relative importance weights were again determined by JCOS and stakeholders throughout a series of collaborative meetings and workshops (Table 3.4 and 3.5).

Table 3.4. Relative importance weights used for combining HVRA categories into a composite ecological benefits map.

CATEGORY	RELATIVE IMPORTANCE
Forest Structure	100
Riparian	90
Vegetation Cover	60
Wildlife	60

The following examples will help illustrate how decisions were made to identify Ecological Benefit HVRAs and relative importance for each HVRA (Table 3.5). Forest structure was represented by montane forest zones (Kaufmann et al., 2006) and canopy cover (Cannon et al., 2020). Tree height was also considered as a metric to further define forest structure; however, canopy cover data was more readily available and was a more comprehensive measure of ecosystem services, e.g., habitat, wildfire risk, understory plant communities, etc.

For example, the Lower Montane > 25% Canopy Cover HVRA had the highest relative importance in the forest structure category because experts determined these areas had been most affected by fire suppression, and had the greatest need for restoration. HVRAs ponderosa pine and mixed conifer were assigned the two highest relative importance values of the vegetation cover category. These were the two forest types JCOS wants to focus on, since they cover much of JCOS land, and ponderosa pine forests have likely departed the most from historical conditions.

Treatment Effects on HVRAs

Treatment effect response functions were elicited for each of three treatment types—mechanical thinning, mechanical thinning + prescribed fire, and prescribed fire only—on a scale from -100 to + 100 for complete loss to complete restoration relative to current conditions. These differ from the risk assessment response functions in that the values were assumed constant over the extent of the target resource and only differ across treatment types. Because the assessment was performed in the absence of fire, the treatment was assumed to occur across the extent of each HVRA, and the dcNVC was calculated directly.

The following examples will illustrate how the treatment responses were determined. JCOS was concerned about the potential for invasive species to spread post-treatment, so the treatment responses for Forest Structure were lowered from the initial values to reflect those concerns. If implemented, treatments in riparian areas could have a negative effect on sensitive plants; however, treatment could also have benefits to reduce tree encroachment. These two considerations were balanced and managers concluded a slight negative impact from treatments in riparian areas was appropriate. Cheatgrass and other invasive plants were considered in the treatment responses for shrubland and grassland since there was insufficient data to account for invasive plants anywhere else in the model. The treatment responses for Abert's squirrel were +50 because scientific research has shown treatments to have either a positive or nonexistent impact on the species (Yarborough et al. 2015). Treatment responses for bighorn sheep winter range were relatively low because the GIS habitat information included only areas that are currently good habitat, thus there as little room for improvement through treatment.

Table 3.5. HVRAs included in the Ecological Benefits Assessment by category. The HVRA relative importance (%) to the category and the relative treatment response functions are specified. All inputs were defined through a collaborative process using stakeholder input.

CATEGORY	HVRA	RELATIVE IMPORTANCE	TREATMENT RESPONSE		
			Mechanical	Mechanical & Rx	Rx Fire
Forest Structure	Lower montane, > 25% Canopy Cover	45	50	100	25
	Lower montane, ≤ 25% Canopy Cover	20	50	100	75
	Lower montane, > 30% Canopy Cover	25	50	75	10
	Lower montane, ≤ 30% Canopy Cover	10	25	65	5
Riparian	Riparian	100	-10	-10	-5
Vegetation Cover	Aspen/Aspen Mixed Conifer	5	50	30	30
	Lodgepole Pine/Spruce-fir	10	50	50	25
	Mixed Conifer	30	50	75	25
	Ponderosa Pine	40	75	100	75
	Shrubland	10	25	75	50
	Grassland	5	50	50	100
Wildlife	Abert's Squirrel	5	50	50	50
	Bighorn Sheep Winter Range	10	20	40	60
	Elk Winter Range	15	60	80	60
	Mule Deer Winter Range	15	60	80	70
	Northern Goshawk	15	20	50	50
	Pawnee Montane Skipper	25	60	80	70
	Preble's Meadow Jumping Mouse	15	20	20	40

Outcome Based Management

Management Units

JCOS vegetative management units consisted of blocks of similar vegetation and were based on floristic surveys, starting in the early 2000s. Vegetation blocks were created via desktop analysis using topography (aspect/slope), hydrology (NWI/NHD), soil data (web soil survey), normalized difference vegetation index (NDVI), and aerial imagery. JCOS adopted the United States National Vegetation Classification System (USNVC) as the definitive source for vegetative cover mapping. Vegetation was classified into an 8-level hierarchy from broad scale (regional) to fine scale (local) vegetation levels. Hierarchy levels from broad to fine scale are class, subclass, formation, division, macro-group, group, alliance, and association. Management units were formed from JCOS vegetation data at a "group" level to delineate units for management. Group level classifications were combinations of relatively narrow sets of diagnostic plant species, including dominants and co-dominants, broadly similar composition, and diagnostic growth forms. Southern Rocky Mountain Ponderosa Pine Open Woodland is an example of a group level classification. Finally, the size of Management Units was considered and were defined by JCOS at an appropriate scale for decision-making within the park system. In the end, management Units were intended to highlight areas for treatment priority.

Treatment Types

This prioritization considered three treatment types: 1) thin only, 2) prescribed fire only, and 3) thin + prescribed fire, where prescribed fire is broadcast burning and not burning of slash piles. For the Wildfire Risk Assessment prioritization, treatments were simulated by changing surface and canopy fuel attributes by the mean effect sizes for hazardous fuels reduction and forest restoration projects in the western U.S. (Ziegler et al., 2017; Fulé et al., 2012; Stephens et al., 2009; Stephens & Moghaddas, 2005) from the baseline fuels data from LANDFIRE (2014) and the Colorado Wildfire Risk

Assessment (Technosylva, 2018). Treatment effects on canopy attributes were applied as proportional adjustments to the pre-treatment data (Appendix B). Treatment effects on surface fuels were represented by changing the fire behavior fuel model (Scott & Burgan, 2005). For this assessment, it was assumed that: the thin only treatment would not alter the fire behavior fuel model, except in the case where baseline conditions were mapped as slash blowdown; prescribed fire would shift the fire behavior fuel model to the least intense model in the same category; and thin + prescribed fire treatment would achieve the same effects as prescribed fire (Appendix B). For the Ecological Benefits Assessment treatment was assumed to occur if planned across the feasible extent, and the dcNVC was calculated using the treatment response functions directly.

Treatment Feasibility

Hard constraints were captured in binary rasters representing whether each pixel was feasible (1) or infeasible (0) for each of the target treatment types. Treatment feasibility does not consider economic constraints, and was meant to capture the greatest possibility for treatment. Operational constraints, such as steep slopes, and the practicality of treatment were instead captured with variable treatment costs described in the Treatment Cost section.

Feasible locations for the thin only treatment were defined by the following constraints:

- Forest presence (LANDFIRE canopy cover ≥ 10%)
- No treatment in wilderness
- No treatment in upper tier roadless

THIN ONLY AND THIN + Rx FIRE FEASIBILITY

Figure 3.6. Feasible locations for the thin only and thin + prescribed fire treatments in Jefferson County.

JCOS PARK/ PROPERTY	TOTAL ACRES ACROSS MANAGEMENT UNITS	ACRES FEASIBLE FOR THINNING	ACRES FEASIBLE FOR RX FIRE	ACRES FOR RX FIRE ONLY	TOTAL ACRES FEASIBLE TREATMENT
Coal Creek Canyon Study Area	6002.4	3639.9	5558.3	2166.3	5806.3
White Ranch Park	4133.8	2722.3	4039.6	1331.3	4053.6
Centennial Cone Park	3637.8	2154.8	3503.4	1375.3	3530.1
Clear Creek Canyon Park	3393.4	2265.1	3091.7	886.7	3151.8
Matthews/Winters Park	2462.5	715.7	2330.0	1638.2	2353.8
Mount Falcon Park	2233.8	1684.6	2212.4	534.4	2219.1
Reynolds Park	2044.1	1761.1	1980.0	268.7	2029.8
North Table Mountain Park	2066.8	93.4	1960.9	1891.7	1985.1
Douglas Mountain Study Area	1819.9	1590.1	1298.8	171.9	1762.0
Deer Creek Canyon Park	1632.4	1165.8	1592.3	437.4	1603.2
Hildebrand Ranch Park	1644.7	182.1	1565.9	1394.0	1576.1
Elk Meadow Park	1474.4	791.7	1259.2	542.0	1333.7
Alderfer/Three Sisters Park	1131.2	1056.4	1025.7	49.6	1106.0
South Valley Park	994.1	66.7	852.0	788.4	855.1
Mount Lindo	831.8	700.3	804.4	121.0	821.3
South Table Mountain Park*	856.6	101.2	765.3	674.3	775.5
Mount Galbraith Park	804.6	465.2	759.5	306.2	771.5
Cathedral Spires Park	788.4	683.4	740.6	66.9	750.4
Pine Valley Ranch Park	882.0	600.7	731.0	132.1	732.8
Windy Saddle Park	746.7	452.6	691.0	250.2	702.8
Apex Park	693.8	289.1	666.1	384.1	673.2
Meyer Ranch Park	666.7	530.4	484.8	66.1	596.5
Lippincott Ranch Property	426.5	282.0	417.2	135.4	417.4
Beaver Ranch Park	445.0	347.4	340.7	48.9	396.3
Flying J Ranch Park	420.6	331.1	307.3	50.5	381.6
Lair o' the Bear Park	392.1	332.0	367.8	46.5	378.5
Mount Glennon*	357.2	66.9	338.5	274.7	341.6
Stafford Hogback*	115.7	28.0	111.2	83.2	111.2
Lookout Mountain Preserve	121.0	82.1	95.4	26.2	108.3
Crown Hill Park*	228.5	56.3	32.2	28.7	85.0
Van Bibber Park*	164.6	23.6	53.2	43.4	66.9
Welchester Tree Grant Park*	20.9	8.2	17.6	10.0	18.2
JCOS Park System	43633.8	25270.5	39993.9	16224.1	41494.6

Table 3.6. Acres feasible for treatment by park.

*RADS did not identify any priority acres for treatment within the park

Feasible locations for the thin + prescribed fire treatment were assumed to be the same as the thin only treatment. Given these constraints, 25,270 acres or 58% of JCOS (managed units) were considered feasible for the thinning only or thin + prescribed fire treatment (Figure 3.6).

Feasible locations for the prescribed fire-only treatment were limited to “frequent” fire forest, shrubland, and grassland types that can be burned with prescribed fire as a first entry treatment —no high elevation forest types (lodgepole or spruce-fir), developed areas, or non-burnable vegetation types.

To capture that it was unrealistic to drastically increase prescribed fire use in the short-term, an additional constraint was created to limit spending on prescribed fire to 25% of the total budget. Given these constraints, 39,993 acres or 92% of JCOS (managed units) were considered feasible for the prescribed fire-only treatments (Figure 3.7).

Given all management constraints, approximately 41,495 acres or 95% of JCOS parks were feasible for thinning and/or prescribed fire treatments. 96% of those feasible acres allowed for prescribed fire, while almost 40% of the feasible acres were in areas where thinning treatments were not feasible, and prescribed fire was the only treatment feasible. The largest JCOS parks had the greatest totals of feasible acres with significant portions of the area only feasible for prescribed fire.

Rx FIRE ONLY FEASIBILITY

Figure 3.7. Feasible locations for the prescribed fire treatment in Jefferson County.

Treatment Cost

Treatment costs were based primarily on expert opinion because current treatment cost models either do not consider landscape-scale variation (Calkin & Gebert, 2006), or require detailed data on stand conditions that is not available for most landscapes (Fight et al., 2006).

Per-acre cost for the thin only treatment was approximated by adapting a model developed in northern Colorado (Gannon et al., 2019) for use in Jefferson County. Cost was considered a function of base treatment cost under ideal conditions ($1,800/ac) with adjustments for distance from roads and slope steepness. Cost increased with distance from roads > 800 m, and cost increased with slope > 35%. Total thinning cost was limited to a maximum of $10,000/ac if the combined costs of road distance and slope adjustments exceeded $10,000/ac. The thin only treatment costs are shown in Figure 3.8.

Per-acre cost for the prescribed fire-only treatment was assumed constant depending on the distance from WUI. While prescribed fire costs do vary widely, the causes of this variation are highly site and condition specific and therefore difficult to quantify with coarse spatial data. Prescribed fire costs are difficult to characterize in part because preparation costs are not consistently recorded. We therefore assumed a flat rate of $1,000/ac when > 250m from mapped WUI to cover both the preparation and day-of costs. Within 250 m of mapped WUI, we

THIN ONLY COST

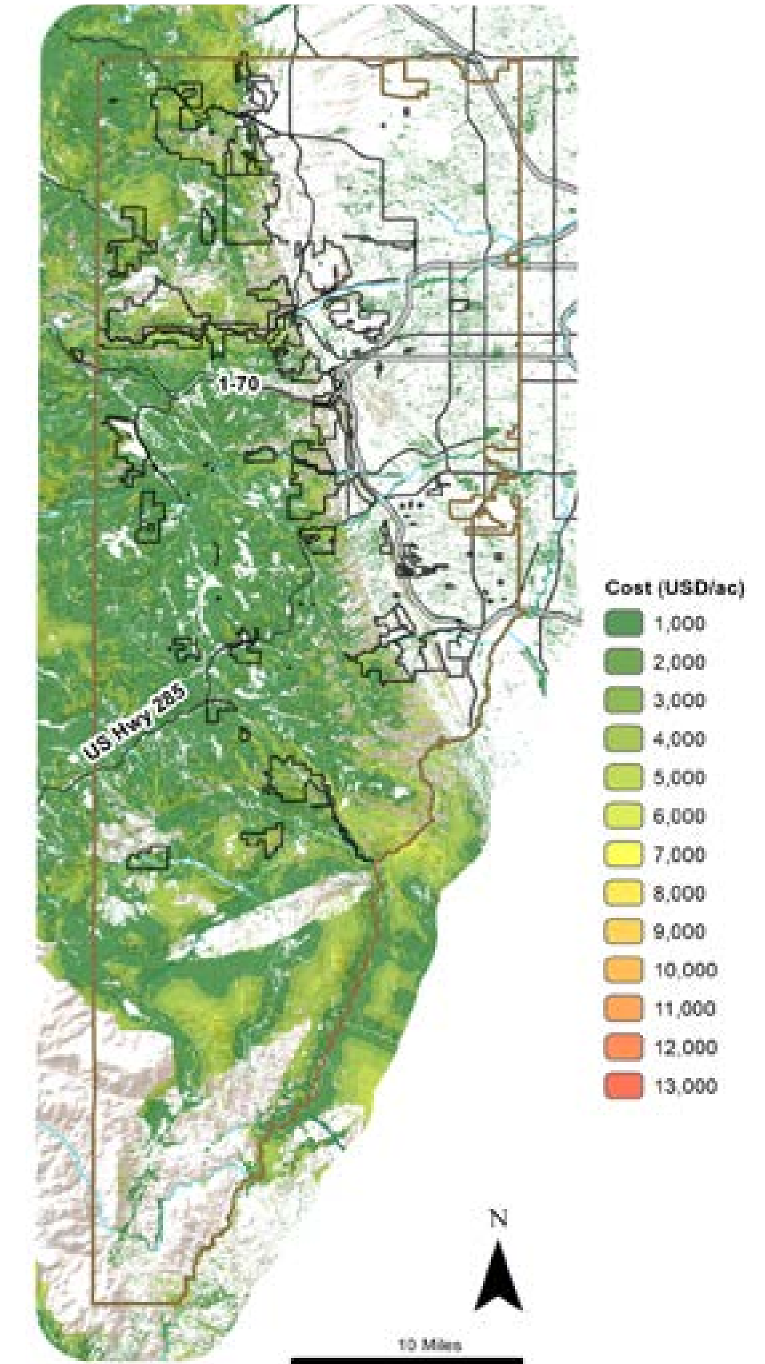


Figure 3.8. Thin only treatment costs for Jefferson County estimated using distance from roads and slope steepness.

assumed an increase in costs of $3,000/ac due to extra planning and increased safety measures around homes and structures. The prescribed fire only treatment costs are shown in Figure 3.9.

Per-acre cost for the thin + prescribed fire treatment was assumed to be the sum of the thinning and prescribed fire treatment costs. The complete treatment costs are shown in Figure 3.10.

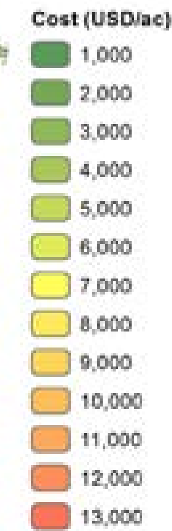


Figure 3.9. Prescribed fire-only treatment costs for Jefferson County estimated as a constant value based on distance to WUI.

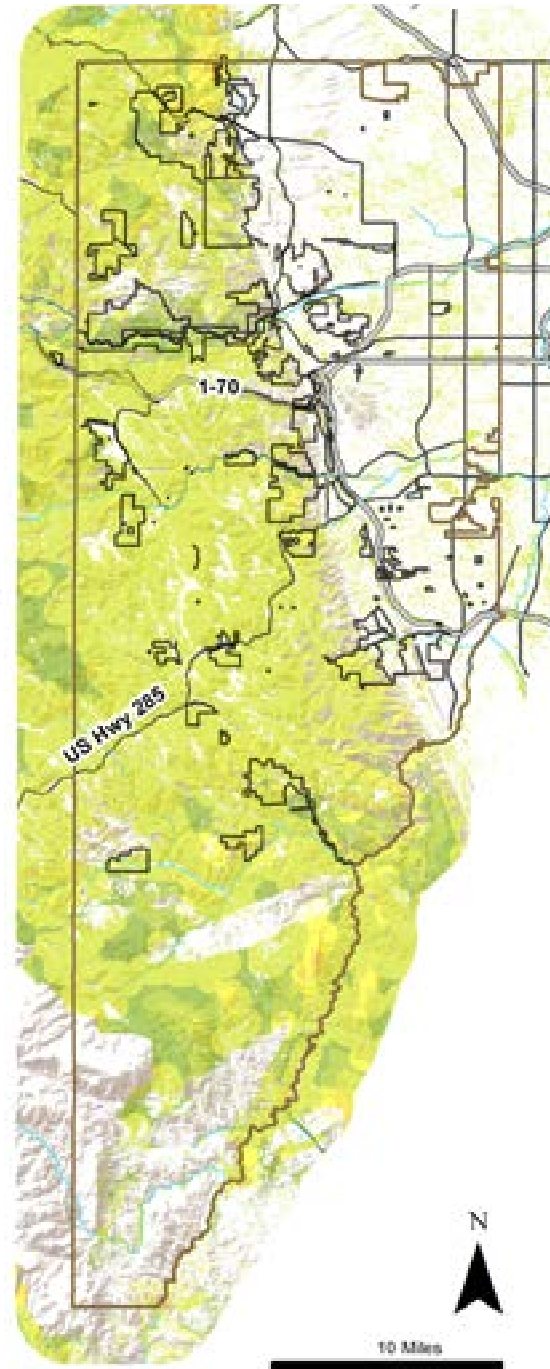


Figure 3.10. Thin + prescribed fire treatment costs for Jefferson County estimated as the sum of the thinning and prescribed fire costs.

Risk Reduction

The risk reduction benefit of treatment was assessed on a per-pixel basis as the difference between current risk and simulated post-treatment risk using the Wildfire Risk Assessment. The benefit of fuel treatment was only represented as changing fire behavior (flame lengths, crown fire activity) as modeled with FlamMap 5 (Finney et al., 2015), not burn probability. This approach was consistent with the primary objectives of fuel treatments (Reinhardt et al., 2008), but it could underestimate fuel treatment benefits where they are expected to reduce area burned (Thompson et al., 2013). Risk reduction estimates are mapped for each treatment type in Figure 3.11 through Figure 3.13.

For the thin-only treatment, the greatest risk (eNVC) reduction was concentrated around the central area of the county where many of the HVRAs were concentrated. The prescribed fire-only treatment reduced risk over a greater area of Jefferson County than the thin only treatment. The thin + prescribed fire treatment showed the greatest risk reduction per pixel, since it was essentially two treatments, each incrementally decreasing risk.

Within JCOS parks, total possible risk reduction was greatest within White Ranch Park. By treating all of the feasible acreage within White Ranch Park, JCOS would reduce the overall risk to the JCOS park system by approximately 10%. However, on a per acre basis, Lookout Mountain Preserve had the highest risk reduction, so that a single acre treated at that park reduced risk substantially more relative to even the largest parks, such as Clear Creek Canyon Park.

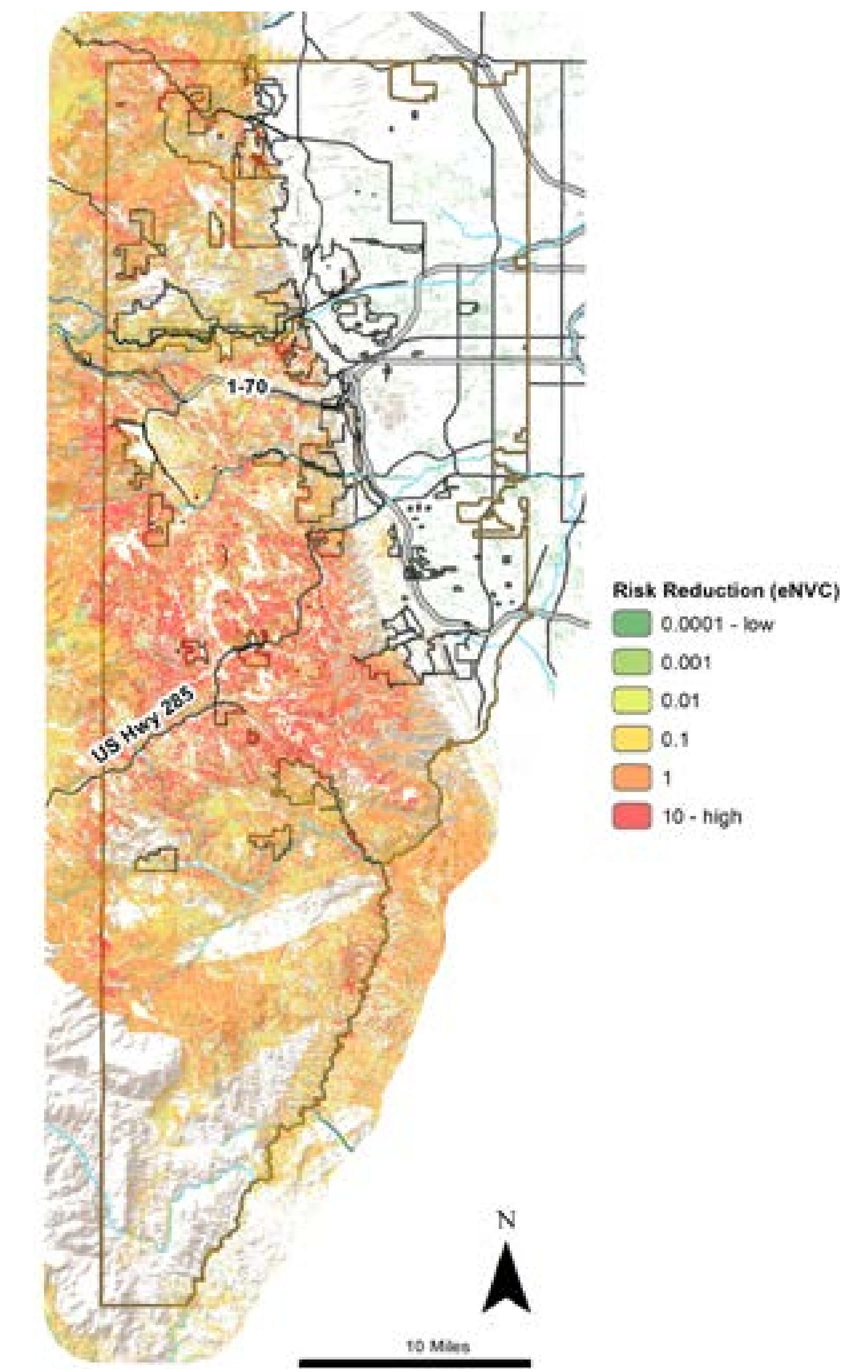
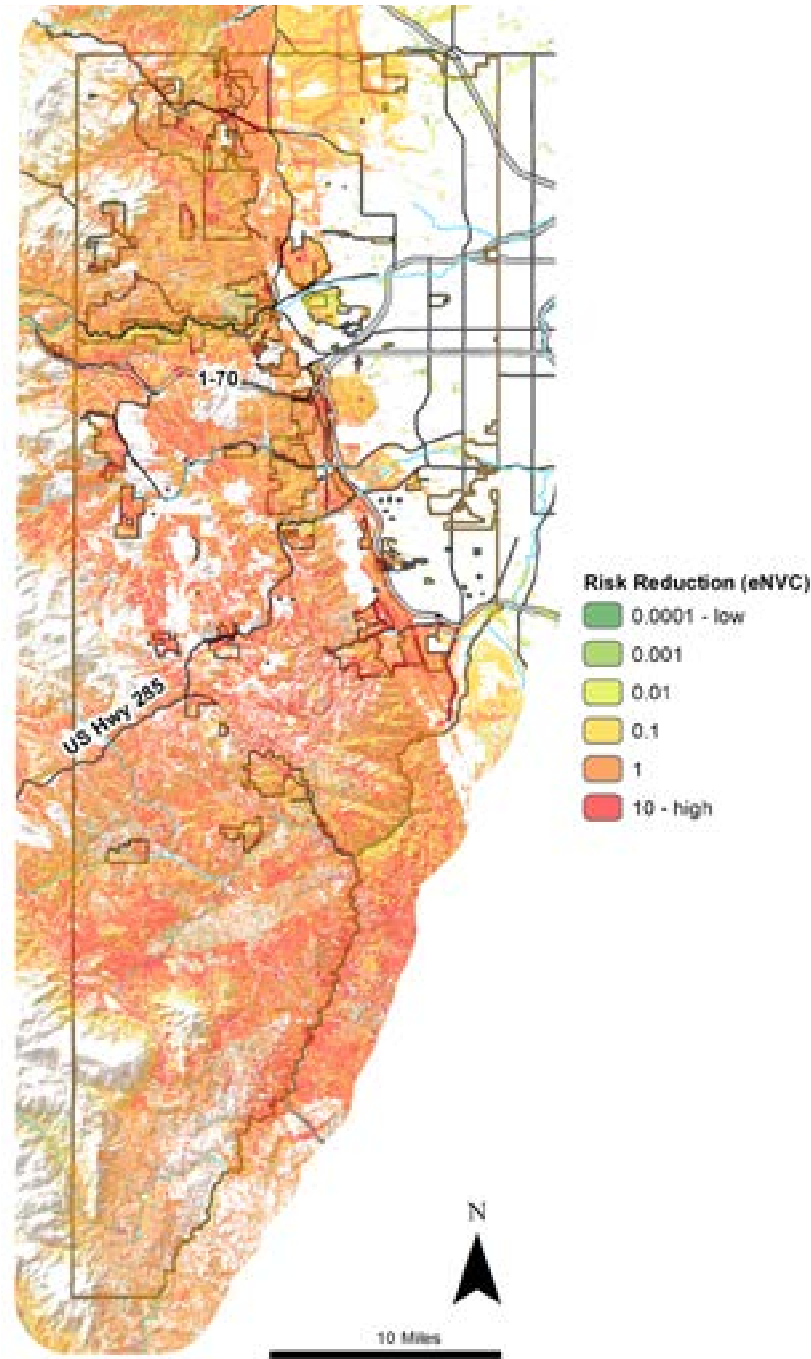


Figure 3.11. Estimated risk reduction for the thin only treatment.

Rx FIRE ONLY RISK REDUCTION



THIN + Rx FIRE RISK REDUCTION

Figure 3.12. Estimated risk reduction for the prescribed fire only treatment.

Figure 3.13. Estimated risk reduction for the thin + prescribed fire treatment.

Table 3.7. Wildfire risk (eNVC) reduction by park. Percent of total risk reduction is the amount of risk reduction each park contributes to the total risk reduction across the entire JCOS park system if every feasible acre was treated. The average risk reduction per acre is a unitless (or relative) measure of expected Net Value Change before and after simulated treatments. Higher values indicate greater average wildfire risk reduction for a park.

JCOS PARK/ PROPERTY	PERCENT OF TOTAL RISK REDUCTION	AVERAGE RISK REDUCTION PER ACRE
Lookout Mountain Preserve	1.9	47.1
Beaver Ranch Park	4.4	30.1
Flying J Ranch Park	4.7	28.9
Reynolds Park	8.3	24.2
Alderfer/Three Sisters Park	8.6	23.3
Meyer Ranch Park	4.6	23.1
Elk Meadow Park	6.8	12.8
South Valley Park	2.5	10.2
Pine Valley Ranch Park	3.2	9.5
Deer Creek Canyon Park	4.3	7.9
Apex Park	1.1	6.9
Mount Lindo	2.4	6.8
Douglas Mountain Study Area	3.9	6.4
Lair o' the Bear Park	0.9	6.1
White Ranch Park	10.6	5.8
Windy Saddle Park	1.4	5.2
Mount Galbraith Park	1.3	4.8
Hildebrand Ranch Park	2.4	4.2
Cathedral Spires Park	1.3	4.0
Mount Falcon Park	3.8	3.9
Coal Creek Canyon Study Area	8.5	3.7
North Table Mountain Park	2.9	3.7
Matthews/Winters Park	3.0	3.5
Lippincott Ranch Property	0.5	2.8
Centennial Cone Park	3.9	2.7
Stafford Hogback	0.1	2.6
Clear Creek Canyon Park	2.4	2.0
Mount Glennon	0.3	1.9
South Table Mountain Park	0.1	0.3
Van Bibber Park	0.0	0.3
Welchester Tree Grant Park	0.0	0.1
Crown Hill Park	0.0	0.0
JCOS Park System	100.0	9.2

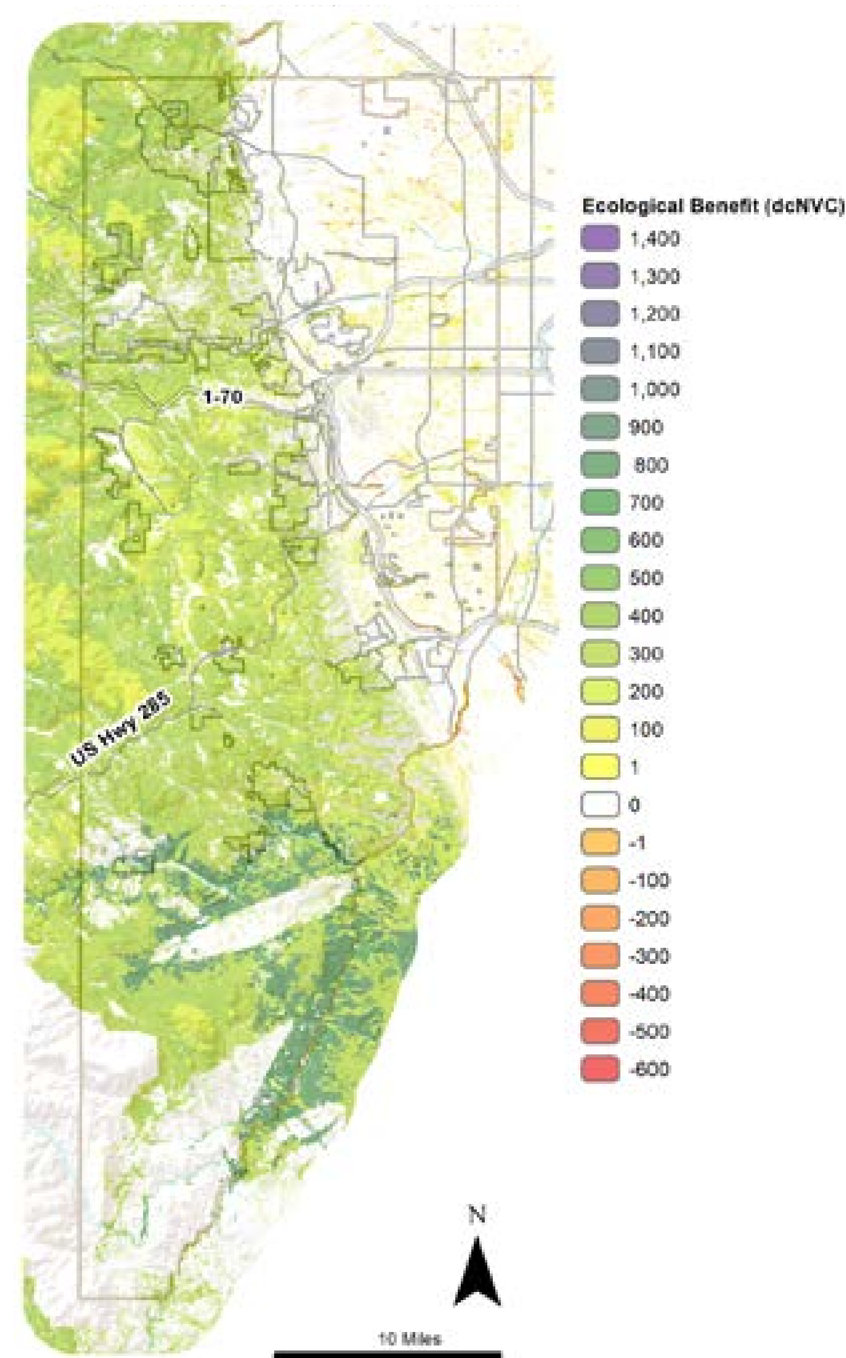
ECOLOGICAL BENEFIT

The ecological benefit of treatment was assessed on a per-pixel basis as the difference between pre- and simulated post-treatment vegetation conditions using the Ecological Benefits Assessment. Ecological benefit estimates are mapped for each treatment type in Figure 3.14a-c.

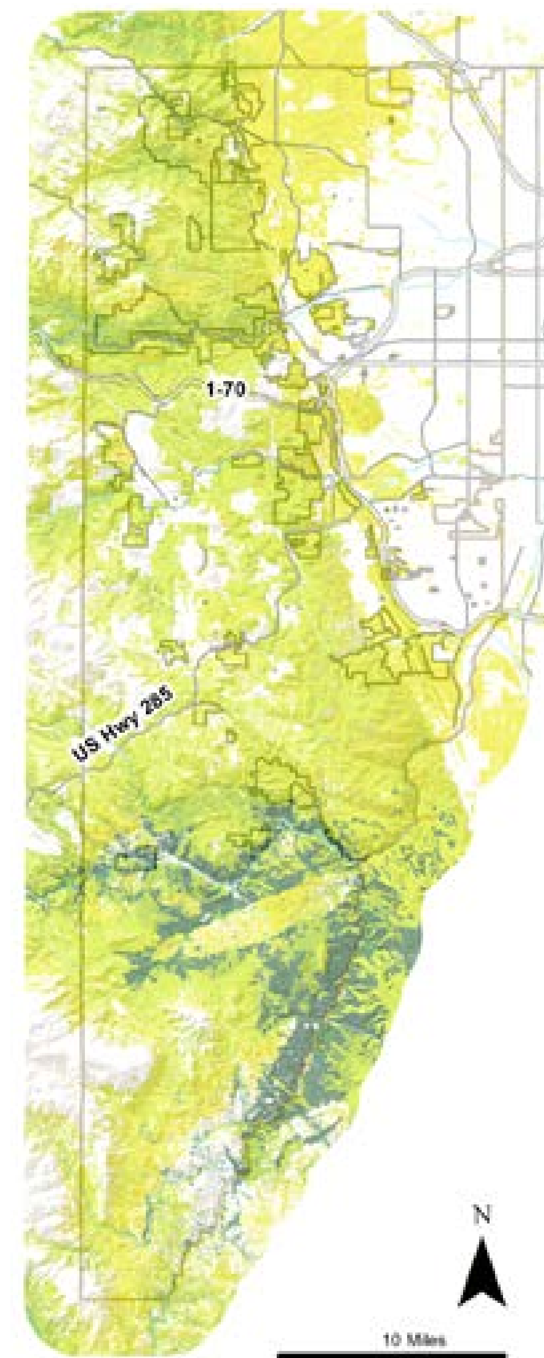
For all treatments, the ecological benefit (dcNVC) was greatest in the southeast portion of the county where habitat for the Pawnee montane skipper butterfly was located; however, this habitat was generally outside of the JCOS park system. In general, the thin-only treatment showed greater benefit across the landscape than the prescribed fire-only treatment due to JCOS' concern that current forest structure conditions were not conducive to first-entry fire without prior thinning treatment. The thin + prescribed fire treatment showed the greatest ecological benefit per pixel, since it was essentially two treatments, each incrementally increasing benefit. Although limited in extent, negative dcNVC, or loss due to treatment was mapped along riparian areas for all treatments.

Within JCOS parks, total possible ecological benefit was greatest within Coal Creek Canyon Study Area. By treating all of the feasible acreage within Coal Creek Canyon Study Area, JCOS would increase the overall ecological benefit to the JCOS park system by approximately 14%, based on the indicator metrics used in this evaluation. However, on a per-acre basis, Pine Valley Ranch Park had the highest ecological benefit.

A THIN ONLY ECOLOGICAL BENEFIT



B Rx ONLY ECOLOGICAL BENEFIT



C THIN AND Rx FIRE ECOLOGICAL BENEFIT

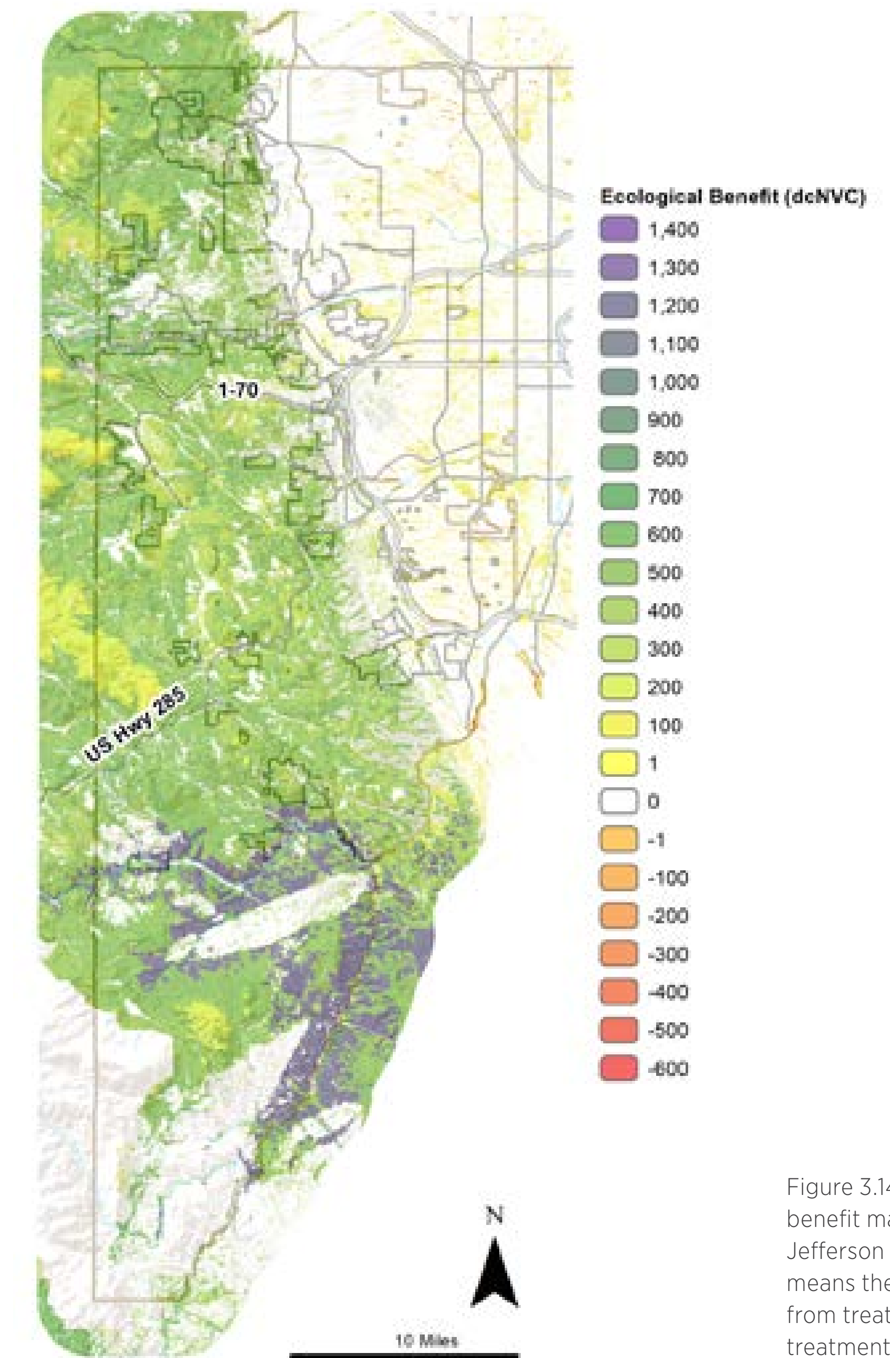


Figure 3.14a-c. Composite ecological benefit maps by treatment type for Jefferson County. Positive dcNVC means there is an expected benefit from treatment. Negative dcNVC means treatment will have a negative effect.

Table 3.8. Ecological benefit (dcNVC) by park. Percent of total ecological benefit is the amount of ecological benefit gained each park contributes to the total ecological benefit across the entire JCOS park system if every feasible acre was treated. The average ecological benefit per acre is a unitless (or relative) measure of the delta conditional Net Value Change before and after simulated treatments. Higher values indicate greater average ecological benefit for a park.

JCOS PARK/ PROPERTY	PERCENT OF TOTAL ECOLOGICAL BENEFIT	AVERAGE ECOLOGICAL BENEFIT PER ACRE
Pine Valley Ranch Park	4.80	2738.84
Cathedral Spires Park	3.46	2456.68
Douglas Mountain Study Area	5.53	1692.90
Alderfer/Three Sisters Park	3.53	1635.24
Lippincott Ranch Property	1.00	1627.19
Mount Lindo	2.43	1622.23
Reynolds Park	5.81	1582.16
Mount Falcon Park	6.07	1539.19
Lookout Mountain Preserve	0.28	1532.96
Centennial Cone Park	10.14	1512.35
Clear Creek Canyon Park	9.14	1509.06
Deer Creek Canyon Park	4.09	1504.70
Coal Creek Canyon Study Area	14.76	1478.37
Lair o' the Bear Park	1.06	1468.62
Beaver Ranch Park	1.18	1459.24
Windy Saddle Park	1.64	1325.65
White Ranch Park	9.97	1296.93
Meyer Ranch Park	1.56	1150.85
Mount Galbraith Park	1.74	1128.18
Apex Park	1.16	1126.89
Flying J Ranch Park	1.21	1041.39
Elk Meadow Park	2.82	1005.83
Matthews/Winters Park	3.37	781.16
Stafford Hogback	0.15	594.48
Mount Glennon	0.32	433.35
South Table Mountain Park	0.43	313.07
South Valley Park	0.51	265.47
Welchester Tree Grant Park	0.01	250.65
North Table Mountain Park	1.00	243.64
Hildebrand Ranch Park	0.80	140.94
Van Bibber Park	0.02	47.83
Crown Hill Park	-0.01	-336.70
JCOS Park System	100.00	1130.29

Jefferson County Open Space Fuel Treatment Prioritization

After assessing wildfire risk and ecological benefit, the RADS model prioritized fuel treatment type and location considering the constraints on treatment feasibility and cost. RADS uses a generalized form of the linear programming optimization model described in Gannon et al. (2019) to select treatment locations and types that each maximize risk reduction or maximize ecological benefit for the available budget. Spatial management units were defined by JCOS at an appropriate scale for decision-making within their parks. Each management unit was attributed with the area feasible for treatment and the average risk reduction or ecological benefit and treatment cost for each treatment type. Linear optimization was then used to identify the optimal treatment plan for the available budget. The model resulted in two treatment plans that represent the most cost-effective means to reduce wildfire risk or to maximize ecological benefit given the specified constraints.

The RADS model identified the optimal treatment locations and types for a wide range of budget levels: $5M, $10M, $25M, and $50M. Although wildfire risk, ecological benefits, and constraints were calculated across Jefferson County, treatment priorities were assessed at the management unit level within JCOS parks. Areas selected at a lower budget level were more cost effective than those selected at higher budget levels. Cost effectiveness in the RADS model balanced risk reduction with treatment cost (risk reduction/treatment cost), and often selected the more expensive thin + prescribed fire treatment because there was substantial benefit to treating surface fuels. No priority acres for wildfire risk or ecological benefit were identified in the following parks using the $50 million maximum budget level: Stafford Hogback, Mount Glennon, South Table Mountain Park, Van Bibber Park, Welchester Tree Grant Park, and Crown Hill Park.

WILDFIRE RISK PRIORITIES

WILDFIRE RISK PRIORITIES

The wildfire risk prioritization map identified priority acres across 25 of the JCOS parks, totaling 12,881 acres (Figure 3.15, Table 3.9). Overall, 31% of the feasible acres on JCOS properties were prioritized. There were 1,341 acres identified as the highest priority within nine JCOS parks. Flying J Ranch Park contained the most 'highest' priority acres; however, Coal Creek Canyon Study Area had the most priority acres overall, although it had no acres classified as 'highest' or 'higher' priority.

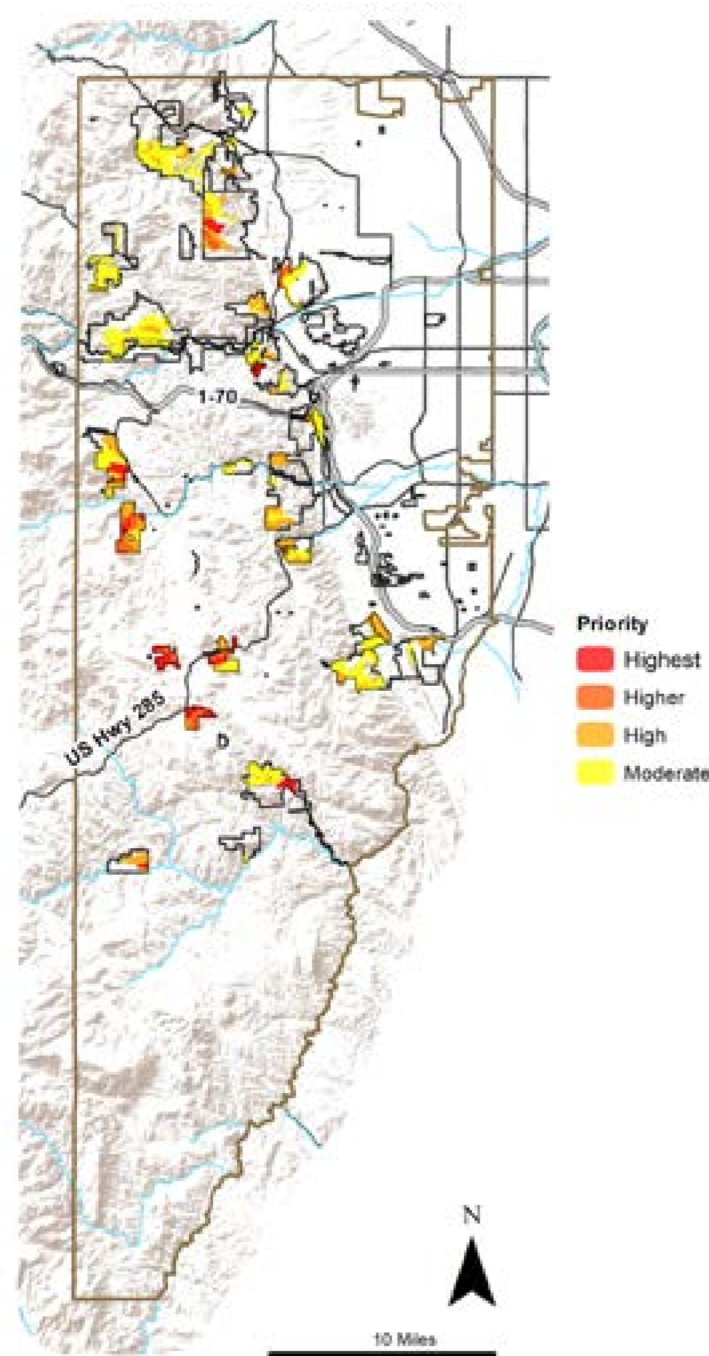


Figure 3.15. Wildfire risk fuel treatment prioritization for JCOS. Highest, higher, high, and moderate treatment priorities correspond to $5M, $10M, $25M, and $50M fuel treatment budgets.

Table 3.9. Wildfire risk priorities by park. The percent of total feasible acres is the percent treatable acres within each park that are a priority.

*RADS did not identify any priority acres for ecological benefit within the park.

JCOS PARK/PROPERTY	HIGHEST	HIGHER	HIGH	MODERATE	TOTAL PRIORITY ACRES	PERCENT OF TOTAL FEASIBLE ACRES (%)
Flying J Ranch Park	292.9	67.4	0.0	0.0	360.3	94.4
Elk Meadow Park	244.4	0.0	261.8	576.9	1083.1	81.2
Meyer Ranch Park	161.0	38.5	57.6	265.8	522.8	87.7
White Ranch Park	149.4	207.9	346.0	284.7	988.1	24.4
Beaver Ranch Park	144.1	136.6	90.3	0.0	371.0	93.6
Reynolds Park	129.0	0.0	56.7	513.7	699.4	34.5
Lookout Mountain Preserve	100.3	0.0	0.0	0.0	100.3	92.6
Alderfer/Three Sisters Park	91.2	416.1	490.2	81.4	1078.8	97.5
Pine Valley Ranch Park	28.5	0.0	246.4	0.0	274.9	37.5
North Table Mountain Park*	0.0	117.2	0.0	320.7	437.9	22.1
Mount Lindo	0.0	58.0	214.6	236.6	509.3	62.0
Mount Falcon Park	0.0	0.0	363.2	138.1	501.3	22.6
Coal Creek Canyon Study Area	0.0	0.0	337.4	1116.2	1453.6	25.0
South Valley Park*	0.0	0.0	236.0	217.3	453.2	53.0
Mount Galbraith Park	0.0	0.0	216.2	27.6	243.7	31.6
Matthews/Winters Park	0.0	0.0	202.8	184.1	387.0	16.4
Deer Creek Canyon Park	0.0	0.0	193.0	638.0	831.1	51.8
Hildebrand Ranch Park*	0.0	0.0	174.8	66.7	241.5	15.3
Centennial Cone Park	0.0	0.0	70.9	985.4	1056.4	29.9
Windy Saddle Park*	0.0	0.0	56.0	156.1	212.2	30.2
Douglas Mountain Study Area	0.0	0.0	52.9	476.4	529.3	30.0
Apex Park	0.0	0.0	38.7	72.5	111.2	16.5
Clear Creek Canyon Park	0.0	0.0	0.0	314.2	314.2	10.0
Lair o' the Bear Park	0.0	0.0	0.0	94.5	94.5	25.0
Cathedral Spires Park	0.0	0.0	0.0	26.0	26.0	3.5
JCOS Park System	1340.8	1041.7	3705.5	6793.0	12881.1	31.0

ECOLOGICAL BENEFITS PRIORITIES

The ecological benefit prioritization map identified priority acres across 22 of the JCOS parks, totaling 20,258 acres (Figure 3.16, Table 3.10). Overall, approximately 49% of the feasible acres on JCOS properties were prioritized. There were 2,524 acres identified as the 'highest' priority within six JCOS parks. Centennial Cone Park contained the 'highest' priority acres; however, similarly to the wildfire risk prioritization, Coal Creek Canyon Study Area had the most priority acres overall.

ECOLOGICAL BENEFIT PRIORITIES

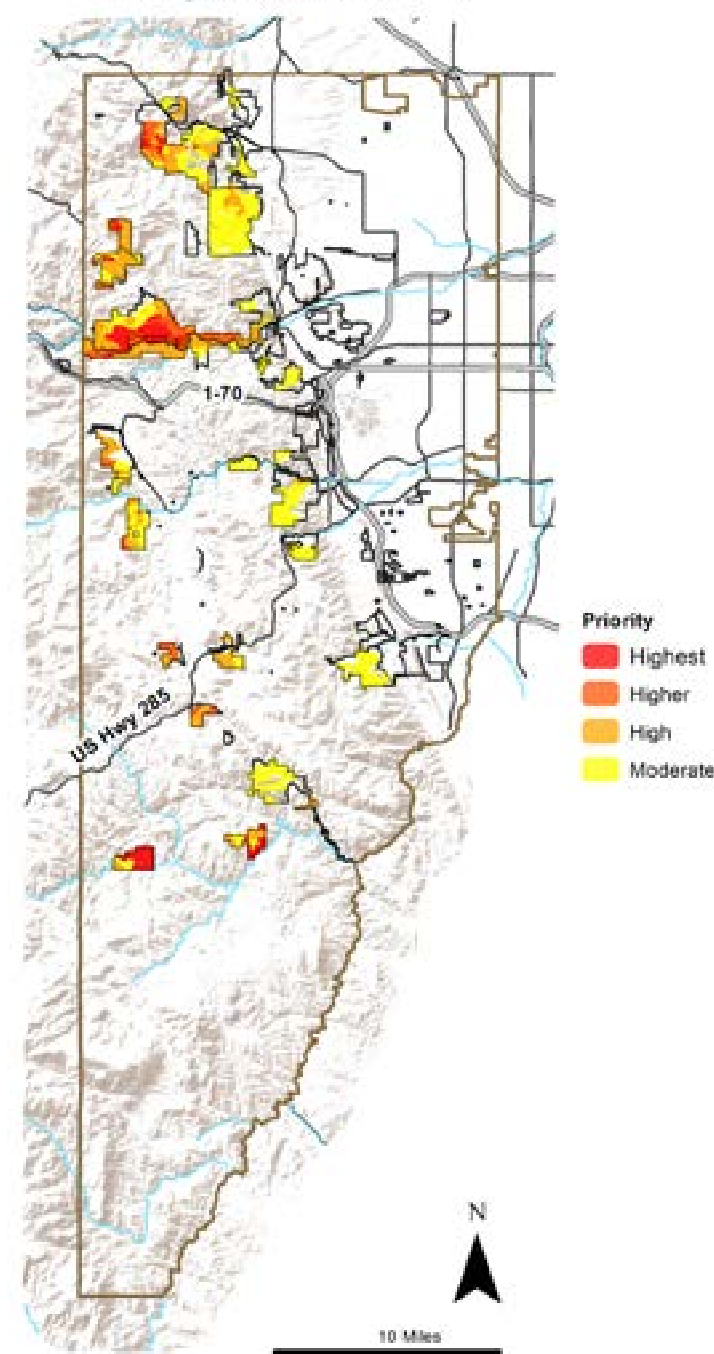


Figure 3.16. Ecological benefit fuel treatment prioritization for JCOS. Highest, higher, high, and moderate treatment priorities correspond to $5M, $10M, $25M, and $50M fuel treatment budgets.

Table 3.10. Ecological benefit priorities by park. The percent of total feasible acres is the percent treatable acres within each park that are a priority.

*RADS did not identify any priority acres for wildfire risk within the park.

JCOS PARK/PROPERTY	HIGHEST	HIGHER	HIGH	MODERATE	TOTAL PRIORITY ACRES	PERCENT OF TOTAL FEASIBLE ACRES (%)
Centennial Cone Park	982.3	651.8	949.0	312.5	2895.6	82.0
Pine Valley Ranch Park	492.4	0.0	49.8	146.6	688.8	94.0
Clear Creek Canyon Park	425.4	569.1	1339.0	226.2	2559.8	81.2
Cathedral Spires Park	314.0	0.0	252.9	155.0	721.9	96.2
Coal Creek Canyon Study Area	181.0	426.8	1290.3	1200.9	3099.1	53.4
Douglas Mountain Study Area	128.8	87.8	975.6	325.6	1517.8	86.1
Flying J Ranch Park	0.0	187.3	85.6	0.0	272.9	71.5
Beaver Ranch Park	0.0	116.8	205.5	0.0	322.2	81.3
Elk Meadow Park	0.0	112.8	380.7	306.5	800.0	60.0
Alderfer/Three Sisters Park	0.0	83.8	398.5	569.3	1051.7	95.1
White Ranch Park	0.0	0.0	453.0	1757.4	2210.4	54.5
Meyer Ranch Park	0.0	0.0	321.8	123.4	445.2	74.6
Reynolds Park	0.0	0.0	67.2	900.9	968.1	47.7
Mount Lindo	0.0	0.0	58.0	340.0	398.1	48.5
Mount Falcon Park	0.0	0.0	57.8	911.2	969.0	43.7
Deer Creek Canyon Park	0.0	0.0	0.0	697.0	697.0	43.5
Lair o' the Bear Park	0.0	0.0	0.0	173.0	173.0	45.7
Apex Park	0.0	0.0	0.0	144.8	144.8	21.5
Mount Galbraith Park	0.0	0.0	0.0	122.5	122.5	15.9
Lookout Mountain Preserve	0.0	0.0	0.0	100.3	100.3	92.6
Matthews/Winters Park	0.0	0.0	0.0	60.3	60.3	2.6
Lippincott Ranch Property*	0.0	0.0	0.0	39.1	39.1	9.4
JCOS Park System	2524.0	2236.2	6884.9	8612.4	20257.5	48.8

RISK REDUCTION AND ECOLOGICAL BENEFIT BY BUDGET

Treatment acres and locations were prioritized by maximizing risk reduction and ecological benefit relative to treatment costs. The returns for reducing additional risk or ecological benefit with higher budgets decreased as the treatment plan included lower priority acres where benefits are low and/or treatment costs are high. This prioritization process highlights the most cost-effective acres as the highest priority, informing where the JCOS treatment plan can gain the biggest 'bang for the buck' implementing forest management.

An avoided risk analysis showed that treating the highest priority acres would reduce overall risk within the JCOS park system by approximately 20% with a budget of $5 million (Figure 3.17a). Increasing the budget to $10 million to treat additional higher priority acres would reduce risk by another 10% for a total of 30% risk reduction across 2,383 acres in 11 parks (Table 3.10, includes the highest and higher priority acres). Prescribed fire and thinning + prescribed fire were identified as the most cost-effective treatments across the possible range of budgets to achieve the greatest amount of wildfire risk reduction (Figure 3.17c).

A similar analysis on the impact of treatment on ecological benefit followed a similar trend to the avoided risk curve (Figure 3.17b). However, the curve is noticeably flatter because treatments increased ecological benefit consistently across the JCOS park system. This is due to the relatively larger extents of the ecological benefit HVRAs when compared to wildfire risk HVRAs. For example, evacuation routes and communication points occupy a relatively smaller area and extent across the landscape where smaller treatment areas can have greater impacts on risk reduction. In contrast, ponderosa pine vegetation cover or mule deer winter range cover much of the county and require changes across large areas to impact ecological conditions. The relative importance of an HVRA is spread out over the entire extent of the HVRA, so that treating to benefit an HVRA with a relatively large extent tends to be expensive and have less impact per dollar spent than treating to benefit a similarly important HVRA with a smaller extent. There are still areas within the JCOS park system where it is cost effective to gain ecological benefit, especially where multiple ecological values overlap. Planning projects to meet both wildfire risk and ecological benefit objectives can be broken into multiple phases, where mechanical thinning can be used as a first entry to focus on meeting ecological objectives, and then prescribed fire can be used as a second entry to meet wildfire risk objectives.

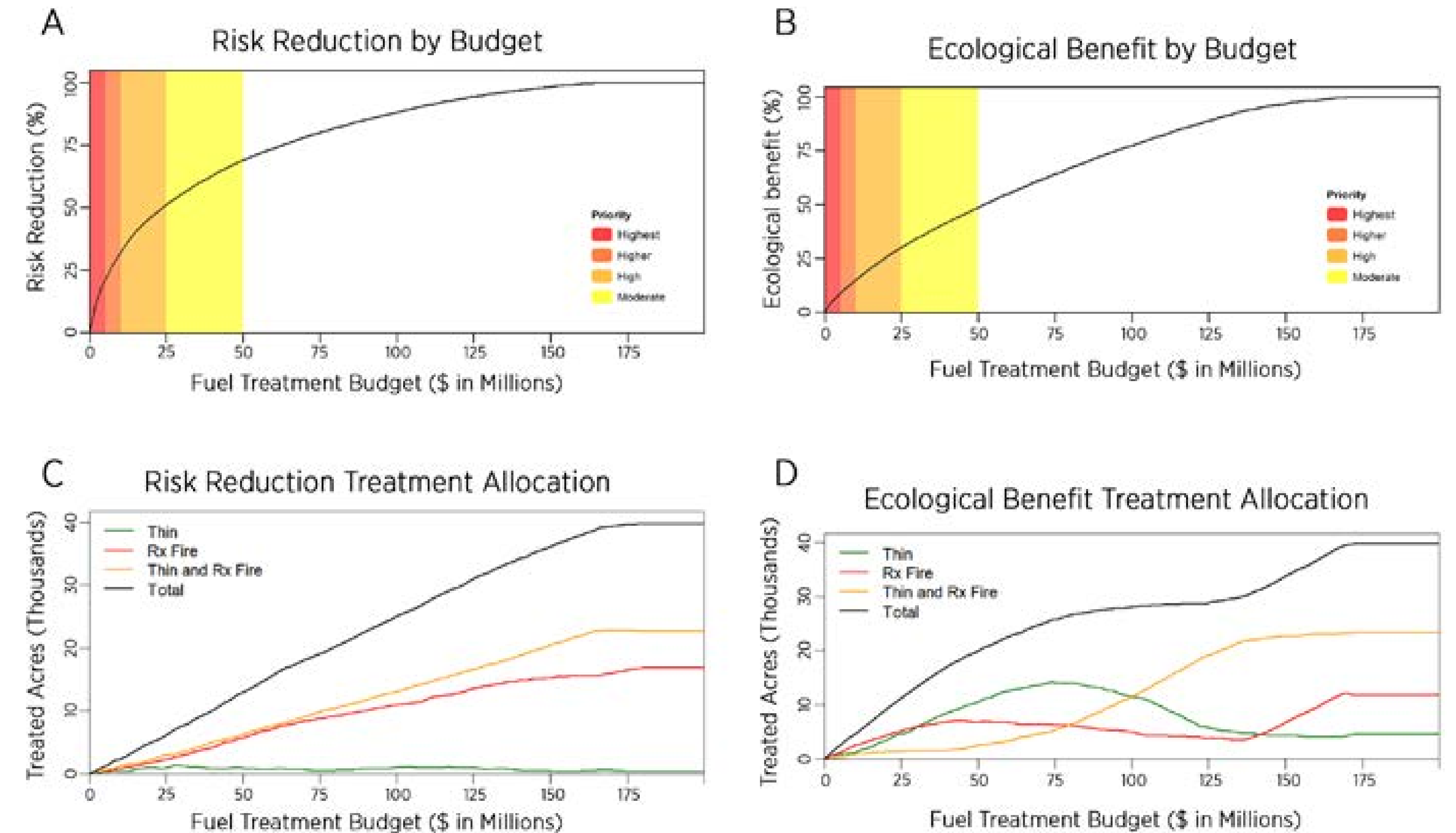


Figure 3.17. The top panels show cumulative wildfire risk reduction (A) and ecological benefit (B) achieved as budgets increase to support more forest treatment. Risk reduction and ecological benefit are presented as the percent of total risk reduction and ecological benefit achieved if every acre in the JCOS park system is treated. Idealized treatment type allocations are tracked across the possible range of budgets in the lower panels for both wildfire risk (C) and ecological benefit (D).

COMBINED PRIORITIES

Although each of the Wildfire Risk Assessment and Ecological Benefits Assessment prioritizations can be used separately to plan management or restoration activities, we developed a framework for combining the two assessment prioritizations into a single prioritization of management units. Using the treatment priority rankings in each assessment, we ranked management units based on their overlapping priority ranking such that management units that were assigned 'highest' in both assessments were ranked first priority; units where wildfire risk priorities were not assigned as priority and ecological benefit priorities were assigned 'moderate' were ranked as last priority (Table 3.11). Based on consultation with JCOS and the steep avoided risk curve shown in figure 3.17a, we chose to slightly prioritize wildfire risk over ecological benefit in our ranking. Treating the highest priority areas for wildfire risk often

Table 3.11. Combined priorities ranking.

		ECOLOGICAL BENEFIT				
	Priority	Highest	Higher	High	Moderate	None
WILDFIRE RISK	Highest	1	2	3	4	5
	Higher	6	7	8	9	10
	High	11	12	13	14	15
	Moderate	16	17	18	19	20
	None	21	22	23	24	NA

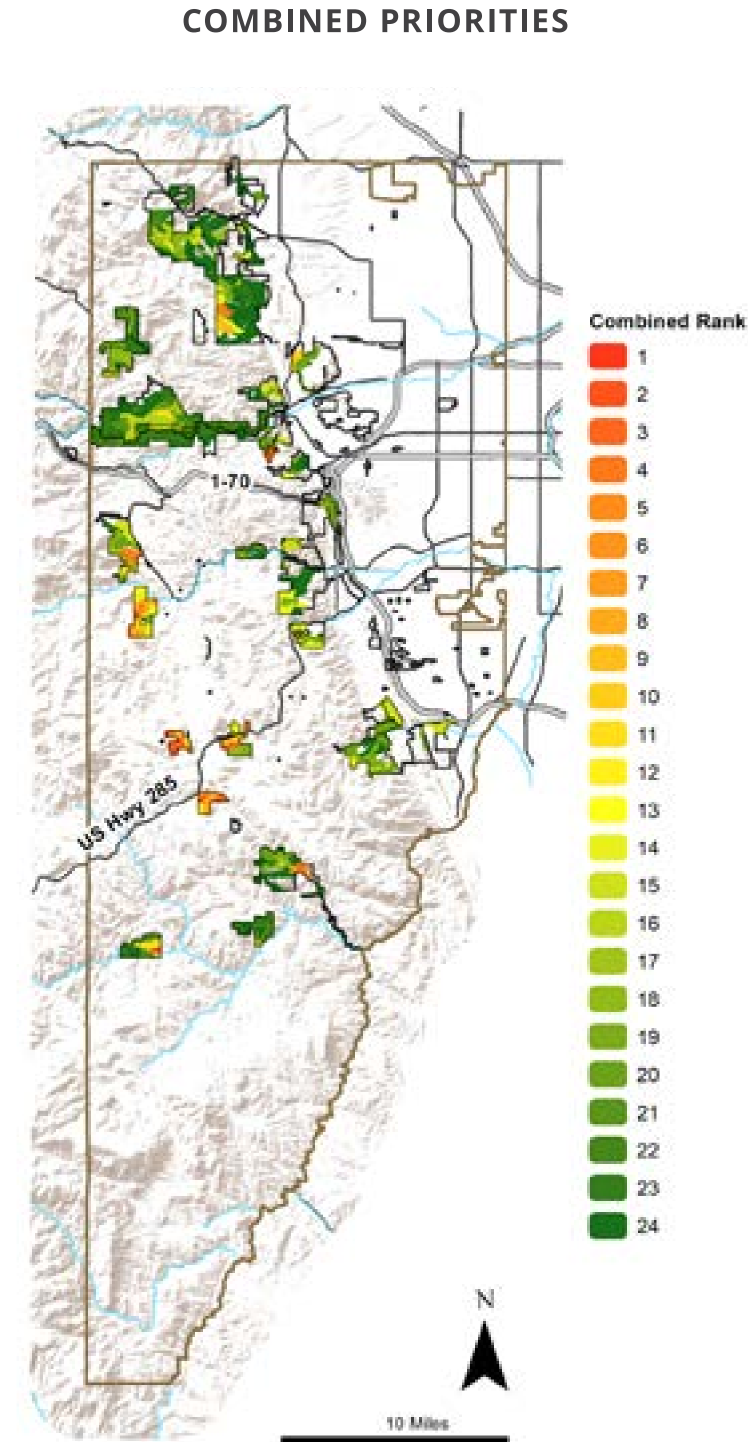


Figure 3.18. Combined prioritization for JCOS

Table 3.12. Combined priority acres by park. The percent of total feasible acres is the percent treatable acres within each park that are a priority.

JCOS PARK/PROPERTY	TOTAL ACRES FROM MANAGEMENT UNITS	ACRES FEASIBLE FOR TREATMENT	THIN ONLY	RX FIRE ONLY	COMPLETE	TOTAL PRIORITY ACRES	PERCENT OF TOTAL FEASIBLE ACRES (%)
Alderfer/Three Sisters Park	1,131.2	1106.0	58.7	38.5	981.6	1,078.8	97.5
Cathedral Spires Park	788.4	750.4	369.8	303.1	48.9	721.9	96.2
Flying J Ranch Park	420.6	381.6	0.0	58.5	301.8	360.3	94.4
Pine Valley Ranch Park	882.0	732.8	55.4	226.0	407.4	688.8	94.0
Beaver Ranch Park	445.0	396.3	0.0	48.7	322.2	371.0	93.6
Lookout Mountain Preserve	121.0	108.3	0.0	24.5	75.8	100.3	92.6
Elk Meadow Park	1,474.4	1,333.7	130.5	473.0	586.7	1,190.3	89.2
Meyer Ranch Park	666.7	596.5	0.0	38.5	484.4	522.8	87.7
Douglas Mountain Study Area	1,819.9	1,762.0	998.8	38.7	480.4	1,517.8	86.1
Centennial Cone Park	3,637.8	3,530.1	210.2	2,037.1	648.3	2,895.6	82.0
Clear Creek Canyon Park	3,393.4	3,151.8	0.0	2,423.7	136.1	2,559.8	81.2
Reynolds Park	2,044.1	2,029.8	530.4	177.2	589.3	1,297.0	63.9
Mount Lindo	831.8	821.3	0.0	107.0	402.3	509.3	62.0
Deer Creek Canyon Park	1,632.4	1,603.2	221.5	127.7	636.9	986.1	61.5
Coal Creek Canyon Study Area	6,002.4	5,806.3	1,373.3	885.1	1,206.0	3,464.5	59.7
White Ranch Park	4,133.8	4,053.6	542.9	577.6	1,127.3	2,247.7	55.5
South Valley Park	994.1	855.1	0.0	452.1	1.1	453.2	53.0
Lair o' the Bear Park	392.1	378.5	99.2	20.7	73.8	193.7	51.2
Mount Galbraith Park	804.6	771.5	88.5	250.2	27.6	366.3	47.5
Mount Falcon Park	2,233.8	2,219.1	306.2	137.0	550.6	993.9	44.8
Windy Saddle Park	746.7	702.8	156.1	0.0	56.0	212.2	30.2
North Table Mountain Park	2,066.8	1,985.1	0.0	437.9	0.0	437.9	22.1
Apex Park	693.8	673.2	106.1	0.0	38.7	144.8	21.5
Matthews/Winters Park	2,462.5	2,353.8	192.1	216.2	38.9	447.2	19.0
Hildebrand Ranch Park	1,644.7	1,576.1	0.0	241.5	0.0	241.5	15.3
Lippincott Ranch Property	426.5	417.4	39.1	0.0	0.0	39.1	9.4
JCOS Park System	41,890.4	40,096.2	5,478.9	9,340.3	9,222.5	24,041.7	57.9

overlaps with priority areas for ecological benefit. Carefully designing treatments to accomplish multiple objectives will increase the effectiveness and benefits of forest management activities.

The combined prioritization map identified priority acres across 26 of the JCOS parks, totaling 24,042 acres (Figure 3.18, Table 3.12). A single 28-acre treatment unit in Pine Valley Ranch Park was given a priority rank 1 as it was identified as a 'highest' priority for both the wildfire risk and ecological benefits treatment prioritization. Overall, approximately 58% of the feasible acres on JCOS properties were prioritized. The largest parks, Coal Creek Canyon Study Area, Centennial Cone Park, and Clear Creek Canyon Park had the greatest number of total priority acres within each park. However, parks such as Alderfer/Three Sisters Park and Cathedral Spires Park had almost all of their feasible acres ranked as combined priority. Appendix E shows zoomed in maps for each park with wildfire risk, ecological benefit, and combined priorities.

PRESCRIBED FIRE OPPORTUNITIES

Prescribed fire, and the use of broadcast burning in particular, will be an important management tool for JCOS going forward. From an operational perspective, broadcast burning can often be used over larger areas that are inaccessible to mechanical thinning treatments and is typically implemented at a lower cost (Hunter et al., 2007). Furthermore, prescribed fire is quite effective in reducing surface fuels, and studies have shown that implementing mechanical thinning treatments without prescribed fire is less effective at reducing future fire risk (Graham et al., 2012). Fire is a fundamental ecological process in many of Colorado's forests. It supports nutrient cycling, promotes regeneration of fire adapted species, and creates unique habitat features that are difficult to create with mechanical thinning treatments (Ryan et al., 2013; Stephens et al., 2012). The prioritization modeling in this Plan reflects the benefits of prescribed fire balanced with increased costs of implementation near communities. Maximizing management for wildfire risk reduction and enhancing ecological benefit cannot be achieved without returning fire to the landscape. Wildfires will continue to occur and are predicted to increase in frequency and intensity. Implementing prescribed fire within and adjacent to

Table 3.13. Prescribed fire opportunities. The management units listed in this table are in the highest and higher prioritization categories, and more than 50% of the unit can only be treated with prescribed fire. Many of these units are open meadows with low forest cover, and provide opportunities to pursue lower complexity burns and increase the capacity of the JCOS prescribed fire program.

JCOS PARK/PROPERTY	PARK UNIT ID	COMBINED RANK PRIORITY	WILDFIRE RISK PRIORITY	ECOLOGICAL BENEFITS PRIORITY	TOTAL ACRES	TOTAL ACRES FEASIBLE FOR TREATMENT	RX FIRE FEASIBLE ACRES	RX FIRE ONLY ACRES
Alderfer/Three Sisters Park	ALD8	4	Highest	Moderate	78.31	64.05	63.60	38.47
Lookout Mountain Preserve	LKT2	4	Highest	Moderate	50.31	45.37	40.70	24.46
White Ranch Park	WHR31	4	Highest	Moderate	158.77	149.45	149.23	80.95
Beaver Ranch Park	BVR5	5	Highest	None	50.37	20.68	20.68	15.35
Beaver Ranch Park	BVR7	5	Highest	None	34.18	29.13	28.02	20.46
Elk Meadow Park	ELK15	5	Highest	None	47.80	40.25	36.92	36.70
Reynolds Park	REY17	5	Highest	None	31.61	29.13	29.13	18.01
Flying J Ranch Park	FJR4	10	Higher	None	93.87	67.39	59.82	38.47
Meyer Ranch Park	MEY10	10	Higher	None	56.16	38.47	38.47	24.46
North Table Mountain Park	NTM13	10	Higher	None	140.87	126.54	117.20	113.42
Coal Creek Canyon Study Area	CCP1	12	High	Higher	117.85	114.31	114.31	63.60
Centennial Cone Park	CNT10	17	Moderate	Higher	185.78	185.92	185.92	101.86
Clear Creek Canyon Park	CCC51	17	Moderate	Higher	52.78	48.70	47.59	30.69
Pine Valley Ranch Park	PVR14	21	None	Highest	159.85	106.75	106.75	84.95
Centennial Cone Park	CNT7	22	None	Higher	165.43	158.12	158.12	95.41
Clear Creek Canyon Park	CCC43	22	None	Higher	65.66	59.82	56.49	34.47
Clear Creek Canyon Park	CCC16	22	None	Higher	175.06	157.90	155.68	88.51
Total					1664.65	1442.01	1408.65	910.26

JCOS open space parks offers the best tool to increase beneficial fire outcomes and sustain resilient forests on the landscape.

The optimal treatment plan identifies opportunities for prescribed fire to be used on over 77% of the total priority acres (Table 3.12). This is in line with recent research showing high suitability for prescribed fire within many JCOS parks, particularly in the northern and southern parks in the JCOS park system (Addington et al., 2020). Furthermore, many acres in the highest prioritization category can only be enhanced by prescribed fire due to low existing forest cover. While mechanical thinning can be used to reduce tree regeneration, only prescribed fire can enhance resilience of existing large conifer trees within open meadows with low tree cover (<10%), while also serving as a cost effective means to maintain low tree density; examples include Elk Meadow, and the meadow surrounding the ranch and west trailhead at White Ranch. Table 3.13 identifies all the JCOS management units that were in the highest prioritization categories where prescribed fire treatments yield the largest benefit-cost ratio. JCOS has a long history of using prescribed fire; however, the prescribed fire program needs a reset before increasing the pace and scale of fire as a restoration tool and taking on more complex burns. JCOS' prescribed fire program can begin with lower-complexity burns in the management units in Table 3.13, and use these opportunities to build internal capacity and external partnerships for using prescribed fire as a management tool moving forward.

Collaboration

The strategic planning process in this Forest Health Plan highlights JCOS parks, and management units within parks, where forest management can yield the biggest bang for the buck to best achieve wildfire risk reduction and enhance ecological processes. Some of these goals can likely be accomplished relying heavily on forest management of JCOS properties. For example, reducing risk of wildfire to communication towers, power line segments and other key infrastructure, enhancing recreation experiences, or improving specific wildlife habitat characteristics, are all likely achievable goals through forest management focused within the JCOS park system.

However, most ecosystem services and values that JCOS aims to sustain in their forested parks (e.g. Section 2 Desired Conditions and Guiding Principles, Tables 3.2 and 3.5) do not operate solely within the JCOS property boundaries. A coordinated, cross-boundary effort across the county, or potentially beyond, is essential to reduce risk of large wildfires burning over entire parks and overwhelming even the best forestry practices on JCOS management units. For example, the 2020 Cal-Wood fire was a cross-boundary wildfire originating on private property, burned through US Forest Service lands, and overwhelmed two decades of intensive forest management at Heil Valley Ranch, a Boulder County Parks and Open Space property. This wildfire incinerated much of the park open space recreation infrastructure, damaged trails, and reset much of the forest that was being managed towards more resilient old growth ecological characteristics (Brown et al. 2015). Similarly, all wildlife species identified in this Plan utilize habitat within and outside of JCOS parks. Enhancing wildlife habitat and ecological processes solely within our park system may not be enough to benefit targeted wildlife species populations depending on other stressors and habitat changes on adjacent land ownerships.

This Plan provides a detailed, actionable roadmap to sustain and enhance the most important and vulnerable ecosystem services from forests within the JCOS park system. The county wide assessment in Appendix A provides an additional perspective where our shared values overlap throughout all landownerships in Jefferson County, recognizing many processes impacting our forests operate at scales larger than any of our parks. Additionally, partnering with neighboring forest management organizations and communities allows managers to leverage financial resources, encourage investment, and learn from each other to facilitate adaptive management. JCOS strives to be a leader stewarding forests using the latest science-based methods, while recognizing the need to engage with our partners and external stakeholders on forestry issues within and outside the JCOS park system in order to achieve our goals. Taken together, the components of this Plan serve as tools to highlight opportunities where working in a collaborative cross-boundary approach can best achieve our shared values to sustain healthy forests.

Collaboration in Jefferson County and the Upper South Platte watershed is well established yet constantly evolving, and we recognize the need to pursue collaboration opportunities with current and emerging entities in order to ensure diverse perspectives continue to inform our forestry program. The Upper South Platte Partnership is currently an important collaborative group where JCOS engages with many of our forestry partners. In addition to participating with established collaborative partnerships, JCOS is committed to working with neighboring private landowners, local communities, and other

stakeholder groups invested in sustaining forest ecosystems in the county. Examples of current partners with whom JCOS maintains an active collaborative relationship to support our forestry program include:

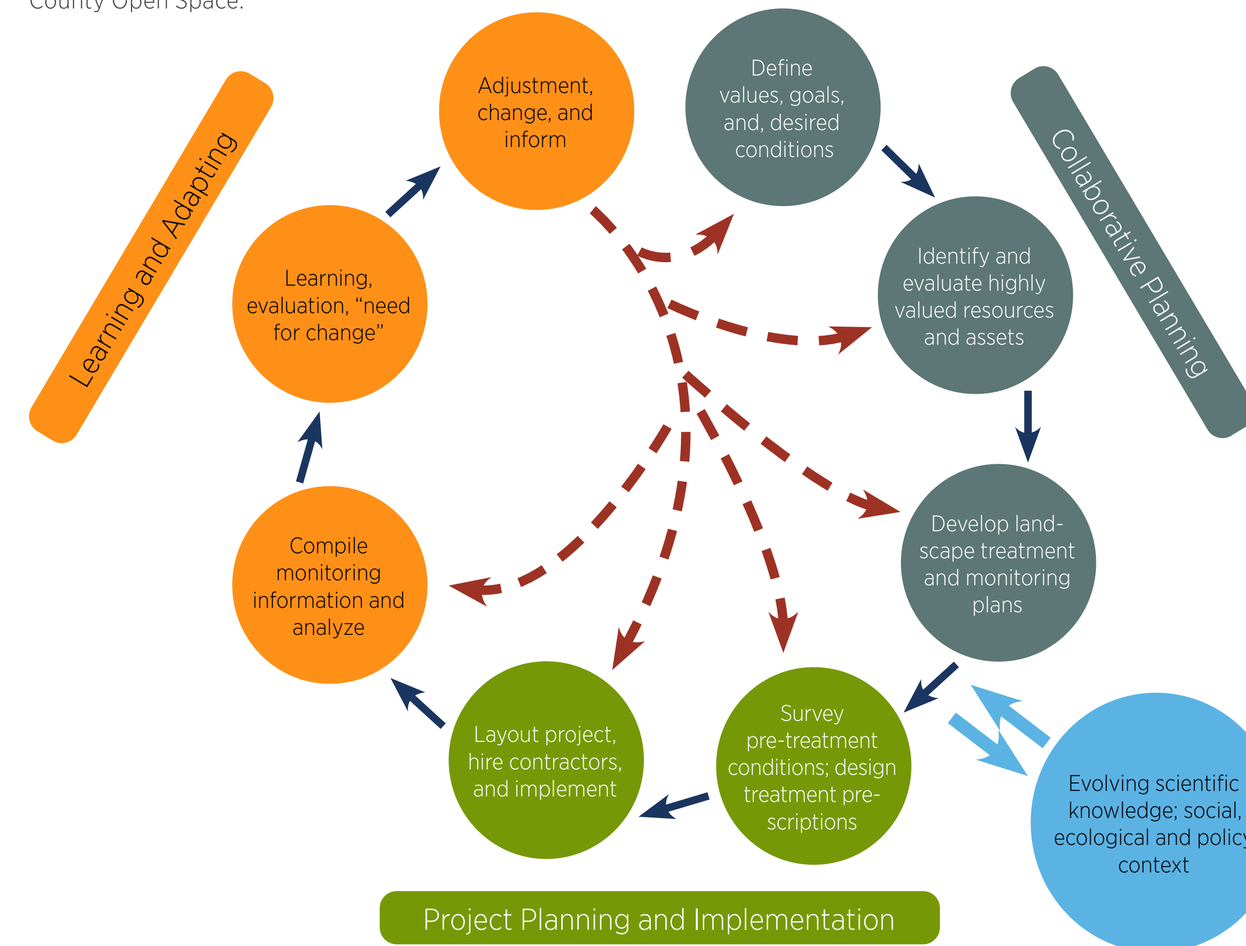
Adaptive Management

Increasing the scale of forest restoration will be crucial to achieving success; however, it will be equally important to take the time to evaluate actions, ensure desired conditions are met, and make adjustments as needed. JCOS is committed to thoroughly monitoring forest management projects to assess the effectiveness of outcomes, create learning opportunities from past projects, and make necessary changes to the forestry program when appropriate. This process follows an adaptive management cycle; there are many frameworks to describe the process (Addington et al., 2018; Aplet et al., 2014; Marcot et al., 2012), but at the highest level adaptive management includes planning, implementation, learning, and adapting. Figure 4.1 shows the more detailed process the JCOS forestry program follows to advance adaptive management.

The adaptive management cycle can be applied to many different aspects of forest management. For example, documenting on-the-ground operations can help improve implementation and lower costs; evaluating collaboration can improve communication with internal staff and collaborative partners. The JCOS forestry program often pursues numerous projects at once that involve coordination with other teams within JCOS, and with external stakeholders. Every individual forest management project, organizational program (e.g. forestry program), and partnership (e.g. USPP) can follow an adaptive management process; therefore, JCOS staff will be involved with multiple adaptive management cycles at any given time. It is important to understand how distinct adaptive management cycles interact and can inform one another.

One of the greatest challenges with the adaptive management cycle is closing the loop and completing the final step of learning and adapting. For any individual forestry project this is a process that continues for years after implementation, and creating opportunities to share information about projects in annual work plans can help structure the learning and adapting phase. Examples include: presenting on projects at conferences and collaborative group meetings; establishing an annual workshop where staff can share information across disciplines; completing final reports that can be used for public communication and grant funding; and hosting regular field tours at certain projects to demonstrate the JCOS forestry program and receive feedback.

Figure 4.1 The adaptive management cycle and process that guides forest management for Jefferson County Open Space.



Monitoring

A crucial component of advancing the adaptive management process is integrating a robust monitoring strategy that identifies the metrics used to describe forest management goals and forest conditions, and then collects comprehensive monitoring data for those metrics before and after implementation. Monitoring should directly link back to the need for treatment and represent a wide range of social, economic, and ecological indicators. At the project scale, monitoring metrics are used to describe outcomes and define current conditions, desired conditions, treatment prescriptions, goals, and objectives.

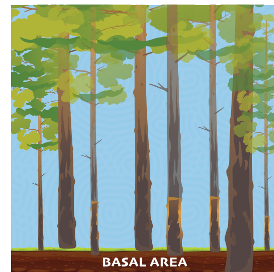
Understanding how key metrics change following restoration actions in the context of program goals and desired conditions can help JCOS forestry managers gauge the effectiveness of restoration actions, understand the need to make changes on upcoming projects, and define success in the forestry program. Furthermore, it is important to link these metrics back to the landscape-scale desired conditions and guiding principles. For example, these metrics can help managers describe landscape and fine scale heterogeneity, disturbances, and ecosystem processes. Additionally, managers can use monitoring metrics to define the historical range of variability, or how conditions change across environmental gradients. Lastly, collecting scientific data helps JCOS communicate information to the public and build support for future management.

Important metrics for monitoring ecological outcomes in forest management are organized under three categories: forest structure and composition, fuel loading and potential fire behavior, and understory plant communities. Along with implementing an ecological monitoring program, developing monitoring metrics to better understand economic and social outcomes of the forestry program will provide key insights for JCOS to improve effectiveness of their operations over time and facilitate engagement with more diverse stakeholders.

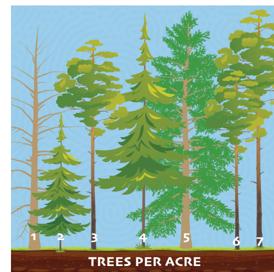
Forest Structure and Composition

Forest Structure and composition metrics provide a basis for planning and monitoring forest management actions. Many of these metrics are directly measured in the field or calculated from tree measurements. Remote sensing methods can also be used to track forest structure metrics, and remotely sensed data is often more practical to collect and analyze at larger spatial scales.

Canopy Cover – The proportion of a fixed area covered by tree canopies above the forest floor.

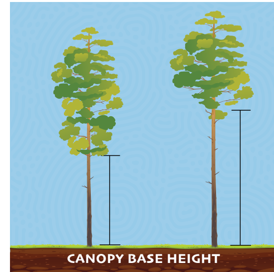


Basal Area – The total cross sectional area of tree boles, measured at breast height. Often used to describe species composition and set targets for mechanical thinning.



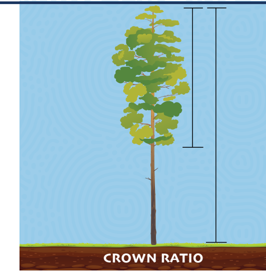
Trees Per Acre – The total number of trees, saplings, and germinated seedlings. Often used to describe species composition and set targets for mechanical thinning.

Tree Size – The average tree size, often calculated as the quadratic mean diameter at breast height. Can be subdivided by species.

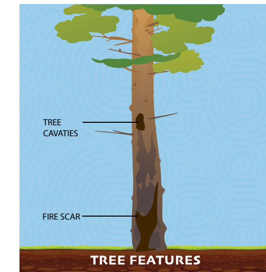


Canopy Base Height – The average height from the forest floor to the lowest live tree branch.

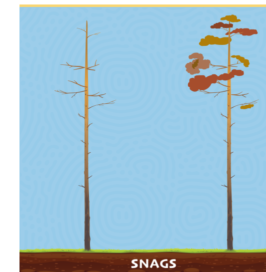
Tree Height – The average height or variability in height of trees.



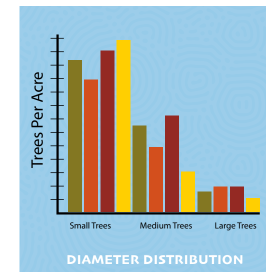
Crown Ratio – The ratio of tree crown height to total tree height.



Tree Features – Features such as fire scars, tree cavities, split stems, broken tops, and other features that identify old and desired trees and unique habitat. Counted over a fixed area.

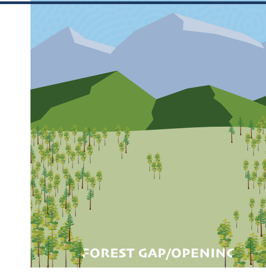


Snags – Standing dead trees counted over a fixed area.



Diameter Distribution – The total number of trees per acre broken down by size classes.

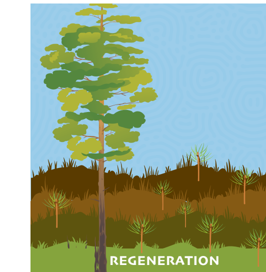
Tree Groups – Often measured in size classes by number of trees. Summarized by count of groups per area, or the proportion canopy cover represented by each tree group size class.



Forest Gaps and Openings – The proportion of a fixed area covered by forest opening or gaps, which are usually defined as areas greater than ¼ acre and less than 10% canopy cover.

Vegetation Patches – A contiguous area of similar forest type or understory plant community. Forest stands and vegetation communities are mapped to determine the size and distribution of patches across the landscape.

Stand Age – The average or variability in tree age in a forest stand. Measured by extracting increment cores and aging trees to evaluate age diversity and identify old growth.

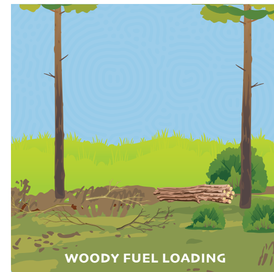


Regeneration – Seedlings germinated after treatment, disturbance, or control. Measured by counting seedlings by height class and species over time (repeated measures).

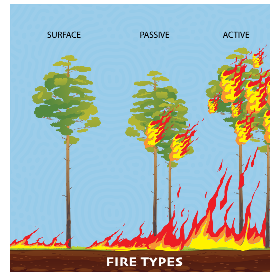
Mortality – A count of standing dead trees over time (repeated measures).

Fuel Loading and Potential Fire Behavior

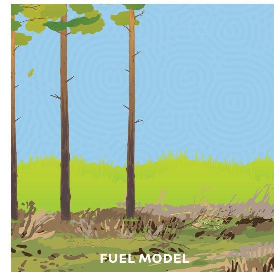
Fuel loading metrics can be directly measured and estimated using field monitoring data, and are used to model the potential fire behavior in a given area. There are many software programs that model potential fire behavior given fuel and fire weather conditions; common programs include, the Fire and Fuels Extension for the Forest Vegetation Simulator (FFE-FVS, Reinhardt & Crookston 2003) and FlamMap 5 (Finney et al., 2015) to model fire behavior spatially. Fuel loading and potential fire behavior metrics can help managers monitor treatment impacts on fire hazard.



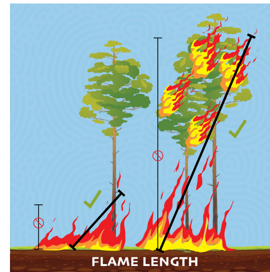
Woody Fuel Loading - The estimated weight of dead woody material on the forest floor, often separated into size classes based on time lag or fuel moisture (e.g. 1-hr, 10-hr, and 100-hr).



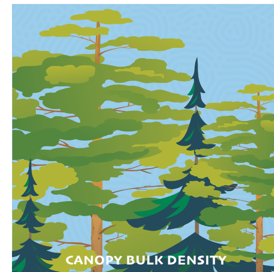
Fire Type – The anticipated fire type given fuel and fire weather conditions. Fire types include surface, passive crown (i.e. isolated tree a group torching), and active crown fire.



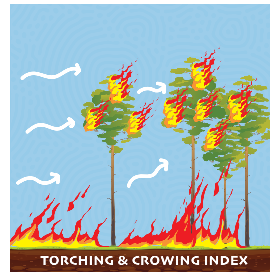
Fuel Model – A set of fuel bed inputs (e.g. loading, surface-area-to-volume ratio, fuel bed depth) used for fire modeling and classified into 53 standard fire behavior fuel models (Burgan & Scott, 2005).



Flame Length – The anticipated height of flames given fuel and fire weather conditions; can be measured as surface fire flames length and total flame length.



Canopy Bulk Density – The density of fuel available to burn in the forest canopy, measured as the mass of fuel per volume unit.



Torching and Crowning Index – The estimated wind speed that is needed to initiate torching and crown fire activity.

Understory Plant Communities

Monitoring understory plant communities can be time intensive, but these communities increase native biodiversity, provide wildlife habitat, and improve overall ecosystem health. Collecting species-level data requires identifying all plants in a given area, which takes time and expertise from monitoring crews. When that species-level data is collected, metrics such as species diversity, evenness, and richness can be calculated; however, this may not be necessary for every project and managers can evaluate the need for these intensive plant surveys. Alternatively, managers can perform field estimates of the percent cover of understory plants by growth form (e.g. forb, shrub, graminoid), native vs. non-native plants, and species of interest. Plant species of interest can include rare and threatened plants, vegetation that provides habitat and a food source for wildlife, and plants associated with human values (e.g. aesthetics and recreation).

There are many ways to collect monitoring data, and keeping a broad toolbox for data collection and analysis will help monitoring be effective with limited resources. The foundation for monitoring data will be field data collected within project boundaries, and possibly in control plots. Additionally, remotely sensed data from aerial imagery and LiDAR can analyze some of the forestry metrics listed above. Methods for data collection and analyses are always evolving, and JCOS will continue to explore new ways of monitoring forest management projects.

Many forestry metrics can be linked to key metrics in other disciplines, and forest managers should help coordinate monitoring for other disciplines, including wildlife, watershed, and socio-economic impacts. Similar to the forestry monitoring program, each discipline should identify key metrics and develop a monitoring plan to evaluate those metrics. Lastly, the list of forestry metrics described above are dynamic, and could change as part of the adaptive management process.

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APPENDIX A. Jefferson County Wildfire Risk Assessment and Prioritization

Jefferson County Open Space ran a parallel assessment using the Colorado Forest Restoration Institute's Risk Assessment Decision Support (RADS) tool to assist in facilitating collaborative management with JCOS partners within Jefferson County. The Jefferson County Wildfire Risk Assessment is intended to assist JCOS and its adjacent landowners and partners in identifying restoration opportunities, goals, and approaches for the broader landscape within Jefferson County. The end goal of these complementary assessments was to prioritize management within the JCOS park system, but also strongly consider an individual park or forest stand within the context of the broad landscape scale. In that vein, to complement the park-level assessment, a collaborative wildfire risk analysis and treatment prioritization was also assessed at the watershed unit level across Jefferson County. Through collaboration with its partners, JCOS can jointly prioritize where restoration actions would have the greatest impact relative to the values at a county scale.

Differences from JCOS Assessment

Inputs into the Jefferson County WRA were kept the same with the exception of HVRAs located only on JCOS properties (Table A1). Specifically, this included two HVRAs in the infrastructure category, Occupied Buildings and Structures, which were integrated into the WUI layer, and two HVRAs in the recreation category: Picnic areas, Bridges, Stairs and Turnpikes/Trail Features. HVRA relative importance for these two categories were adjusted to account for the removal of the HVRAs. Relative importance of categories remained the same as the JCOS WRA (Table A2). Additionally, National Hydrography Dataset Plus (NHDPlus) catchments were used as treatment units for the prioritization at the county level instead of within-park management units used for the JCOS assessment.

Table A1. HVRAs included in the Jefferson County risk assessment by category. The buffer distance used to define an influence zone for wildfire around the HVRA, the HVRA relative importance (%) to the category, and the relative wildfire response functions by intensity level are specified. All inputs were defined through a collaborative process using stakeholder input. Changes from the JCOS assessment were made for the Infrastructure and Recreation categories.

Category	HVRA	Buffer (m)	Relative Importance	Wildfire Response – Flame Length (feet)					
				0-2	2-4	4-6	6-8	8-12	> 12
Life Safety	Evacuation Routes – First Priority	200	60	-20	-40	-80	-100	-100	-100
	Evacuation Routes – Second Priority	200	40	-20	-40	-80	-100	-100	-100
Infrastructure	Electrical Power Lines	200	60	-10	-20	-30	-50	-60	-80
	Communication Points	200	40	-10	-20	-30	-50	-60	-80
Water	Drinking Water Protection	0	100	-20	-40	-80	-100	-100	-100
Vegetation Cover	Aspen/Aspen Mixed Conifer	0	5	30	40	60	60	40	30
	Lodgepole Pine/ Spruce-fir	0	15	25	25	50	25	-25	-50
	Mixed Conifer	0	30	25	50	50	25	-25	-50
	Ponderosa Pine	0	35	100	75	50	25	-25	-80
	Shrubland	0	10	50	50	25	-25	-75	-100
	Grassland	0	5	50	50	25	20	0	-10
WUI	Adjacent Private Property	0	100	-20	-40	-80	-100	-100	-100
Wildlife	Abert's Squirrel	0	5	100	75	0	0	-50	-100
	Bighorn Sheep Winter Range	0	15	100	100	100	50	0	-50
	Elk Winter Range	0	15	100	100	50	50	0	-100
	Mule Deer Winter Range	0	10	100	100	50	50	0	-100
	Northern Goshawk	0	15	100	100	50	0	-50	-100
	Pawnee Montane Skipper	0	25	100	80	30	20	10	0
	Preble's Jumping Mouse	0	15	70	40	0	-50	-75	-100
Recreation	Campgrounds	400	60	0	-10	-10	-20	-50	-70
	Trails	100	40	0	-10	-10	-20	-30	-30

Table A2. Relative importance weights used for combining HVRA categories into a composite risk map. Relative importance scores are the same as the JCOS assessment.

Category	Relative Importance
Life Safety	100
Infrastructure	90
Water	90
Vegetation Cover	90
WUI	50
Wildlife	50
Recreation	50

Wildfire Risk for Jefferson County

Composite wildfire risk maps were generated for Jefferson County after the removal of the JCOS-only HVRAs (Figure A1, Figures A2a-A2g). The more negative the eNVC, the greater the risk to HVRAs from wildfire, while a positive eNVC means there is an expected benefit from wildfire. Despite the removal of JCOS buildings, and park and trail features, the wildfire risk remains highest in the central part of Jefferson County. The high density of WUI (Figure A2g), trails (Figure A2c), and evacuation routes (Figure A2b), as well as high fuel loads, located both within and outside of JCOS parks throughout this part of the county are the main drivers of this risk. The dark red circles indicating high risk, most noticeable along Buffalo Creek in the south end of Jefferson County, are campgrounds.

Expected positive benefits from wildfire remain concentrated along Clear Creek Canyon Road/U.S. Hwy 6 due to the positive effects expected from wildfire on Bighorn Sheep habitat (Figure 2Af) along the canyon. Mapped Pawnee Montane Skipper habitat at the south end of the county within the Pike-San Isabel National Forest is also expected to receive positive benefit from wildfire.

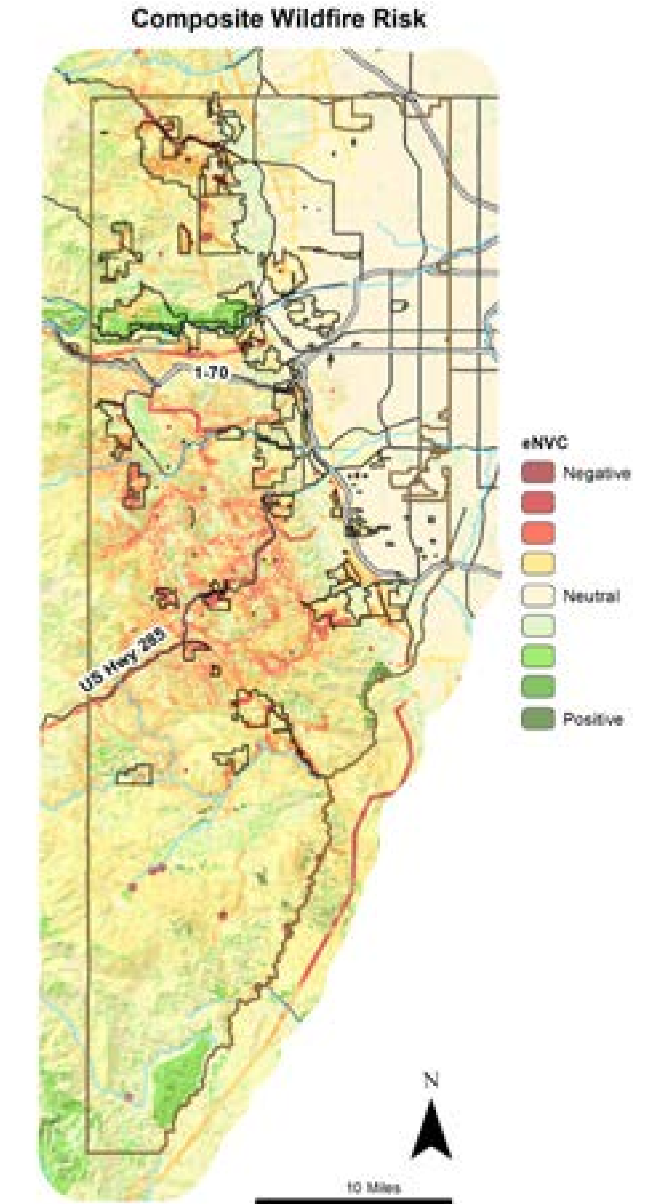
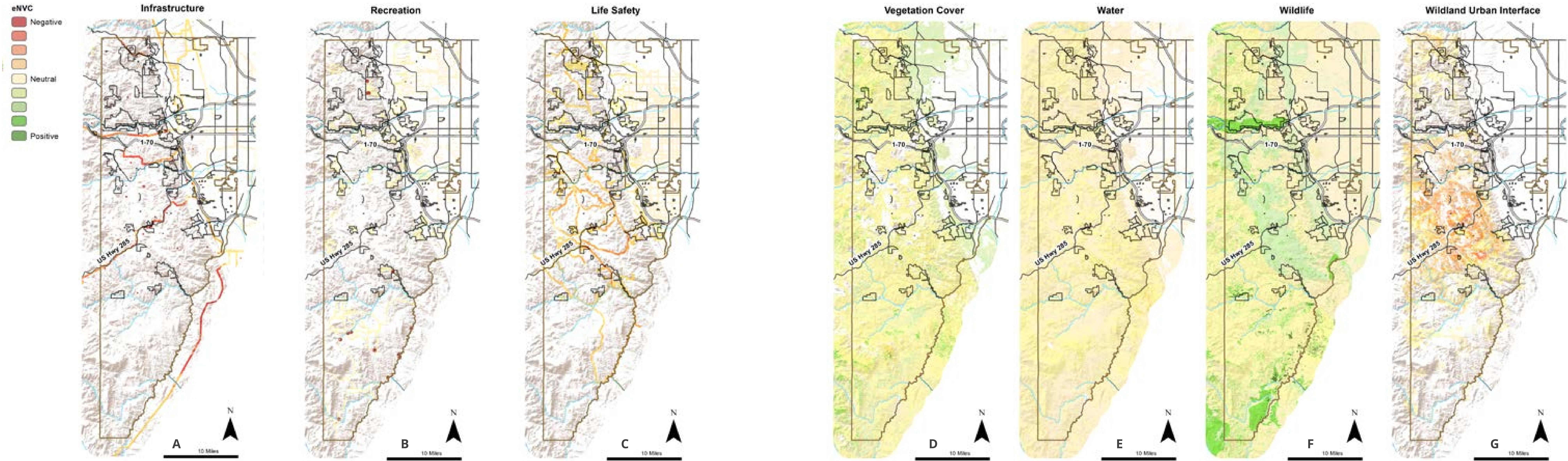


Figure A1. Composite wildfire risk map for Jefferson County. Negative eNVC means high risk. Positive eNVC means there is an expected benefit from wildfire.

Figure A.2a-g. Composite wildfire risk map for each HVRA category. Negative eNVC means high risk. Positive eNVC means there is an expected benefit from wildfire.



Management Units

Jefferson County Open Space selected National Hydrography Dataset Plus (NHDPlus) catchments as treatment units for the prioritization at the county level. There are 435 catchments in Jefferson County. Catchments range in sizes from approx. 1 acre to 12,341 acres with a mean size of 1,137 acres.

Treatment Feasibility and Treatment Cost

This prioritization considered the same three treatment types as the JCOS assessment: 1) thin only, 2) prescribed fire only, and 3) thin followed by prescribed fire. Feasibility constraints were not altered for the Jefferson County prioritization. For the county assessment, 256,534 acres or 52% of Jefferson County was considered feasible for the thinning only or thin followed by prescribed fire treatment. Similar to the JCOS assessment, to capture that it is unrealistic to drastically increase prescribed fire use in the short-term, an additional constraint was created to limit spending on prescribed fire to 25% of the total budget. Given this constraints, 302,379 acres or 61% of Jefferson County was considered feasible for the prescribed fire only treatments.

Treatment costs were also not altered for the Jefferson County prioritization.

Risk Reduction

The risk reduction benefit of treatment is assessed on a per-pixel basis as the difference between current risk and simulated post-treatment risk using the Wildfire Risk Assessment. The benefit of fuel treatment is only represented as changing fire behavior (flame lengths, crown fire activity) as modeled with FlamMap 5 (Finney et al. 2015), not burn probability. This approach is consistent with the primary objectives of fuel treatments (Reinhardt et al. 2008), but it could underestimate fuel treatment benefits where they are expected to reduce area burned (Thompson et al. 2013). Risk reduction estimates are mapped for each treatment type in Figure A3 through Figure A5.

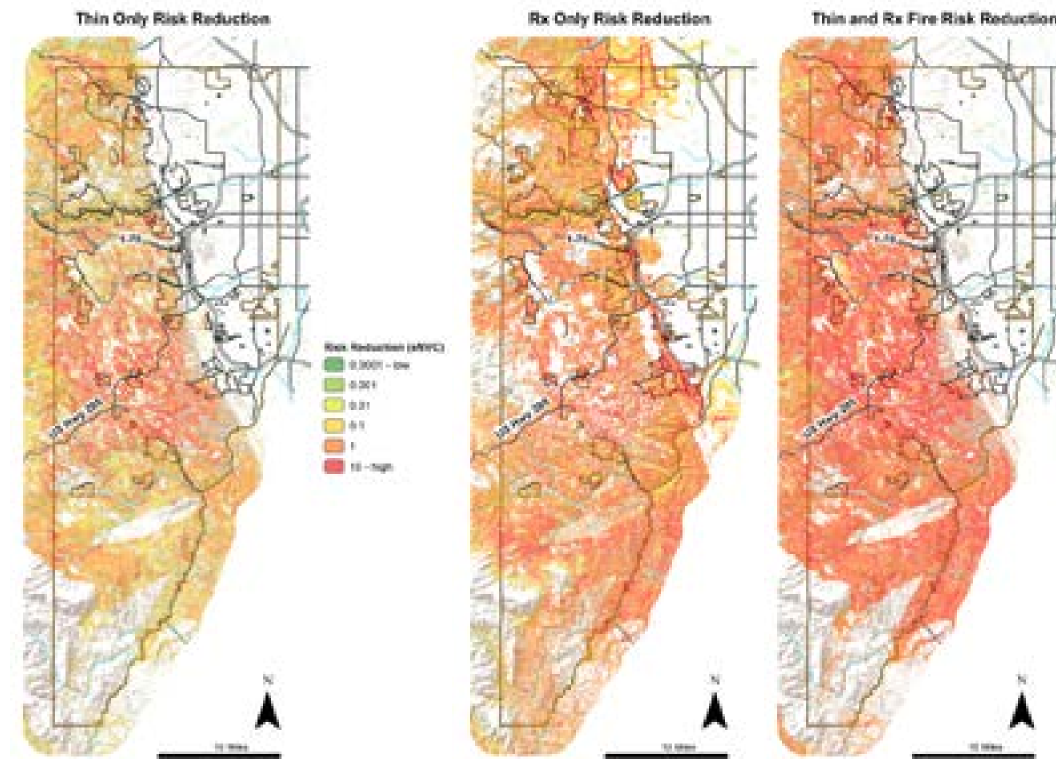


Figure A3. Estimated risk reduction for the thin only treatment for Jefferson County.

Figure A4. Estimated risk reduction for the prescribed fire only treatment for Jefferson County.

Figure A5. Estimated risk reduction for the thin followed by prescribed fire treatment for Jefferson County.

Overall, despite the removal of JCOS-specific HVRAs, risk reduction patterns were similar between the JCOS and county-wide assessment. For the thin only treatment, the greatest risk (eNVC) reduction was concentrated around the central area of the county where many of the HVRAs were concentrated. The prescribed fire only treatment reduces risk over a greater area of Jefferson County than the thin only treatment with greater risk reduction across much of the county. The thin followed by prescribed fire treatment shows the greatest risk reduction per pixel, since it is essentially two treatments, each incrementally decreasing risk.

Jefferson County Fuel Treatment Prioritization

After assessing wildfire risk, the RADS model prioritizes fuel treatment type and location considering constraints on treatment feasibility and cost. RADS uses a generalized form of the linear programming optimization model described in Gannon et al. (2019) to select treatment locations and types that maximizes risk reduction for the available budget. Each NHDplus watershed was attributed with the area feasible for treatment and the average risk reduction and treatment cost for each treatment type. Linear optimization is then used to identify the optimal treatment plan for a given budget. The model results in a treatment plan that represent the most cost-effective means to reduce wildfire risk given the specified constraints.

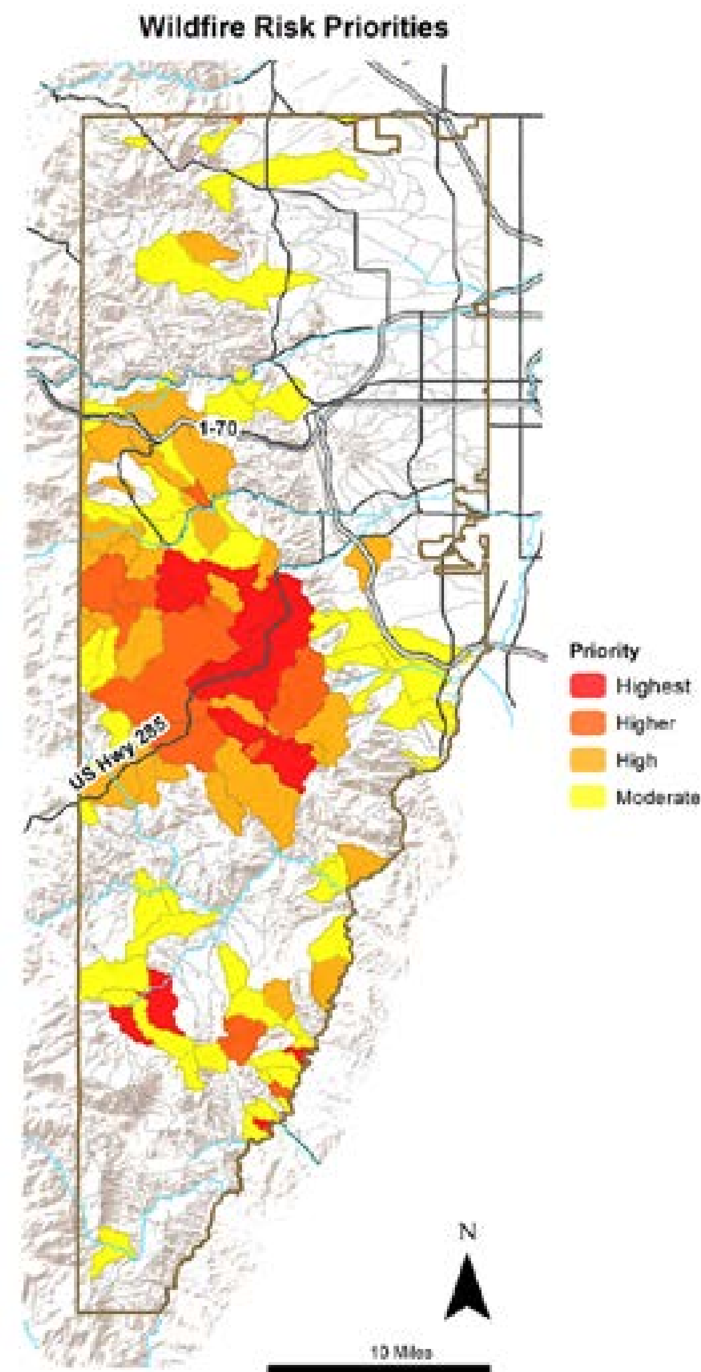
Wildfire Risk Priorities

The RADS wildfire risk prioritization map selected between 19,006 and 129,426 acres for treatment across the modeled budgets (Table A3). Budgets of $50M, $100M, $250M, and $500M correspond to selecting the top 8%, 14%, 28%, and 44% of treatment opportunities, respectively. Areas selected at lower budget levels are more cost effective than those selected at higher budget levels. The fuel treatment priorities for Jefferson County are mapped in Figure A6.

Table A3. Budget summary of percent risk reduction achieved and treatment allocation for Jefferson County. Acres are not cumulative.

Priority	Budget	Thin Only (acres)	Rx fire Only (acres)	Thin & Rx Fire (acres)	Total (acres)	Percent Risk Reduc-tion
Highest	$50M	13,414	4,939	653	19,006	8
Higher	$100M	27,581	9,446	933	37,960	14
High	$250M	44,030	23,923	13,564	81,517	28
Moderate	$500M	20,592	50,716	58,118	129,426	44

Figure A6. Wildfire risk fuel treatment prioritization for JCOS. Higest, higher, high, and moderate treatment priorities correspond to $50M, $100M, $250M, and $500M fuel treatment budgets.



The wildfire risk prioritization map identified priority acres across 118 watersheds, totaling 267,909 manageable acres (Figure A6, Table A3). Many of the 'highest' priority watersheds are located in the central part of Jefferson County along the US HWwy 285 corridor. Additional 'highest' priority watersheds also fell within the southern end of the county. All of the JCOS property Meyer's Ranch Park and approximately half of Mount Lindo Park fell within a watershed management unit identified as 'highest' priority. Flying J Ranch Park and Beaver Ranch Park overlapped 'higher' priority watersheds. Several other JCOS parks fell within 'high' and 'moderate' priority watersheds.

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APPENDIX B. Jefferson County Open Space Wildfire Hazard Modeling

Methods

Fuels

Fuels were acquired from the LANDFIRE (2019) refresh, which represents fuel conditions circa 2016. The first adjustment we made to the data was targeted at increasing the intensity of fire behavior in lodgepole pine forests to match recent fire behavior observations (Moriarty et al. 2019). This was accomplished by reducing the canopy base height by 30% and changing any low load (TL1) or moderate load (TL3) conifer litter fuel models to high load conifer litter (TL5) (Scott and Burgan 2005). We then updated the fuels data to reflect current conditions using forest management actions reported by the USDA Forest Service (USFS) and Colorado State Forest Service (CSFS) between 2016 and present. USFS treatments were assigned generalized canopy and surface treatment types as described in Table B1. CSFS treatments were assigned a canopy treatment of "Thin" if silviculture activities were reported and a surface treatment of "Rx fire" if fire activities were reported. Any overlapping "Thin" and "Rx fire" treatments were combined into a "Complete" canopy treatment. Canopy and surface fuel adjustments are described in Table B2 and Table B3.

Table B1. Cross walk between USFS treatment types and our generalized canopy and surface treatment effects.

Treatment	Canopy type	Surface type
Biomass Removal	None	Manage
Broadcast Burn	Rx fire	Rx fire
Crushing	None	Masticate
Grazing	None	Manage
Lop and Scatter	None	Lop and scatter
Machine Pile	None	Manage
Machine Pile Burn	None	Manage
Thinning	Thin	None
Chemical	None	None
Chipping	None	Masticate
Fire Use	Rx fire	Rx fire
Jackpot Burn	Rx fire	Rx fire
N/A	None	None

Table B2. Canopy proportional adjustment factors used to represent prior treatment effects on canopy bulk density (CBD), canopy base height (CBH), canopy cover (CC), and canopy height (CH). The complete treatment is thinning followed by prescribed fire.

Treatment	CBD	CBH	CC	CH
Thin	0.6	1.2	0.7	1.2
Rx fire	0.92	1.09	0.95	1.13
Complete	0.5	1.2	0.75	1.2

Table B3. Fire behavior fuel model (FBFM40) reclassification for surface fuel treatment types. Codes and FBFM40 numbers are from Scott & Burgan (2005). Areas of change from the baseline are in bold red font.

Code	FBFM40	Manage	Rx Fire	Rearrange
GR1	101	101	101	**201**
GR2	102	102	**101**	**201**
GR3	103	103	**101**	**201**
GR4	104	104	**101**	**201**
GR5	105	105	**101**	**201**
GR6	106	106	**101**	**201**
GR7	107	107	**101**	**201**
GR8	108	108	**101**	**201**
GR9	109	109	**101**	**201**
GS1	121	121	121	**201**
GS2	122	122	**121**	**201**
GS3	123	123	**121**	**201**
GS4	124	124	**121**	**201**
SH1	141	141	141	**201**
SH2	142	142	**141**	**201**
SH3	143	143	**141**	**201**
SH4	144	144	**141**	**201**
SH5	145	145	**141**	**201**
SH6	146	146	**141**	**201**
SH7	147	147	**141**	**201**
SH8	148	148	**141**	**201**
SH9	149	149	**141**	**201**
TU1	161	161	161	**201**
TU2	162	162	**161**	**201**
TU3	163	163	**161**	**201**
TU4	164	164	**161**	**201**
TU5	165	165	**161**	**201**
TL1	181	181	181	**201**
TL2	182	182	**181**	**201**
TL3	183	183	**181**	**201**
TL4	184	184	**181**	**201**
TL5	185	185	**181**	**201**
TL6	186	186	**181**	**201**
TL7	187	187	**181**	**201**
TL8	188	188	**181**	**201**
TL9	189	189	**181**	**201**
SB1	201	201	201	201
SB2	202	**201**	**201**	**201**
SB3	203	**201**	**201**	**201**
SB4	204	**201**	**201**	**201**

Weather Scenarios

The four percentile weather scenarios were defined with analysis of historical data from six Remote Automated Weather Stations (RAWS) in or near the County (Table B4). The timeframe for the analysis was limited to the years 2000 to 2018 and only observations from the April 1st to October 31st fire season were used. Historical percentiles of 1-hr, 10-hr, 100-hr, 1000-hr herbaceous, and woody fuel moistures and wind speeds were estimated by station with FireFamilyPlus 5.1 (Bradshaw and McCormick 2000) and then averaged across stations into the four scenarios (Table B5). Average 10-min wind speeds were converted to 1-min average wind speeds based on Crosby and Chandler (1966).

Table B4. RAWS used in the analysis.

Station ID	Name	Lat (deg)	Long (deg)	Elevation (ft)
52001	BAILEY	39.381	-105.342	8000
53102	CHEESMAN	39.181	-105.267	7473
51804	CORRAL CREEK	39.640	-105.464	7844
52003	LOOKOUT MOUNTAIN	39.724	-105.250	7504
53103	POLHEMUS	39.255	-105.133	8683
52002	WATERTON NORTH	39.467	-105.210	8714

Table B5. Average percentile conditions across the six RAWS. All values are percent fuel moisture except wind speeds.

Scenario	1-hr	10-hr	100-hr	1000-hr	Herbaceous	Woody	Wind speed (10 min ave. mph @ 20ft)	Wind speed (1 min ave. mph @ 20ft)
Low, 25th	9	10	15	16	62	105	5	9
Moderate, 50th	6	7	11	14	34	74	7	11
High, 90th	3	4	7	10	4	62	11	16
Extreme, 97th	2	3	6	9	3	62	15	19

FlamMap Settings

Flame length and crown fire activity were modeled for each weather scenario with FlamMap 5 (Finney et al. 2015). Fuel moisture was set to the percentile values in Table B5 for all fuel types. No fuel moisture conditioning was performed. Given the diversity of wind directions experienced across the County, especially in areas of high relief, we modeled fire behavior for a consistent worst-case scenario of wind blowing uphill at the 1-min average wind speed. Crown fire activity was modeled using the Scott and Reinhardt (2001) method.

Results

Burn probability is mapped in Figure B1. Flame length is mapped for the low, moderate, high, and extreme scenarios in Figure B2, Figure B3, Figure B4, and Figure B5, respectively. Crown fire activity is mapped for the low, moderate, high, and extreme scenarios in Figure B6, Figure B7, Figure B8, and Figure B9, respectively. These figures are also provided in a large PDF for side-by-side comparison. Burn probability is also summarized by vegetation type in Figure B10 and by elevation zone in Figure B11. Flame length and crown fire activity are also summarized by vegetation type in Figure B12 and by elevation in Figure B13.

Figure B1. Burn probability from Short et al. (2020) reprojected and resampled to 30-m to align with the other hazard layers using bilinear interpolation.

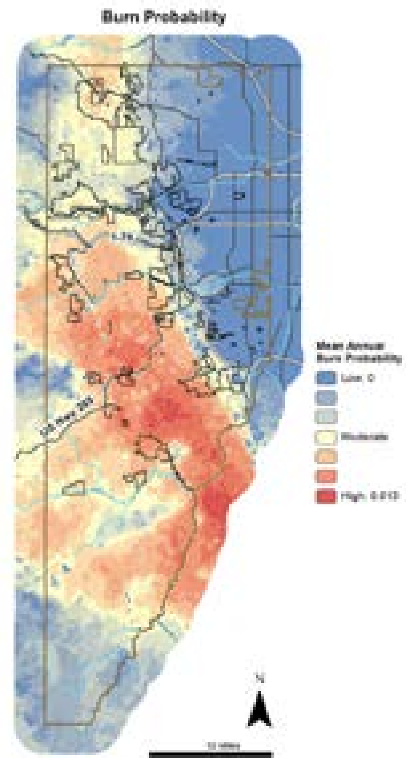


Figure B2. Flame length (ft) modeled with FlamMap 5 for the low weather scenario.

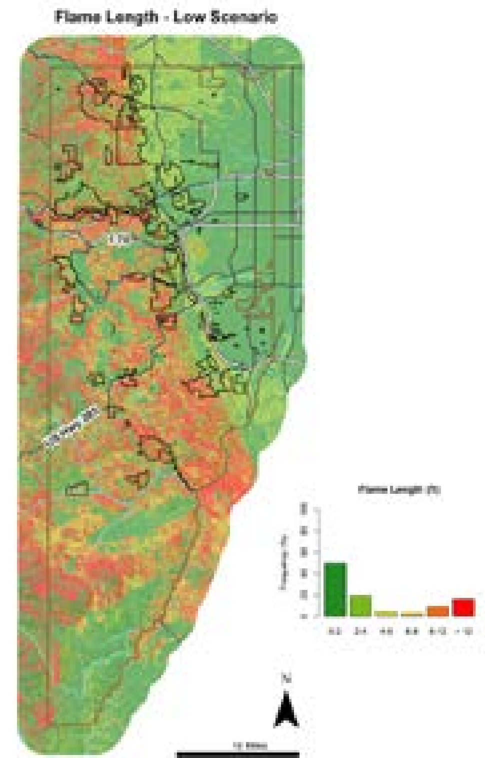


Figure B3. Flame length (ft) modeled with FlamMap 5 for the moderate weather scenario.

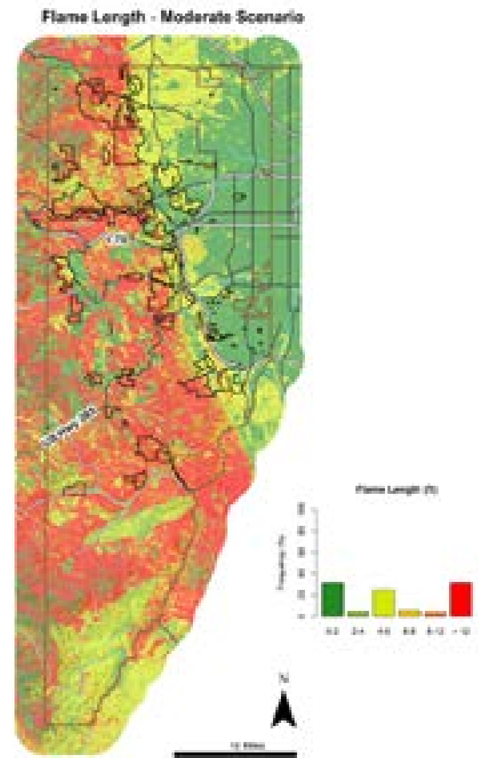


Figure B4. Flame length (ft) modeled with FlamMap 5 for the high weather scenario.

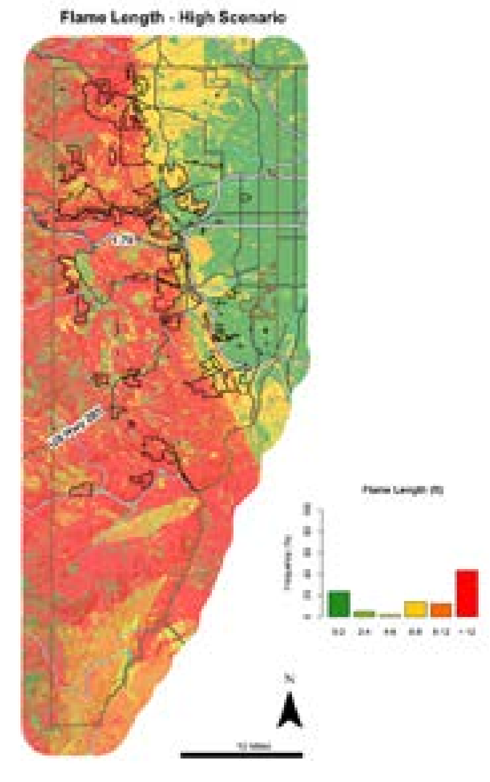


Figure B5. Flame length (ft) modeled with FlamMap 5 for the extreme weather scenario.

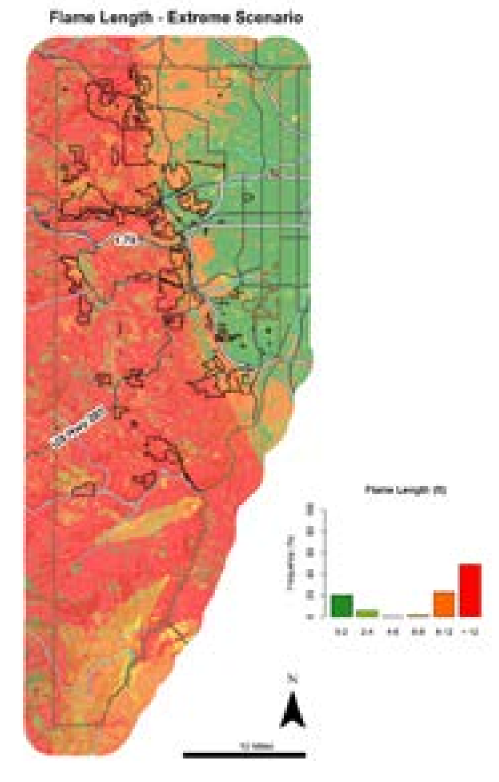


Figure B6. Crown fire activity modeled with FlamMap 5 for the low weather scenario.

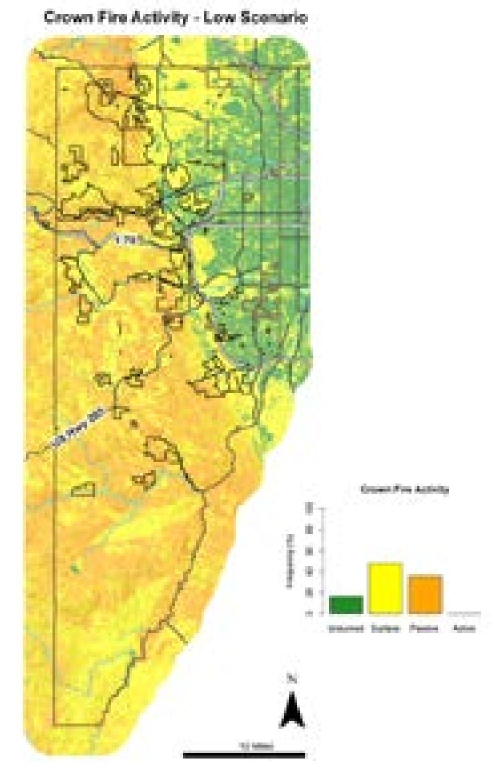


Figure B7. Crown fire activity modeled with FlamMap 5 for the moderate weather scenario.

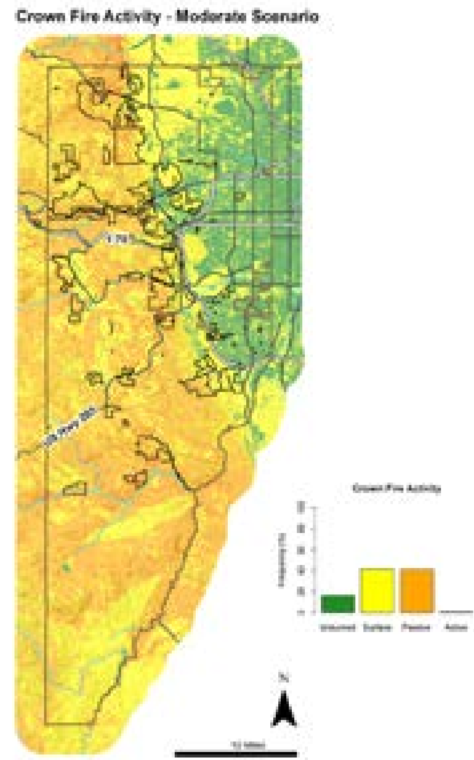


Figure B8. Crown fire activity modeled with FlamMap 5 for the high weather scenario.

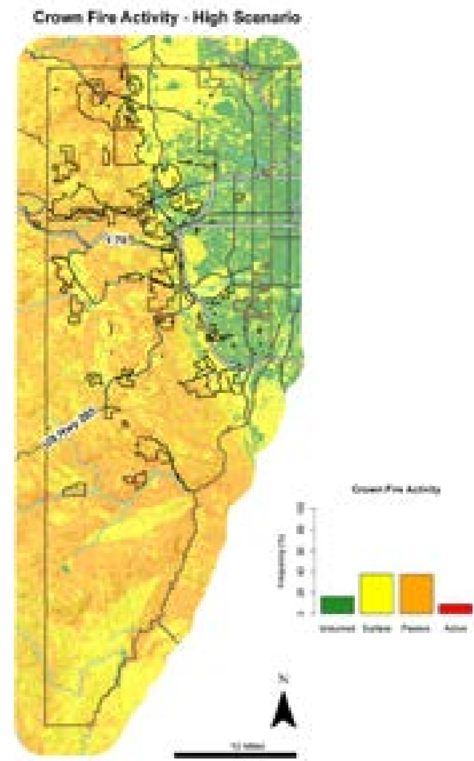


Figure B9. Crown fire activity modeled with FlamMap 5 for the extreme weather scenario.

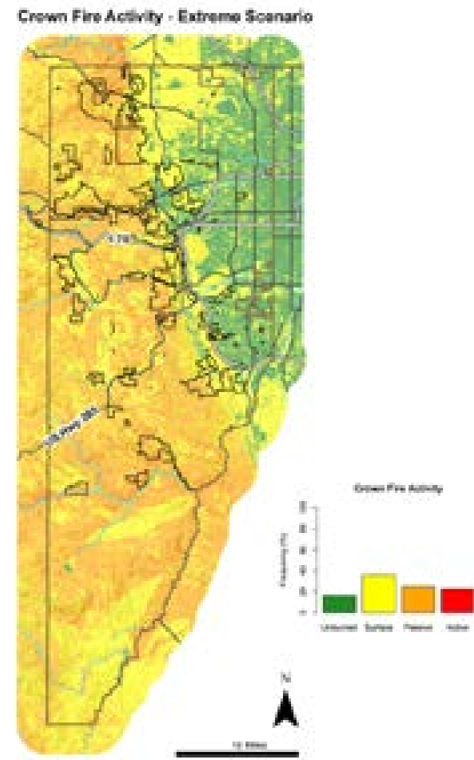


Figure B10. Annual expected area burned based on Short et al. (2020) by existing vegetation type from LANDFIRE (2019).

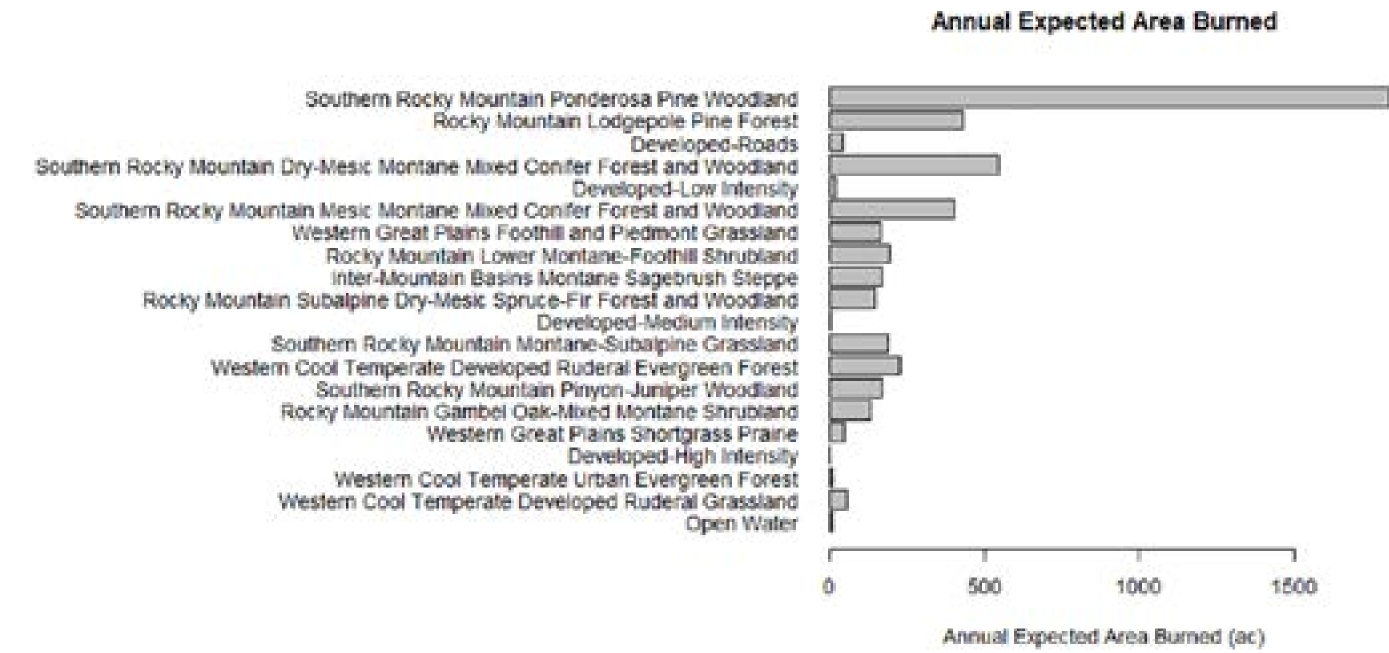


Figure B11. Annual expected area burned based on Short et al. (2020) by elevation from LANDFIRE (2019).

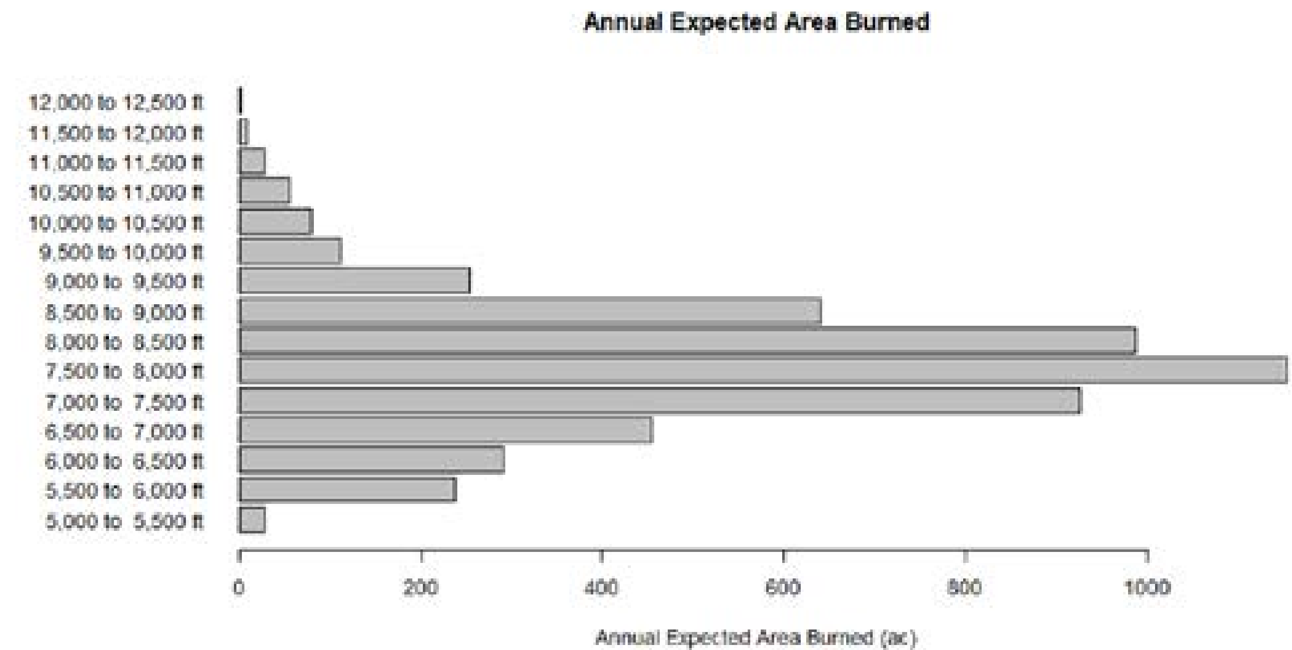


Figure B12. Mean flame length and crown fire activity modeled with FlamMap by existing vegetation type from LANDFIRE (2019).

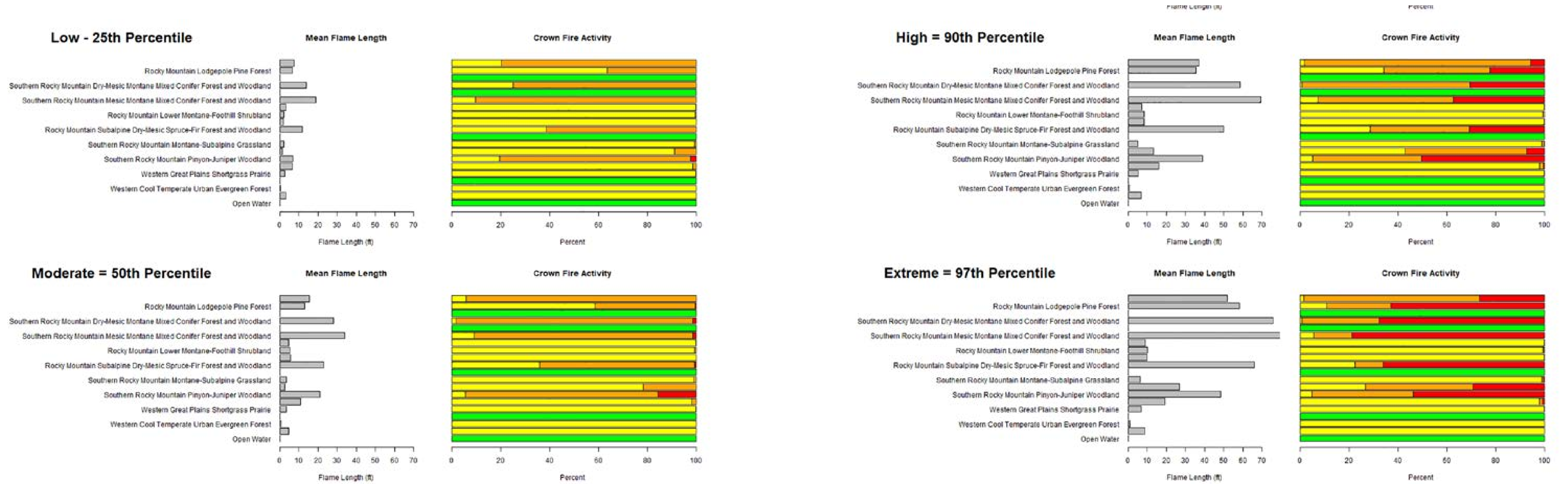
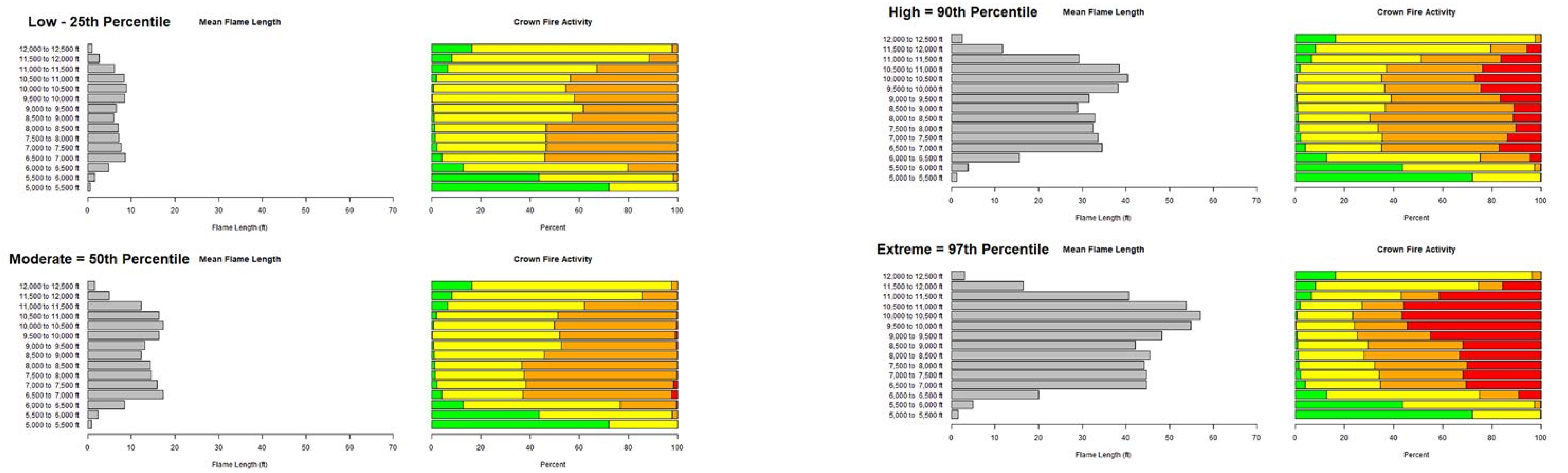


Figure B13. Mean flame length and crown fire activity modeled with FlamMap by elevation from LANDFIRE (2019).



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APPENDIX C. Wildland-Urban Interface cNVC

Potential structure loss in the Wildland Urban Interface (WUI) was estimated with a landscape-scale model of home loss probability from Price and Bradstock (2013). Price and Bradstock developed a multiple logistic regression model of home loss probability from structures exposed to the Black Saturday Fires in Australia and found that landscape characteristics, in contrast to fine-grained information on the home ignition zone (Cohen 2000), explained around 23% of the variation in structure loss. Their model predicts that structure loss increases with increasing proportion of crown fire activity and forest area within a 1 km radius buffer around the structure, the density of structures within a 50 m buffer radius around the focal structure, and local slope. These findings are consistent with structure loss studies in the US that suggest wildland urban interface disasters occur when extreme fire behavior close to communities overwhelms firefighting resources (Calkin et al. 2014) and that structure loss can be high in both areas with low housing density, which tend to have high proportions of natural vegetation nearby (Syphard et al. 2019), and areas of high structure density, which tend to promote structure loss once fire transitions into hard to extinguish urban fuels (Maranghides et al. 2015). The low explanatory power of this model (r-squared = 0.23) suggests it is not appropriate for determining the fate of individual structures, but it provides a good sense of what structures and neighborhoods are most threatened by wildfire and which forested areas should be treated to protect them.

Individual structure location data from Microsoft (2018) were used to represent building locations within a 1 km buffer around Jefferson County. This dataset includes 223,259 buildings. Due to the size of the dataset, it was not possible to quality control all of it, so we focused our validation and editing on the 188 structures that intersected JCOS-managed lands. False positives and any structures that were separately accounted for in other JCOS infrastructure layers (e.g., picnic shelters, outhouses, or maintenance buildings) were removed from the WUI analysis.

The probability of structure loss conditional on wildfire exposure was calculated per Price and Bradstock (2013) as described in equations 1 and 2 with variable definitions in Table C1.

$$x = -2.352+0.068(HD)+3.697(CF)+1.935(FA)+0.063(S)+1.317(HD\times CF)$$ **Equation 1**

$$P = e^x/(1+e^x)$$ **Equation 2**

Table C1. Variable definitions, sources, and processing methods for the home loss model.

Variable	Definition	Source and processing
HD	Housing density (frequency of homes) within a 50 m radius around the target structure	Calculated with a focal neighborhood analysis of building footprints from Microsoft (2018)
CF	Proportion of area within a 1 km radius around the target structure burning as crown fire	Active crown fire from FlamMap modeling in this study
FA	Proportion forested within a 1 km radius around the target structure	Forest classified as ≥ 10% canopy cover from LANDFIRE (2019)
S	Local slope in degrees	Slope from LANDFIRE (2019)

Conditional structure loss was calculated for individual structures and then rasterized into two products. The first product (Figure C1b and Figure C2b) maps WUI cNVC to the structure locations in terms of structures lost per acre conditional on fire occurrence within the 1 km radius around each structure. Given the speckled distribution of pixels that contain structures, this measure was smoothed using a 90-m low pass filter for ease of visual display. This generalization also accounts for some uncertainty in the building location information. This product is useful for communicating with audiences concerned with identifying structures and neighborhoods with high potential for loss.

The second product (Figure C1c and Figure C2c) maps the crown fire component of WUI cNVC back to the crown fire source pixels in terms of structures lost per acre. Specifically, conditional home loss probability was calculated for each structure accounting for the crown fire component and then assuming zero crown fire. The change in probability from crown fire was then distributed evenly to each of the crown fire source pixels. It should be recognized that evenly distributing the change in cNVC to the source components means that subsequent estimates of treatment benefits are approximate when estimated independently for each pixel. This product was used to represent WUI cNVC in RADS because it can be used to calculate the change in WUI cNVC from modifying crown fire activity in the forested source pixels.

To make the second product on the proper scale to use in tRADS, we performed a simple percentile clip and rescale. The 97.5th percentile source WUI cNVC was calculated for the baseline condition. Each layer was then rescaled by first limiting the maximum value to the baseline 97.5th percentile and then performing a linear stretch to make the 97.5th percentile equal 100. Finally, cNVC was multiplied by negative one to reflect loss. The WUI cNVC layer suggests the source of WUI losses should be highest in forests prone to crown fire nearest to structures. cNVC decreases as proximity from structures increases and proportion of active crown fire decreases (Figure C2c).

To create the WUI cNVC layer for the analysis, zero cNVC areas set to null to reduce the layers extent to only those areas with expected conditional exposure from wildfire (Figure C3).

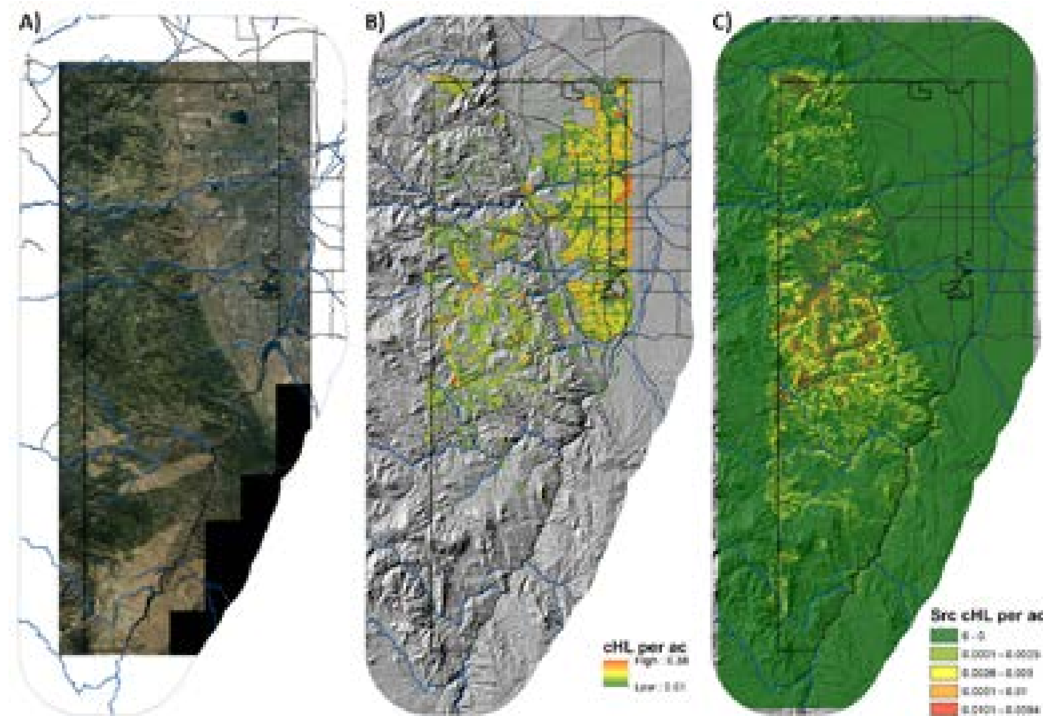


Figure C1. Imagery and reference layers (A), conditional home loss per acre mapped to the structure loss locations (B), and crown fire portion of conditional home loss per acre mapped to the crown fire source pixels (C).

Figure C2. Imagery and Alderfer Three Sisters Park boundary (A), conditional home loss per acre mapped to the structure loss locations (B), and crown fire portion of conditional home loss per acre mapped to the crown fire source pixels (C).

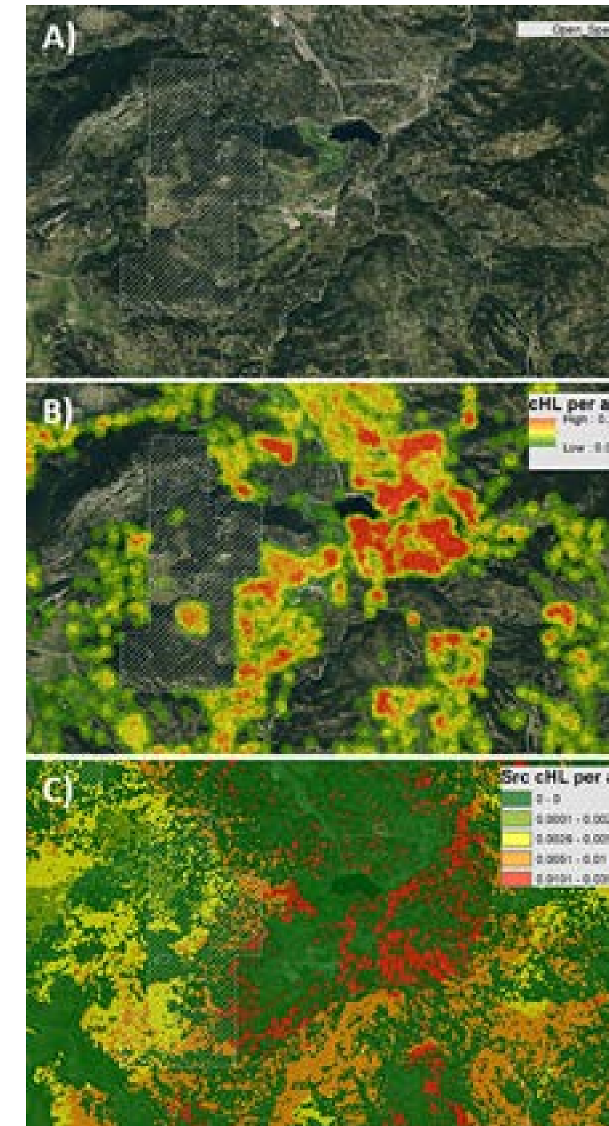
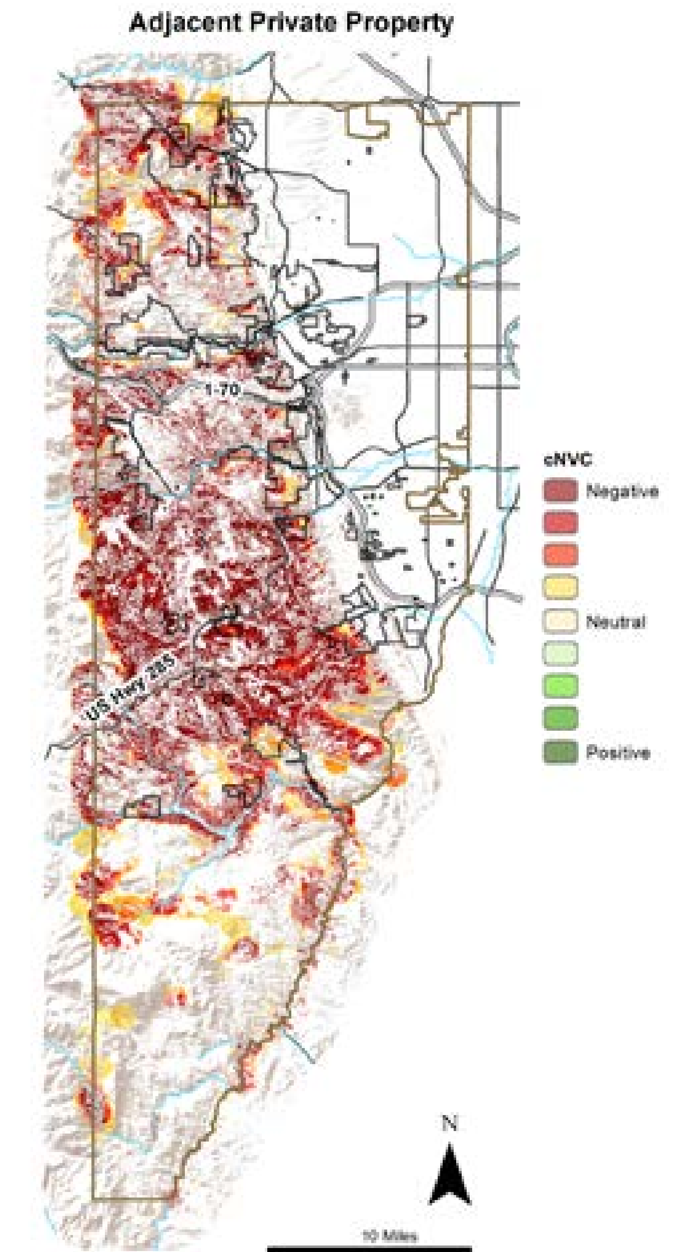


Figure C3. Wildland-Urban Interface Adjacent Private Property cNVC.



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APPENDIX D. Conditional Net Value Change to Water Supplies

Process Summary

We modeled conditional Net Value Change (cNVC) to water supplies using the model depicted in Figure D1. It uses crown fire activity (Scott and Reinhardt 2001) predicted with FlamMap 5 (Finney et al. 2015) as a proxy for soil burn severity by mapping surface, passive crown, and active crown fire to low, moderate, and high burn severity, respectively. The burn severity proxy was then used to modify the cover and soil erodibility factors in the Revised Universal Soil Loss Equation (RUSLE; Renard et al. 1997) based on local observations of fire effects by severity level (Larsen and MacDonald 2007). This provides an estimate of first-year post-fire gross erosion (Mg ha^{-1}). We used the median historical annual rainfall erosivity from eleven NOAA rainfall stations representative of the Front Range climate (615 MJ mm ha^{-1} hr^{-1}) for the erosion predictions. More extreme rainfall would cause higher erosion. In this context, we are interested in how the current characteristics of the landscape influence risk, not the uncertainty in risk magnitude, so erosion predicted for a single rainfall value is sufficient. To predict net sediment delivery to streams (Mg ha^{-1}), we estimated the proportion of sediment generated in each pixel that is delivered to the nearest stream using an empirical model of post-fire sediment delivery ratio developed from wildfires in the western U.S. (Wagenbrenner and Robichaud 2014) with a rough calibration to match local conditions. The fire and watershed modeling details are expanded on in the following sections.

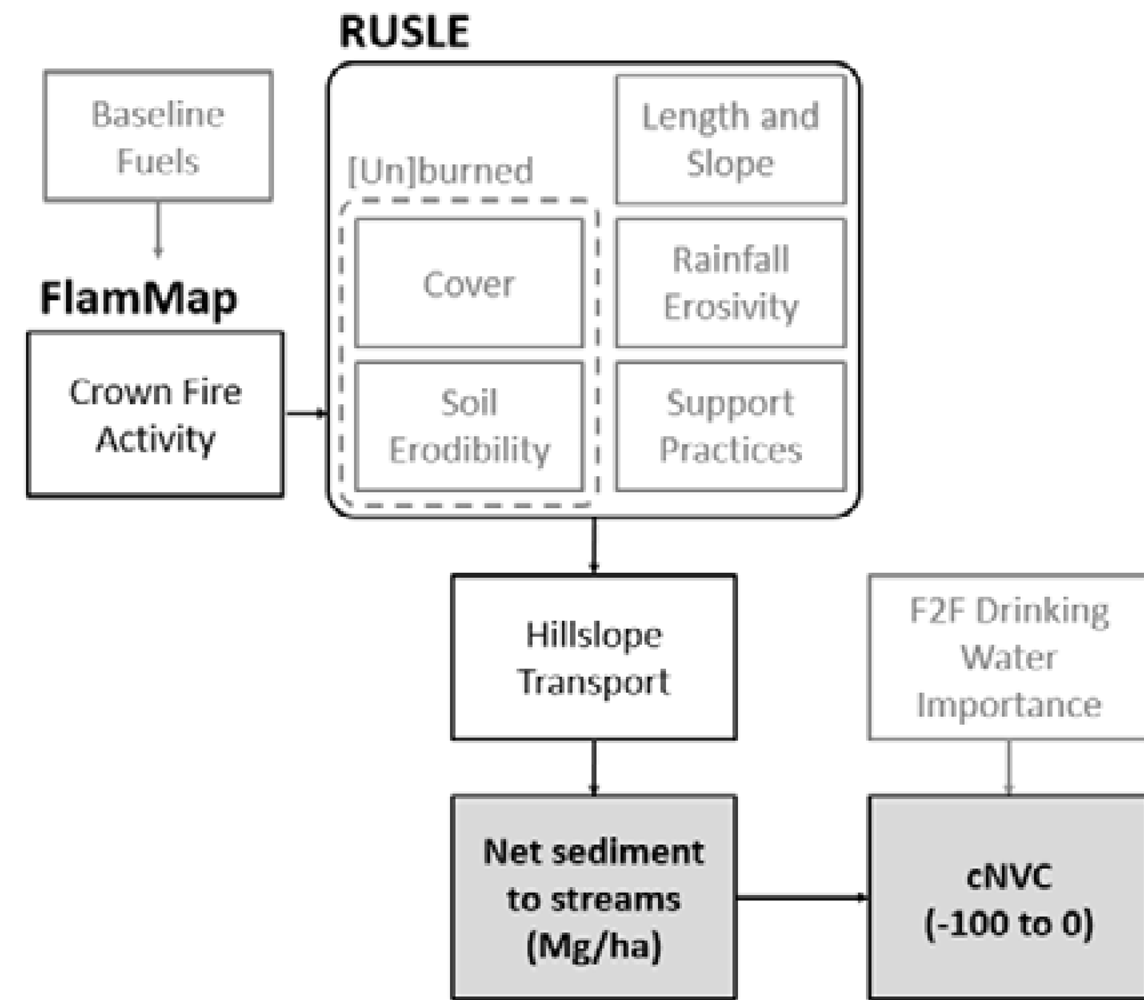
To convert sediment yield predictions into cNVC, we first rescaled the net sediment delivery to streams (NSTS) predictions, then multiplied them by the Forest to Faucets Drinking Water Importance (DWI) to approximate water supply exposure and importance, and finally multiplied by negative one to communicate the direction of change is loss. The first-year post-fire NSTS predictions range from 0 to 100 Mg ha^{-1} but the majority of predictions are < 50 Mg ha^{-1} for forest and < 10 Mg ha^{-1} for non-forest. We decided to consider 50 Mg ha^{-1} of erosion, which is close to the highly impactful first-year post-fire sediment yield from the Buffalo Creek Fire (Moody and Martin 2001), as total loss (-100 cNVC).

$$lNSTS = \begin{cases} NSTS, & NSTS \leq 50 \\ 50, & NSTS > 50 \end{cases}$$ **Equation 1**

$$rNSTS = lNSTS \times \left(\frac{100}{50}\right)$$ **Equation 2**

$$cNVC = (-1) \times rNSTS \times \left(\frac{DWI}{100}\right)$$ **Equation 3**

Figure D1. Effects modeling used to generate estimates of water supply cNVC.



Methods

Fire Behavior

The FlamMap 5.0 spatial fire modeling system (Finney et al. 2015) was used to predict crown fire activity (CFA; Scott and Reinhardt 2001) as a proxy for soil burn severity. CFA is a prediction of fire type in categories of unburned, surface fire, passive crown fire, and active crown fire. Surface fires spread primarily through live and dead fuels on the forest floor including litter, duff, wood, grass, and shrubs. Passive crown fire spreads primarily through surface fuels, but it has sufficient intensity to initiate crown fire in patches of trees (also called "torching"). Active crown fire includes a substantial component of fire spread through the forest canopy (also called "crowning"). Surface fire intensity increases along the spectrum of surface to active crown fire behavior, so CFA is commonly used as a proxy for burn severity in watershed risk assessments by mapping surface, passive crown, and active crown fire to low, moderate, and high burn severity, respectively (Tillery et al. 2014; Haas et al. 2017; Jones et al. 2017; Gannon et al. 2019).

For this analysis, we used CFA modeled by fuel treatment and weather scenario from the JCOS wildfire risk analysis. See the fire modeling section of the report for details on the baseline fuels data, fuel treatment scenario, and weather scenario specifications. Subsequent erosion and sediment transport predictions were made for each fuel treatment and fire weather scenario. A weighted average was then calculated for each fuel treatment scenario using weights of 0.01, 0.09, 0.2, and 0.7 for the low, moderate, high, and extreme scenarios, respectively.

It is important to acknowledge that fire behavior prediction systems, including FlamMap, were not designed to predict fire severity. There remains a need for basic research on the fire behavior metrics, observed or modeled, that best predict burn severity (Moody et al. 2013; Shakesby et al. 2016). CFA is a reasonable, but likely imperfect proxy for burn severity because of the variety of surface and canopy fuel configurations that support crown fire behavior. Imperfect data and model accuracy also create uncertainty in fire behavior predictions. Fuel moisture and fire weather conditions are dynamic in space and time, so modeled fire scenarios and their resulting composites will not match all future fire conditions. The pre-modeled burn severity should be viewed as representing the general tendency in burn severity based on fuels and topography.

Hillslope Erosion

The Revised Universal Soil Loss Equation (RUSLE) predicts annual soil loss (A) in Mg ha^{-1} yr^{-1} as the product of five sub-factors (Eqn 4): rainfall erosivity (R), soil erodibility (K), length and slope (LS), cover (C), and support practices (P) (Renard et al. 1997).

$$A = R \times K \times LS \times C \times P \quad \textbf{Equation 4}$$

Spatial data and analyses were used to approximate the R, K, LS, and C factors for unburned conditions, as described in Theobald et al. (2010), Litschert et al. (2014), and Gannon et al. (2019), at 30-m resolution. Support practices (P), which typically refer to erosion mitigation actions, were not quantified in the assessment to model the unmitigated erosion hazard.

Rainfall Erosivity

Rainfall erosivity (R), also called "rainfall-runoff erosivity", is an annual metric of rainfall calculated as the product of total storm energy and maximum 30-minute intensity (MJ mm ha-1 hr-1). It is a better predictor of erosion magnitude than either rainfall depth or intensity alone, because it accounts for the available energy to detach soil particles and the occurrence of infiltration-excess overland flow to transport mobilized sediment (Renard et al. 1997). Rainfall erosivity was characterized using National Oceanic and Atmospheric Administration (NOAA) 15-minute rainfall data (Perica et al. 2013) from eleven rainfall stations

representative of the Front Range climate that were assembled for a separate study (Wilson et al. 2018) and processed with the Rainfall Intensity Summarization Tool (RIST; Dabney 2016) to calculate storm-level rainfall erosivity. Storm-level rainfall erosivity was summed by year to calculate annual rainfall erosivity for each station and year. This data set spans the years 1971 to 2010 and includes 403 station-years of annual rainfall erosivity observations. The 2-yr recurrence interval rainfall erosivity of 615 MJ mm ha-1 hr-1 (Table D1) was used for the erosion predictions in this assessment. It should be recognized that higher rainfall will produce more sediment.

Table D1. Annual rainfall erosivity metrics for the historical records from eleven rainfall monitoring stations representative of the Front Range climate.

Annual non-exceedance probability	Recurrence Interval (years)	Rainfall erosivity (MJ mm ha^{-1} hr^{-1})
0.50	2	615
0.90	10	1,431
0.99	100	6,399

Soil Erodibility

Undisturbed soil erodibility (K) was described using the Soil Survey Geographic Database (SSURGO) gap-filled where necessary with the State Soil Geographic Database (STATSGO) (NRCS Soil Survey Staff 2020). The procedures of Yochum and Norman (2014) were used to calculate a weighted mean of whole soil K factor (Kwfact) for each map unit. First, the component depth-weighted mean K was calculated for the top 15 cm of soil. Then, the map unit area-weighted mean K was calculated based on the proportional coverage of components. Components mapped as rock do not have K values assigned to them, but complete bedrock coverage is rare within these map units based on inspection of aerial imagery. Instead of treating rock components as zero K, they were assigned 20% of the area-weighted mean K of the other components in the same map unit. SSURGO map units that were missing K values for more than 50% of their area were gap-filled with equivalent metrics from STATSGO. All K values were converted to metric units (Renard et al. 1997). It should be noted that extensive areas of the Pike-San Isabel National Forest in the South Platte Watershed do not have detailed surveys and therefore rely on STATSGO.

Length and Slope

The combined length and slope (LS) factors were calculated using terrain analysis of a 30-m DEM (USEPA and USGS 2012) following methods in Theobald et al. (2010). The slope portion (S) was calculated per Nearing (1997) where θ is slope steepness in radians (Eqn 5). Consistent with previous studies (Theobald et al. 2010; Litschert et al. 2014), θ was limited to 55% when calculating S to not extrapolate beyond the range of Nearing's data.

$$S = -1.5 + \frac{17}{1 + e^{(2.3 - 6.1 \times \sin\theta)}}$$ **Equation 5**

LS was then calculated per Winchell et al. (2008) where *A* is the contributing area to the cell inlet in m^2, *D* is the cell dimension in m, *m* is slope-length exponent, and *x* is the shape factor calculated as a function of cell aspect (α) in radians (Eqns 6-9). The slope-length exponent (*m*) is based on the ratio of rill to interrill erosion (β), which was estimated from slope steepness (θ) based on McCool et al. (1989).

$$LS = S \times \frac{(A + D^2)^{m+1} - A^{m+1}}{D^{m+2} \times x^m \times 22.13^m}$$ **Equation 6**

$$m = \frac{\beta}{1 + \beta}$$ **Equation 7**

$$\beta = \frac{\frac{\sin\theta}{0.0896}}{3 \times \sin\theta^{0.8} + 0.56}$$ **Equation 8**

$$x = |\sin\alpha| + |\cos\alpha|$$ **Equation 9**

Slope steepness (θ), slope aspect (α), and contributing area (*A*) were calculated from a 30-m resolution filled DEM using standard slope, aspect, and D8 flow direction methods in ArcGIS 10.3. When calculating LS, *A* was limited to 3,000 m^2 to approximate the maximum hillslope length of 300 m suggested in Renard et al. (1997). LS values were also constrained to the maximum of 72.15 from Renard et al. (1997).

Cover

Undisturbed cover factors (C) were assigned by mapping an appropriate C reported in previous studies (Table D2) to Existing Vegetation Type (EVT) categories from LANDFIRE (2019). The lowest values of C are assigned to forests (low erosion), moderate values are assigned to sparse grass and shrub cover types, and the highest values are assigned to cover types associated with agriculture or mining. We assigned barren areas with high rock cover, such as alpine bedrock and scree, a C of 0.002 because these environments should be minimally impacted by fire. These baseline estimates of C are of relatively minor importance in the analysis, because they are generally small compared to post-wildfire C (Larsen and MacDonald 2007) and the model calculates the post-fire increase in erosion (difference between burned and unburned).

Table D2. Cover factor (C) values (unitless) from previous studies are assigned to LANDFIRE Existing Vegetation Type (EVT) (2019). The top 31 vegetation types, which account for >95% of the area, are shown here.

Existing vegetation type	C factor	Reference
Southern Rocky Mountain Ponderosa Pine Woodland	0.0027	Miller et al. 2003
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	0.002	Breiby 2006
Rocky Mountain Lodgepole Pine Forest	0.002	Breiby 2006
Developed-Roads	0.0001	Toy and Foster 1998
Developed-Low Intensity	0.002	Fu et al. 2006
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	0.002	Breiby 2006
Western Great Plains Foothill and Piedmont Grassland	0.012	Breiby 2006
Rocky Mountain Lower Montane-Foothill Shrubland	0.025	Breiby 2006
Inter-Mountain Basins Montane Sagebrush Steppe	0.029	McCuen 1998
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	0.002	Breiby 2006
Southern Rocky Mountain Montane-Subalpine Grassland	0.012	Breiby 2006
Developed-Medium Intensity	0.003	Fu et al. 2006
Western Cool Temperate Developed Ruderal Evergreen Forest	0.004	Fu et al. 2006
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	0.025	Breiby 2006
Southern Rocky Mountain Pinyon-Juniper Woodland	0.0928	Miller et al. 2003
Western Great Plains Shortgrass Prairie	0.08	Yang et al. 2003
Developed-High Intensity	0.001	Fu et al. 2006
Rocky Mountain Aspen Forest and Woodland	0.001	Breiby 2006
Western Cool Temperate Developed Ruderal Grassland	0.012	Breiby 2006
Western Cool Temperate Urban Evergreen Forest	0.004	Fu et al. 2006
Open Water	0	Breiby 2006; McCuen 1998
Western Cool Temperate Urban Herbaceous	0.008	McCuen 1998
Western Cool Temperate Urban Deciduous Forest	0.0015	Breiby 2006
Interior Western North American Temperate Ruderal Grassland	0.012	Breiby 2006
Western Cool Temperate Pasture and Hayland	0.14	McCuen 1998
Inter-Mountain Basins Semi-Desert Shrub-Steppe	0.08	Yang et al. 2003
Western Cool Temperate Urban Shrubland	0.029	McCuen 1998
Rocky Mountain Lower Montane-Foothill Riparian Woodland	0.01	Breiby 2006
Western Cool Temperate Developed Ruderal Shrubland	0.029	McCuen 1998
Northern & Central Plains Ruderal & Planted Grassland	0.012	Breiby 2006
Southern Rocky Mountain Ponderosa Pine Savanna	0.0027	Miller et al. 2003

Fire Effects on Erosion

Fire-related increases in erosion are primarily attributed to changes in surface cover (Larsen et al. 2009) and altered soil properties (Shakesby and Doerr 2006); therefore, fire effects on erosion were modeled by modifying the RUSLE C and K factors. For forests (≥ 10% canopy cover as mapped by LANDFIRE [2019]), post-fire C was changed to the mean first-year post-fire C factors by burn severity reported in Larsen and MacDonald (2007) (Table D3). Due to the diversity of non-forested vegetation types (< 10% canopy cover) and the limited estimates of post-fire cover in these systems (Pierson and Williams 2016), proportional adjustment factors were used to model fire effects on C (Table D3). Fire decreases soil infiltration capacity and cohesion owing to deposition of hydrophobic compounds, soil sealing, and consumption of organic material (DeBano et al. 2005; Shakesby and Doerr 2006). Direct measures of post-fire K factors are lacking, but Larsen and MacDonald (2007) back-calculated that K was increased by a factor of 2.5 for high burn severity. Given the limitations with their method of estimating change in K, more conservative adjustment factors were used to estimate fire effects on K (Table D3) like Schmeer (2014).

Table D3. Mean post-fire C factor values by burn severity from Larsen and MacDonald (2007) are used to assign post-fire C for forests (≥ 10% LANDFIRE canopy cover). Fire effects on C factor for non-forest (< 10% LANDFIRE canopy cover) are applied as proportional adjustment factors. Fire effects on K factor for all vegetation are applied as proportional adjustment factors.

		Fire Effects		
Crown Fire Activity	**Burn Severity**	**Forest C**	**Non-forest C Adjustment Factor**	**K Adjustment Factor**
Surface	Low	0.01	1.2	1.5
Passive	Moderate	0.05	1.5	1.75
Active	High	0.20	2.0	2.0

The assessment focused on the increase in post-fire erosion by differencing the predicted post-fire and pre-fire erosion predictions. RUSLE can predict very high erosion rates on the steepest slopes; although erosion potential may be this high, sediment availability will likely limit these high rates from being realized. Post-fire erosion increases were therefore limited to 100 Mg ha^{-1} yr^{-1} based on the maximum observed rates in the western US (Moody and Martin 2009).

The RUSLE model was originally developed for agricultural use (Renard et al. 1997) and the GIS implementation we use approximates the original model. The most significant departure from the original is the raster-based calculation of the LS factor, which has been validated for use in agricultural settings (Winchell et al. 2008), but not for use in mountainous terrain. The implementation used here controls for excessive erosion predictions on very steep, long slopes by limiting the S subfactor, flow accumulation values, combined LS factors, and resulting erosion predictions to the maximum values reported in previous studies. When pixel-level estimates of erosion are averaged to the catchment-level, most of the predicted sediment yields from hillslope erosion are within the range reported by previous studies. The baseline C factor values also have moderate uncertainty due to the use of best judgement to assign values from previous studies to remotely sensed landcover types. This uncertainty is greatest for the non-forest vegetation types because of the way fire effects are modeled with adjustment factors. The soils data are also fairly course and soil properties are sometimes inconsistent across areas that were surveyed at different times by different personnel. Spatial and temporal variability in annual rainfall erosivity spans several orders of magnitude, suggesting the actual post-fire erosion depends

strongly on the subsequent rainfall, which cannot be predicted in advance. Erosion was modeled for median rainfall erosivity in the model so impacts could be higher than predicted if fires are followed by more extreme rainfall.

Hillslope Sediment Transport

The proportion of hillslope sediment delivered to the stream channel network was estimated with an empirical model of post-fire hillslope sediment delivery ratio (*hSDR*) from the western US (Wagenbrenner and Robichaud 2014). *SDR* quantifies the proportion of gross erosion that is delivered to the outlet of a catchment. When hillslope erosion is the primary source of sediment, unit area sediment yields decline with increasing watershed size (*hSDR* < 1) because some sediment is stored on hillslopes and in channels (Walling 1983). First, the NHDPlus stream channel network was extended to include all pixels with greater than 10.8 ha contributing area (Henkle et al. 2011) because the flowline network does not include all channels and it especially underestimates the extent of the channel network after wildfire (Wohl 2013). The annual length ratio model from Wagenbrenner and Robichaud (2014) was then used to estimate post-fire *hSDR* (Eqns 10 and 11). Terrain analysis of a 30-m DEM (USEPA and USGS 2012) was used to calculate the flow path length from each pixel to the nearest stream channel as the "catchment length" and the flow path length across the pixel as the "plot length". We doubled the predicted *hSDR* values to better match the small catchment sediment yields at the Hayman Fire (e.g., Wagenbrenner and Robichaud 2014), which partially overlaps the planning area. Channels pixels are assigned *hSDR* of 1.

$$LR = \frac{\text{Flow path length to nearest channel}}{\text{Flow path length across pixel}}$$ **Equation 10**

$$\log(hSDR) = -0.56 - 0.0094 * LR$$ **Equation 11**

Catchment-level sediment delivery to the draining flowline () was calculated in Mg as the sumproduct of the pixel-level erosion (*A*) and *hSDR* values, indexed with *i*, and a correction factor to adjust for pixel size (Eqn 12).

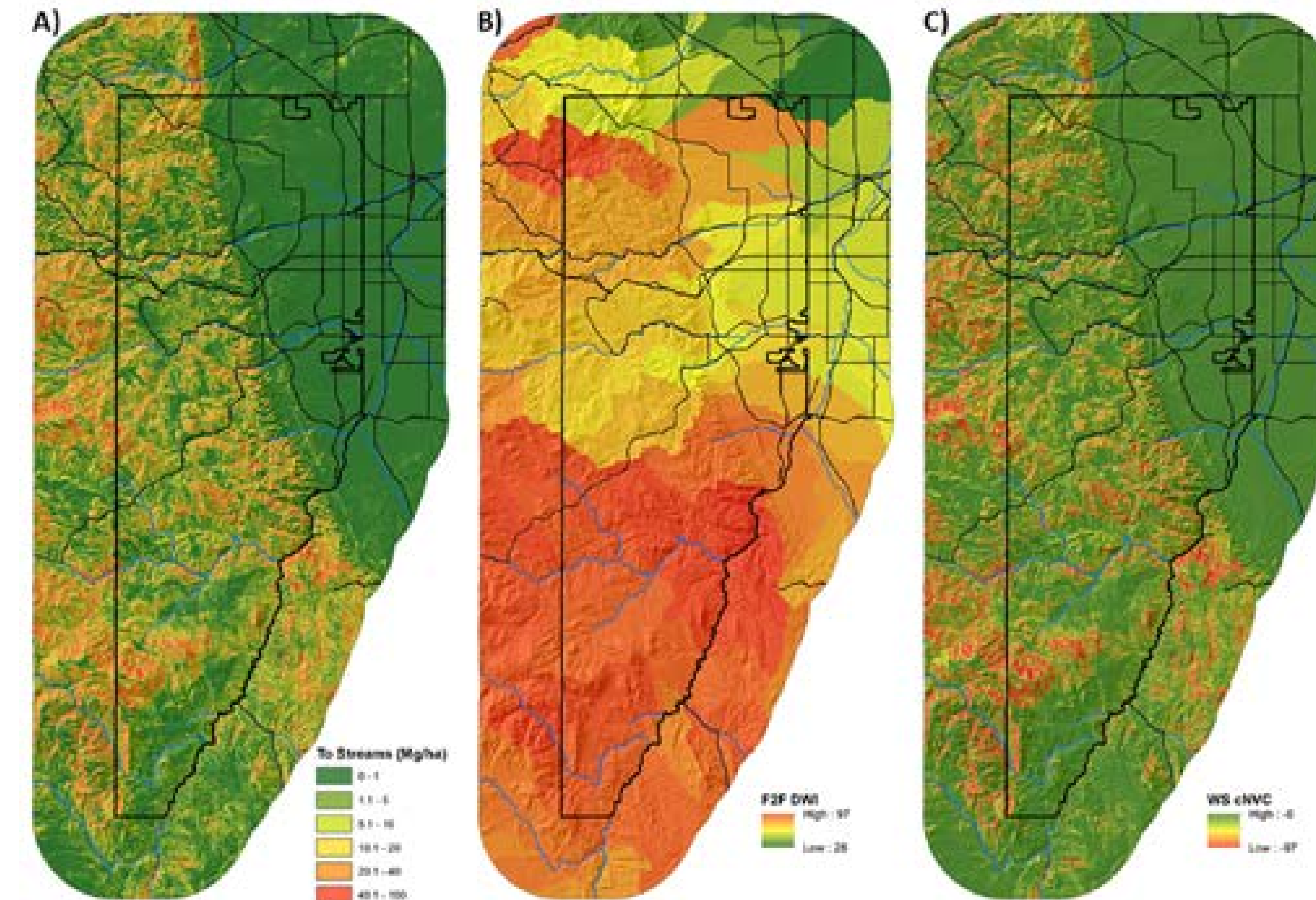
$$TS = \sum_{i=1}^{N} A_i \times 0.09 \frac{ha}{pixel} \times hSDR_i$$ **Equation 12**

hSDR is an approximation of highly dynamic sediment transport processes. The source of the model used here documents that substantial variability in *SDR* remains unexplained by their model (Wagenbrenner and Robichaud 2014). The *hSDR* model was also developed from catchments burned mostly at moderate or high severity, so it could overestimate sediment yield from areas burned at low severity and burned areas separated from the stream by an unburned buffer. Although more sophisticated models are available for predicting sediment transport, they depend strongly on hydrologic conditions, which cannot be predicted in advance.

RESULTS

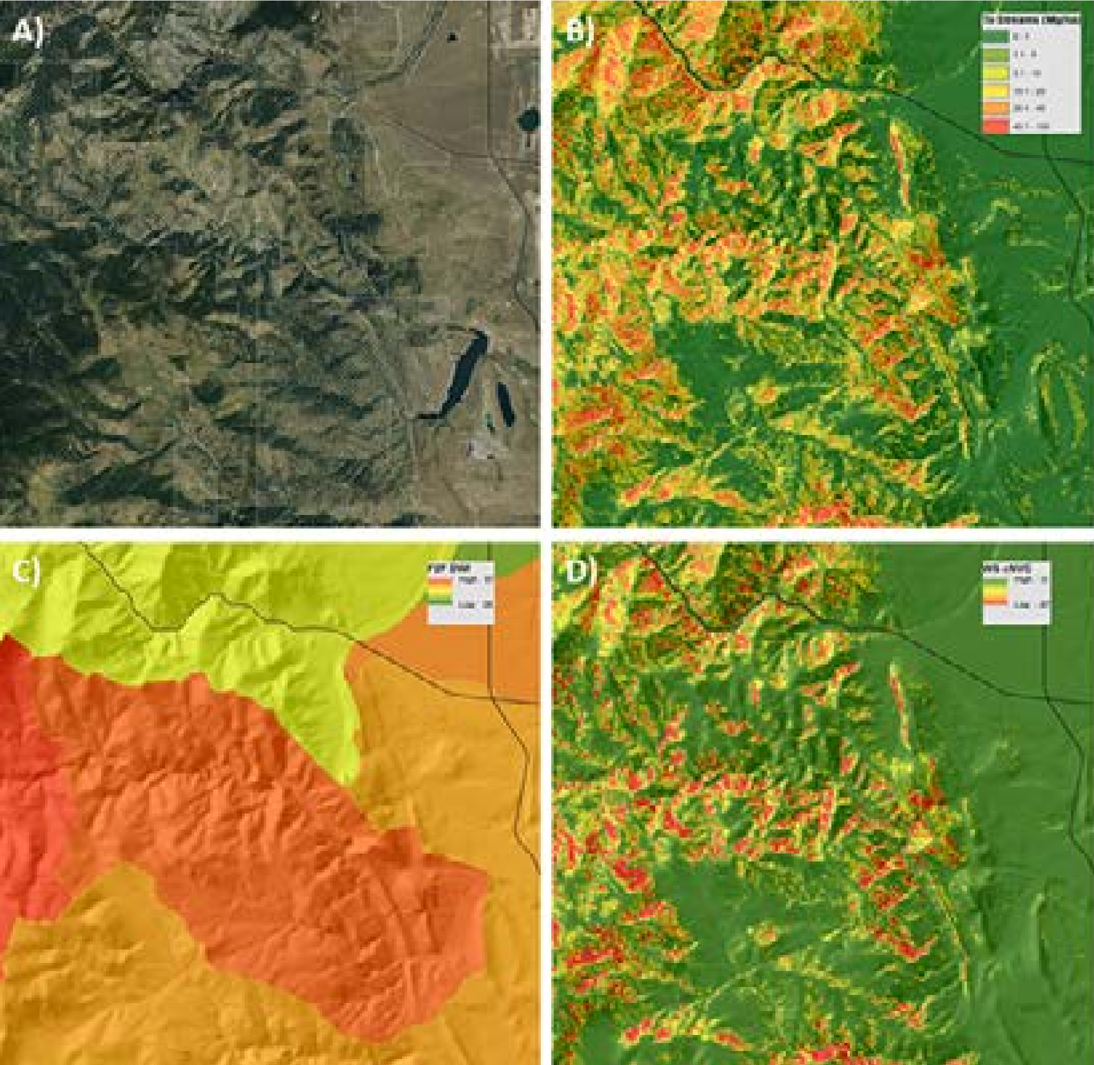
The highest rates of potential sediment delivery to streams are predicted in parts of the County with forests prone to burning at high severity on steep slopes (Figure D2A). Areas that have already experienced wildfire in recent decades tend to have lower sediment yield because of their lower fuel loads, e.g., the Buffalo Creek, Hi Meadow, Hayman, and Indian Gulch Fires. Most of the mountainous portion of the County has high drinking water importance, but some variation is present, relating to the differences in population served by the sub-watersheds (Figure D2B). The South Platte and Ralston Creek Watersheds stand out as exceptionally important. Combining these sources of information, and rescaling their product, produces the cNVC map in Figure D2C. The cNVC map for baseline fuel conditions highlights that there is considerable variability in potential impacts to water supplies that could help target forest management activities across JCOS properties.

Figure D2. County-wide maps of: A) potential post-fire sediment to streams after burning, B) Forests to Faucets (F2F) Drinking Water Importance Index (DWI), and C) water supply (WS) conditional Net Value Change (cNVC).



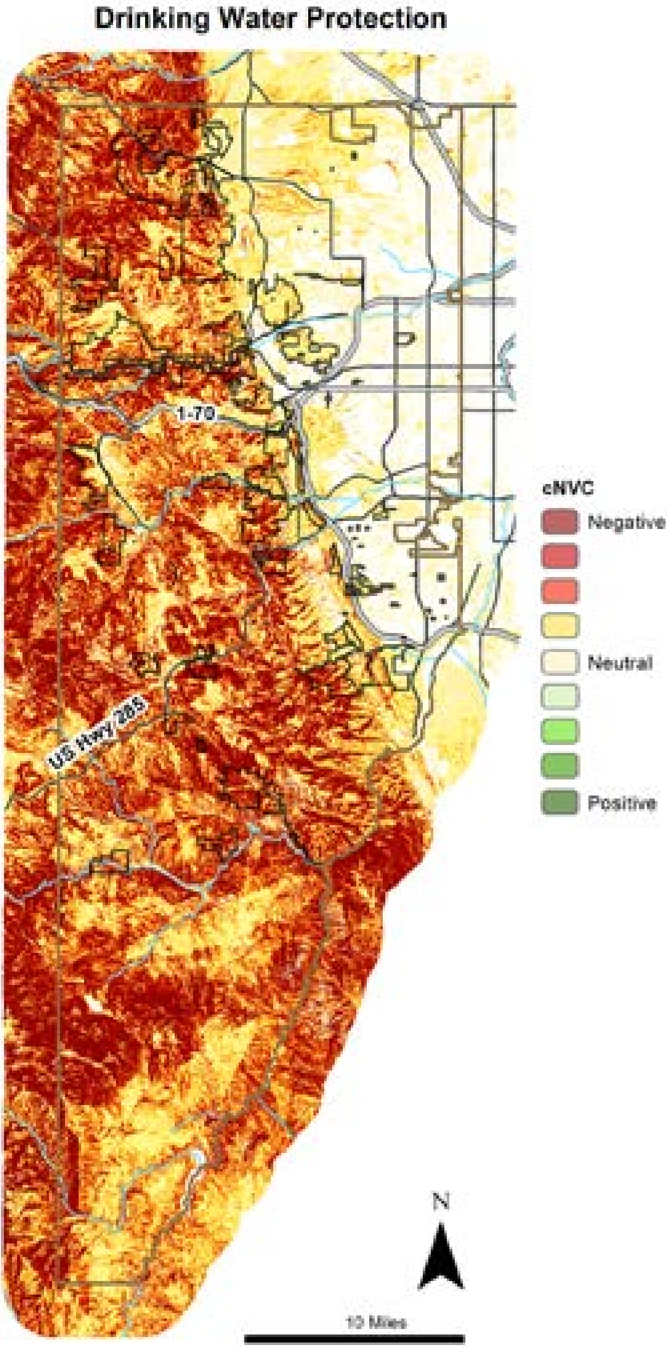
There is also considerable variability in potential water supply impacts within parks. Figure D3 shows an example for White Ranch and the Coal Creek Canyon Study Area. The highest potential sediment yields closely track the densest forests on north-facing slopes (Figure D3B). In this extent, Ralston Creek is the most important watershed because of the population served by the reservoir (Figure D3C). The combined cNVC layer illustrates that most potential for negative water supply impacts is concentrated on a minority of the landscape that can be targeted for mitigation (Figure D3D).

Figure D3. View of White Ranch Park and the Coal Creek Canyon Study area showing: A) JCOS ownership and aerial imagery, B) potential post-fire sediment to streams after burning, C) Forests to Faucets (F2F) Drinking Water Importance Index (DWI), and D) water supply (WS) conditional Net Value Change (cNVC).



To create the Water cNVC layer for the analysis, zero cNVC areas set to null to reduce the layers extent to only those areas with expected conditional exposure from wildfire (Figure D4).

Figure D4. Water Drinking Water Protection cNVC.



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APPENDIX E. Jefferson County Open Space Park Priority Maps

Figure E1. Alderfer/Three Sisters Park priorities

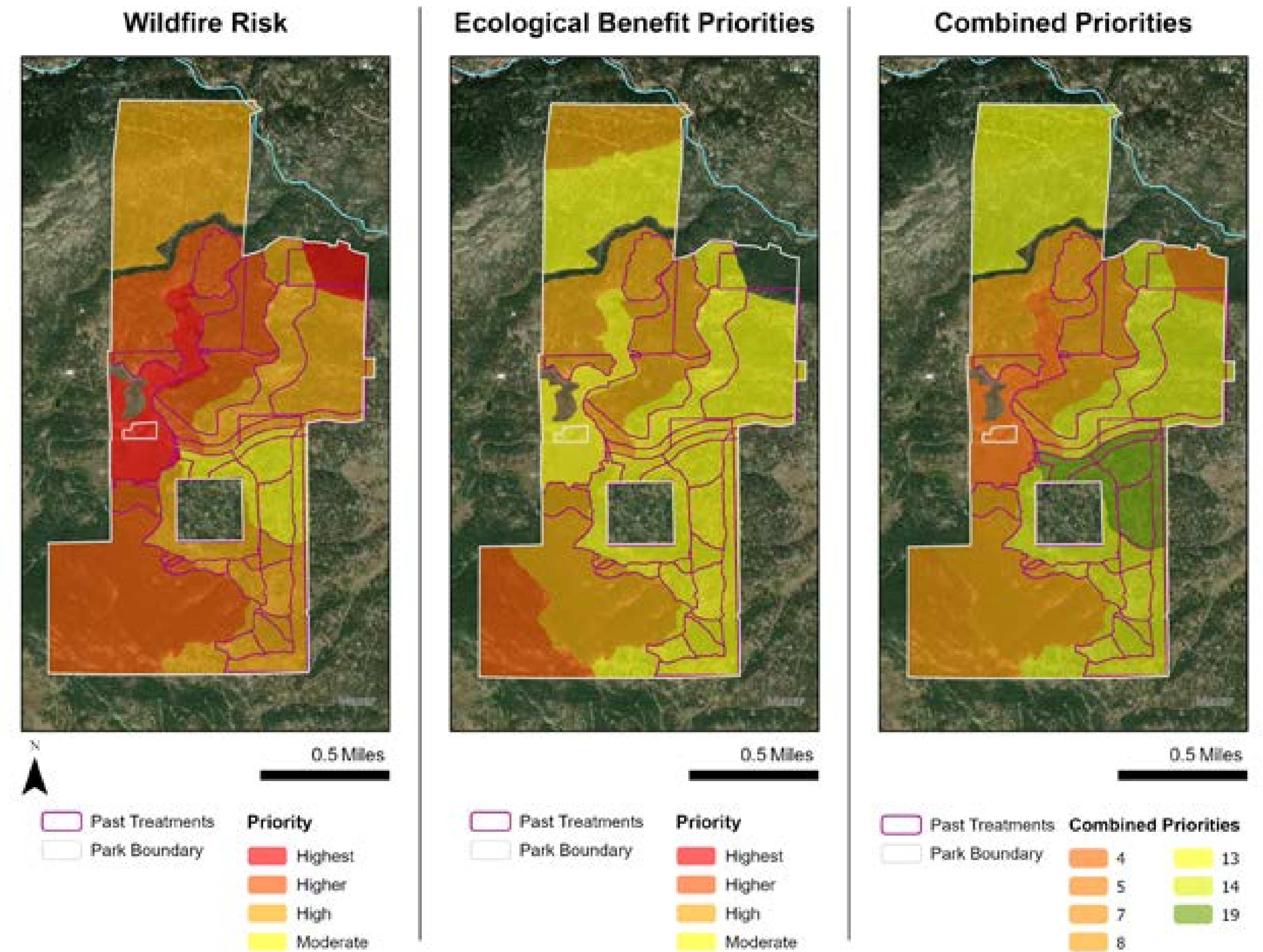
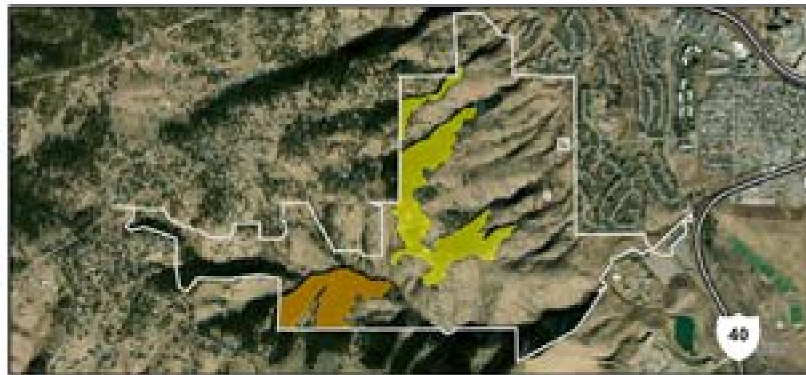
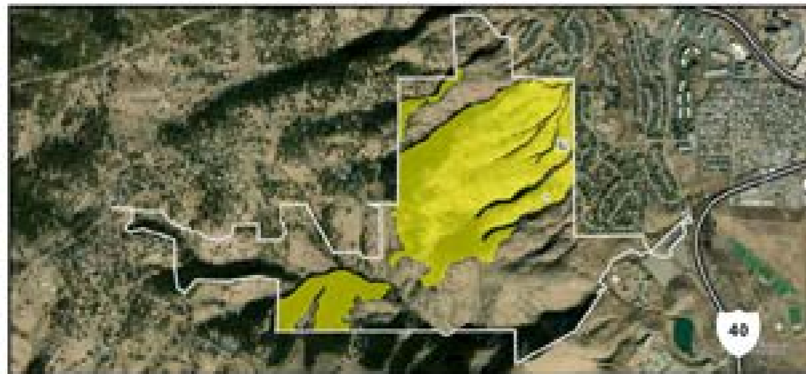


Figure E2. Apex Park priorities

Wildfire Risk



Ecological Benefit Priorities



Combined Priorities

Figure E3. Beaver Ranch Park priorities

Wildfire Risk

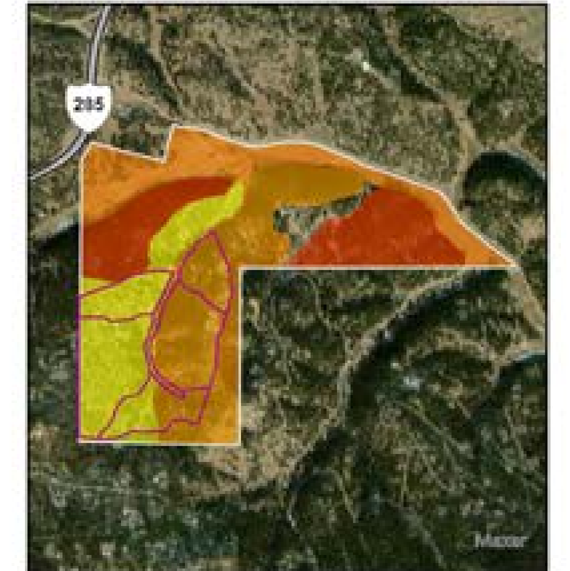
N

0.5 Miles

Ecological Benefit Priorities

0.5 Miles

Combined Priorities



0.5 Miles

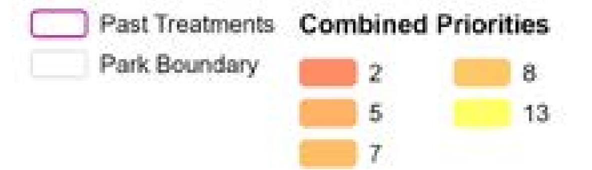


Figure E4. Cathedral Spires Park priorities

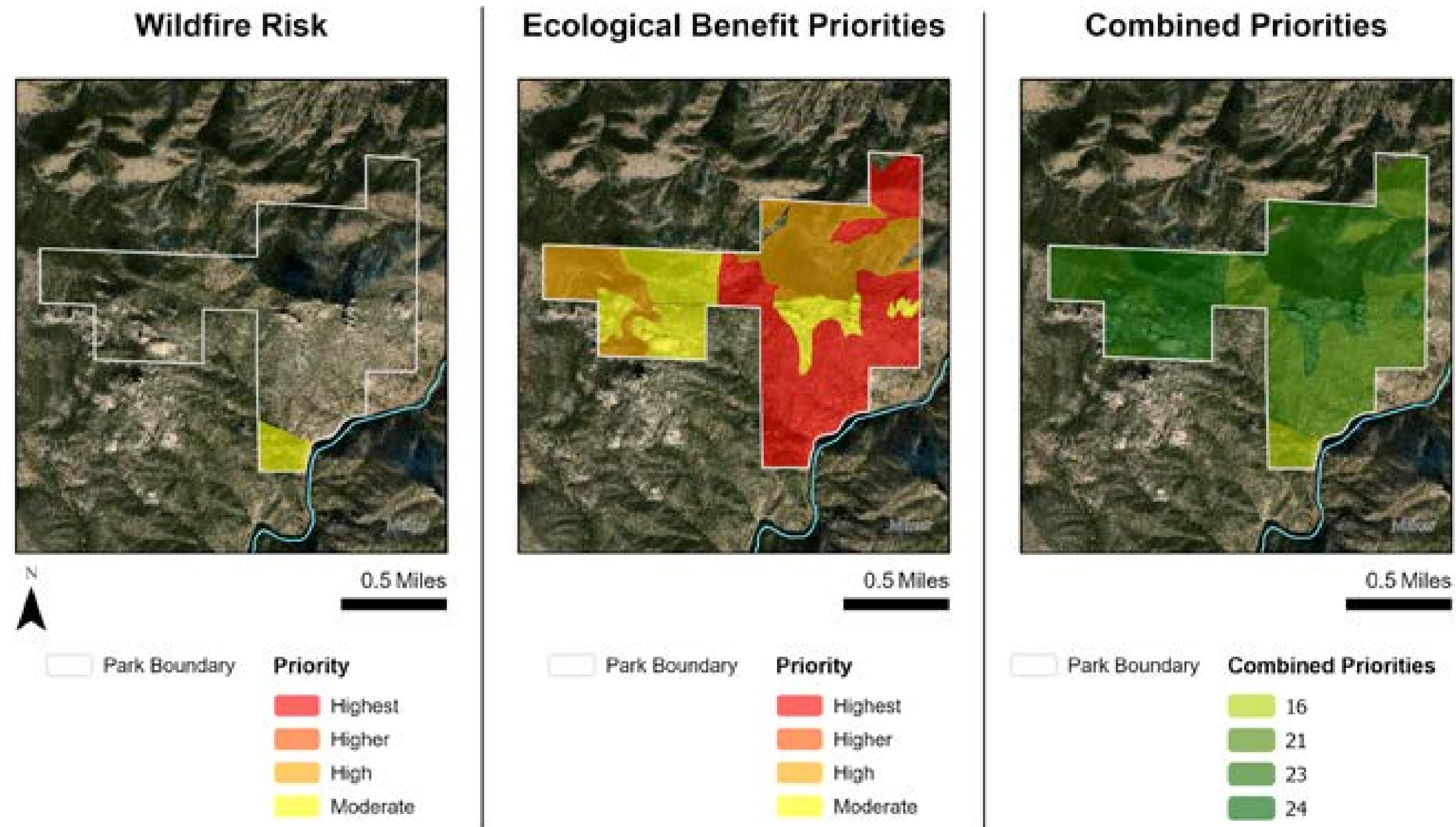


Figure E5. Centennial Cone Park priorities

Wildfire Risk

Park Boundary

Priority

Highest

Higher

High

Moderate

Ecological Benefit Priorities

Park Boundary

Priority

Highest

Higher

High

Moderate

Combined Priorities

Park Boundary

Combined Priorities

11

16

17

21

22

23

24

N

2 Miles

Figure E6. Clear Creek Canyon Park priorities

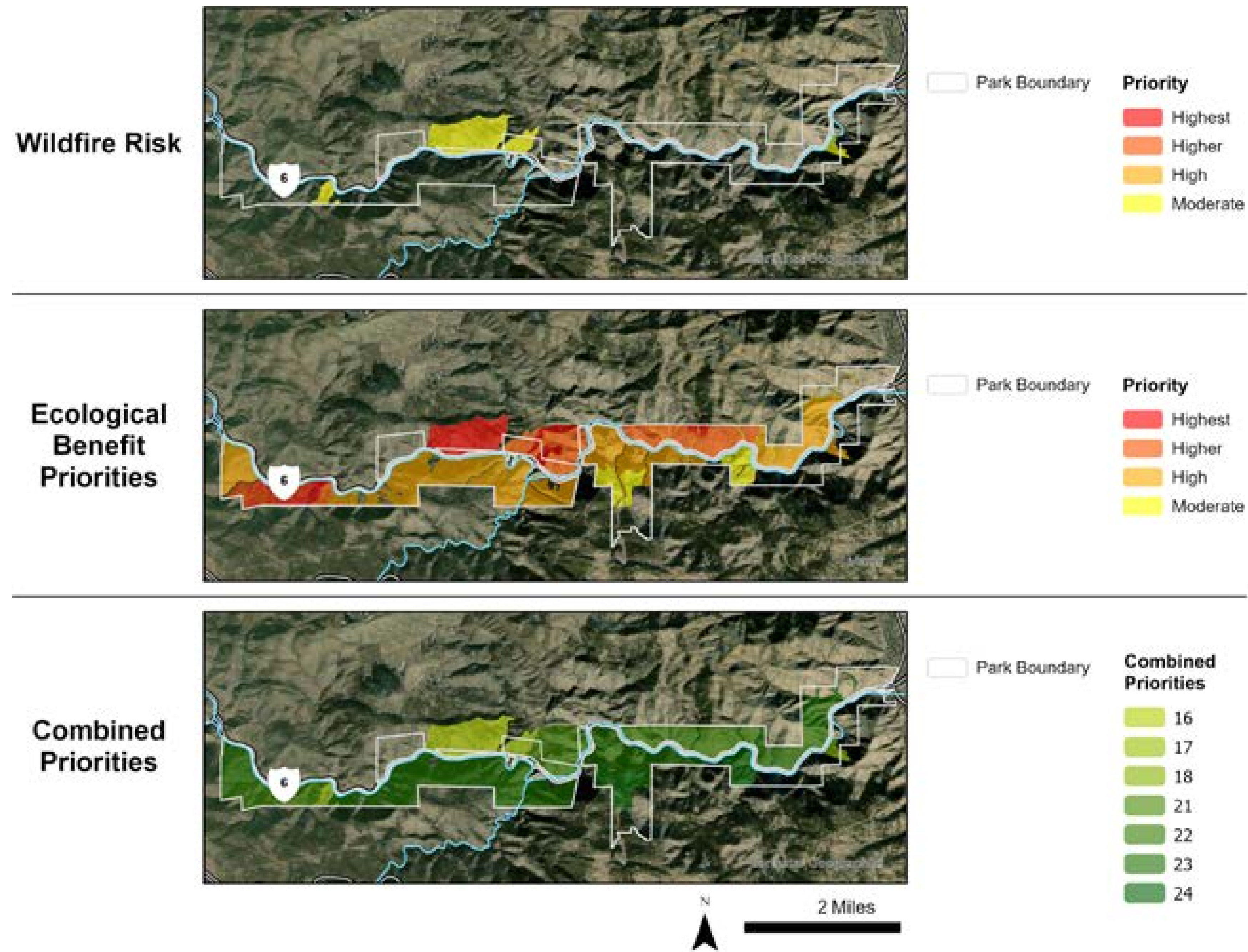


Figure E7. Coal Creek Canyon Study Area priorities

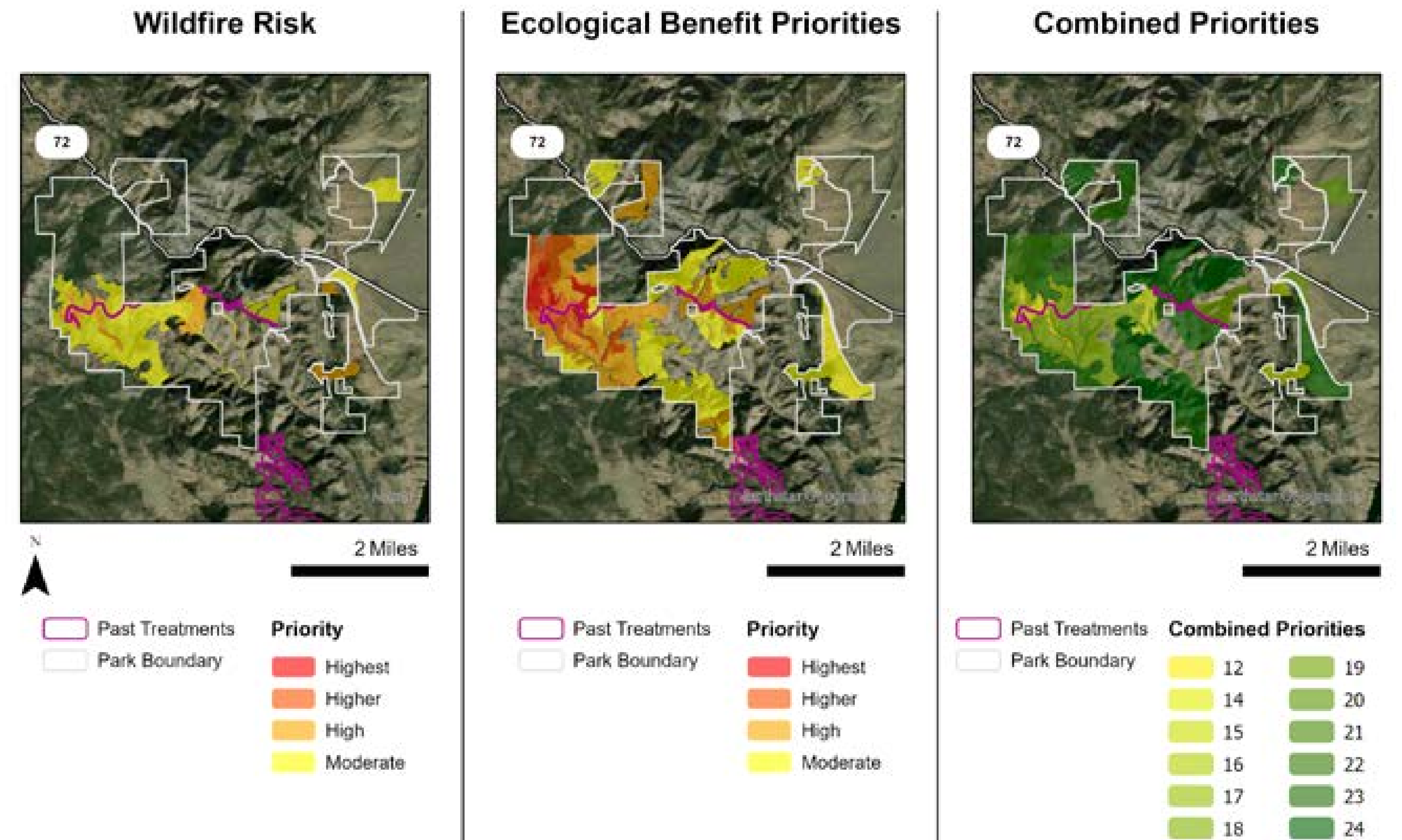


Figure E8. Deer Creek Canyon Park priorities

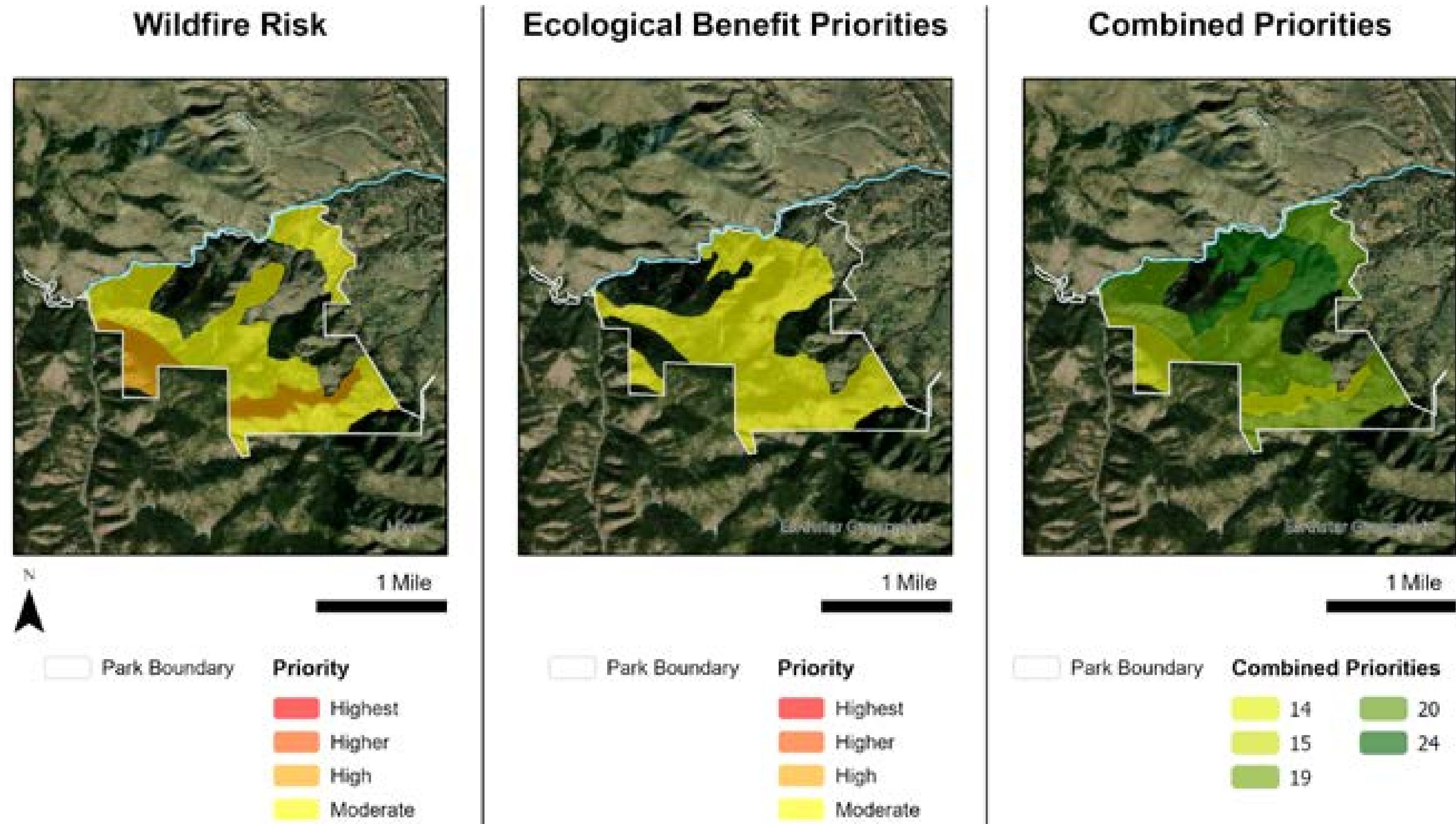


Figure E9. Douglas Mountain Study Area priorities

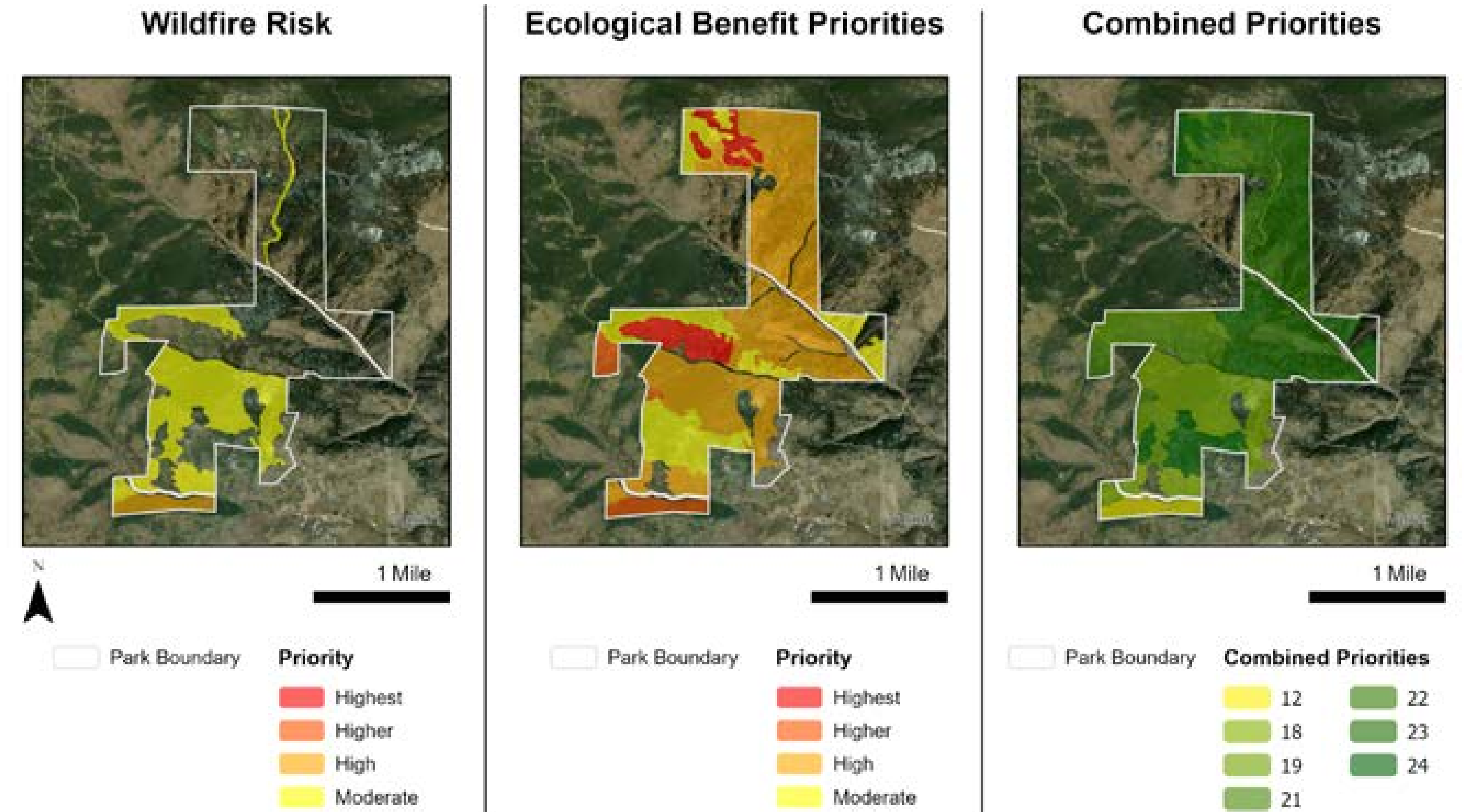


Figure E0. Elk Meadow Park priorities

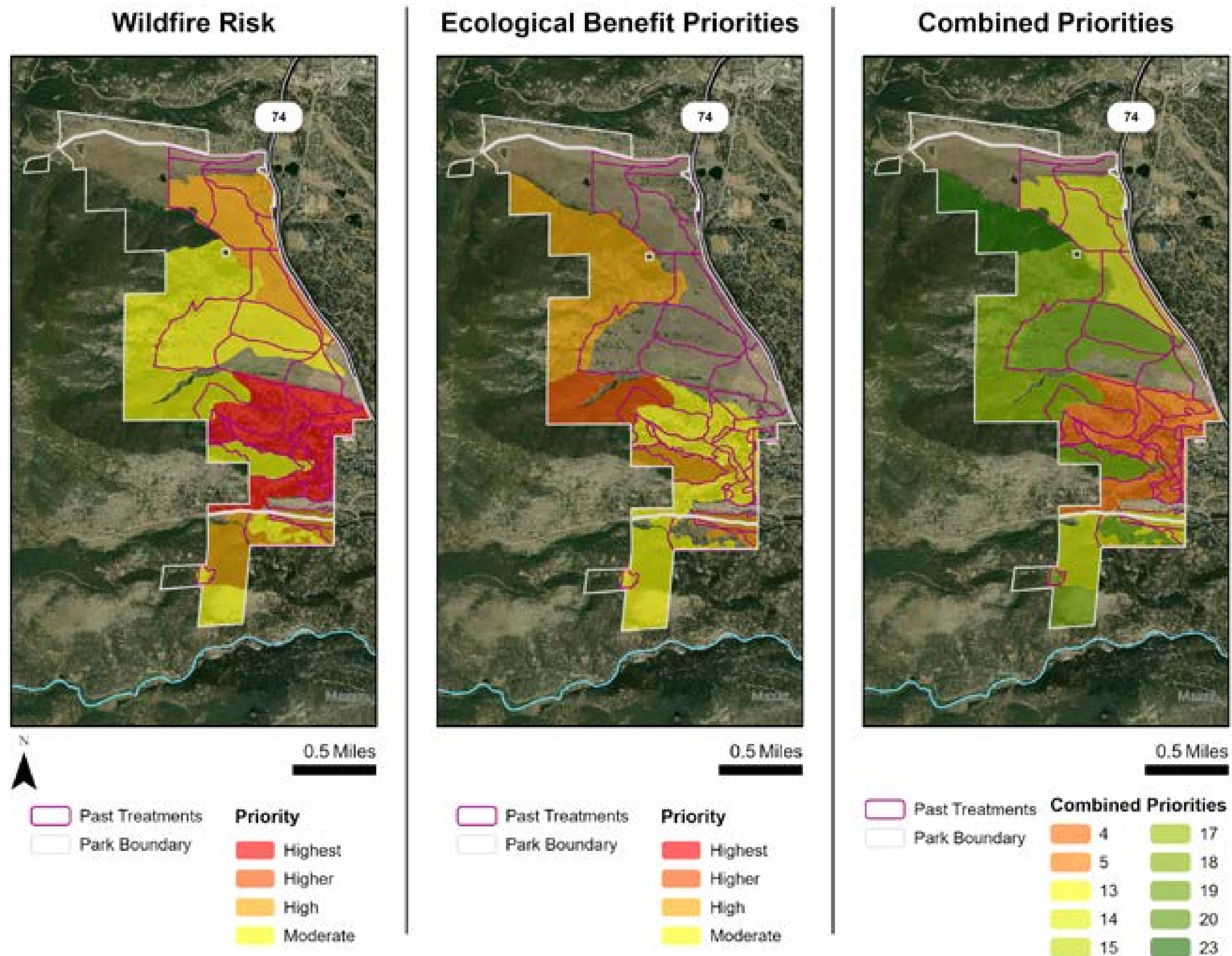


Figure E11. Flying J Ranch Park priorities

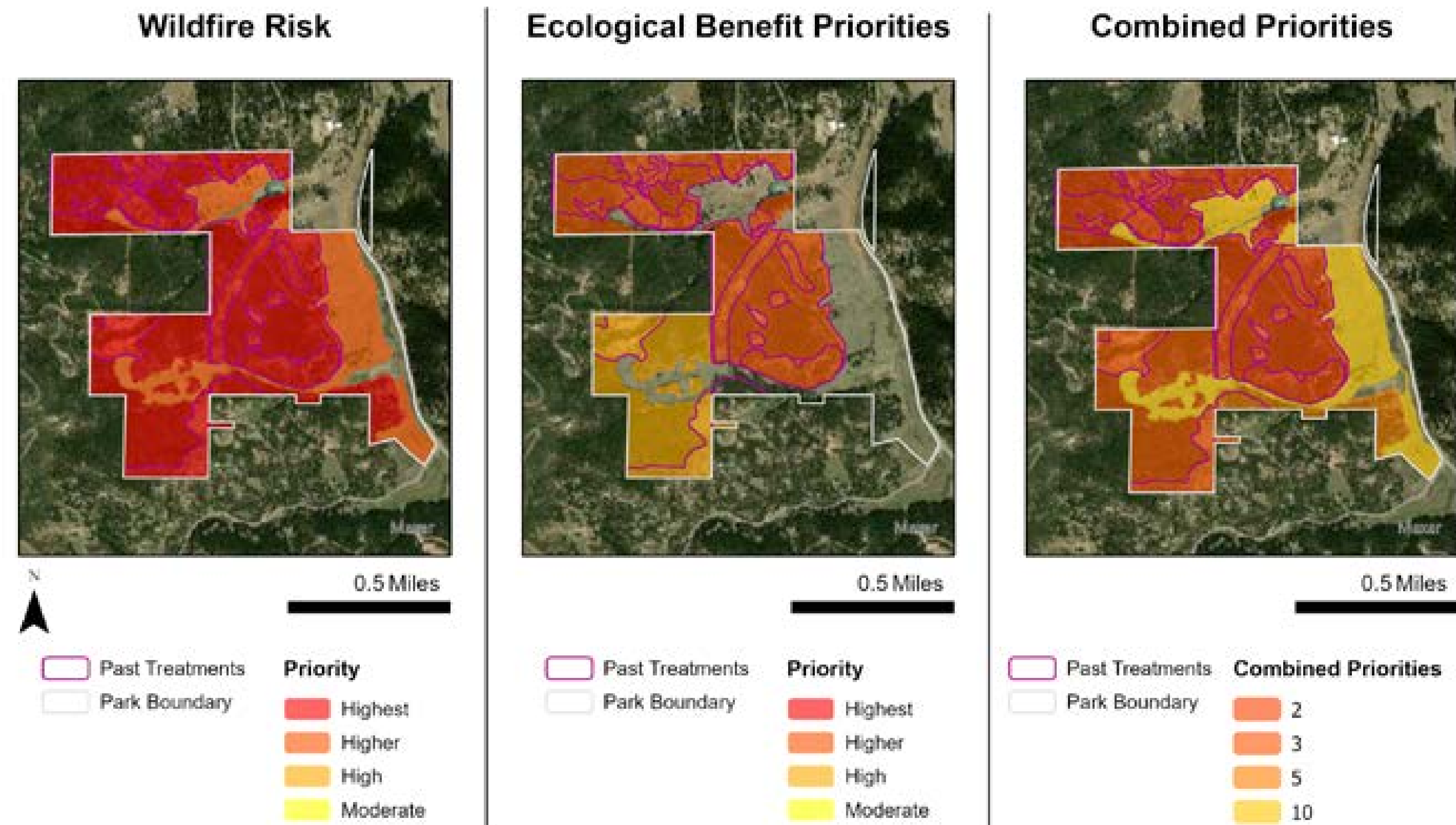


Figure E12. Hildebrand Ranch Park priorities

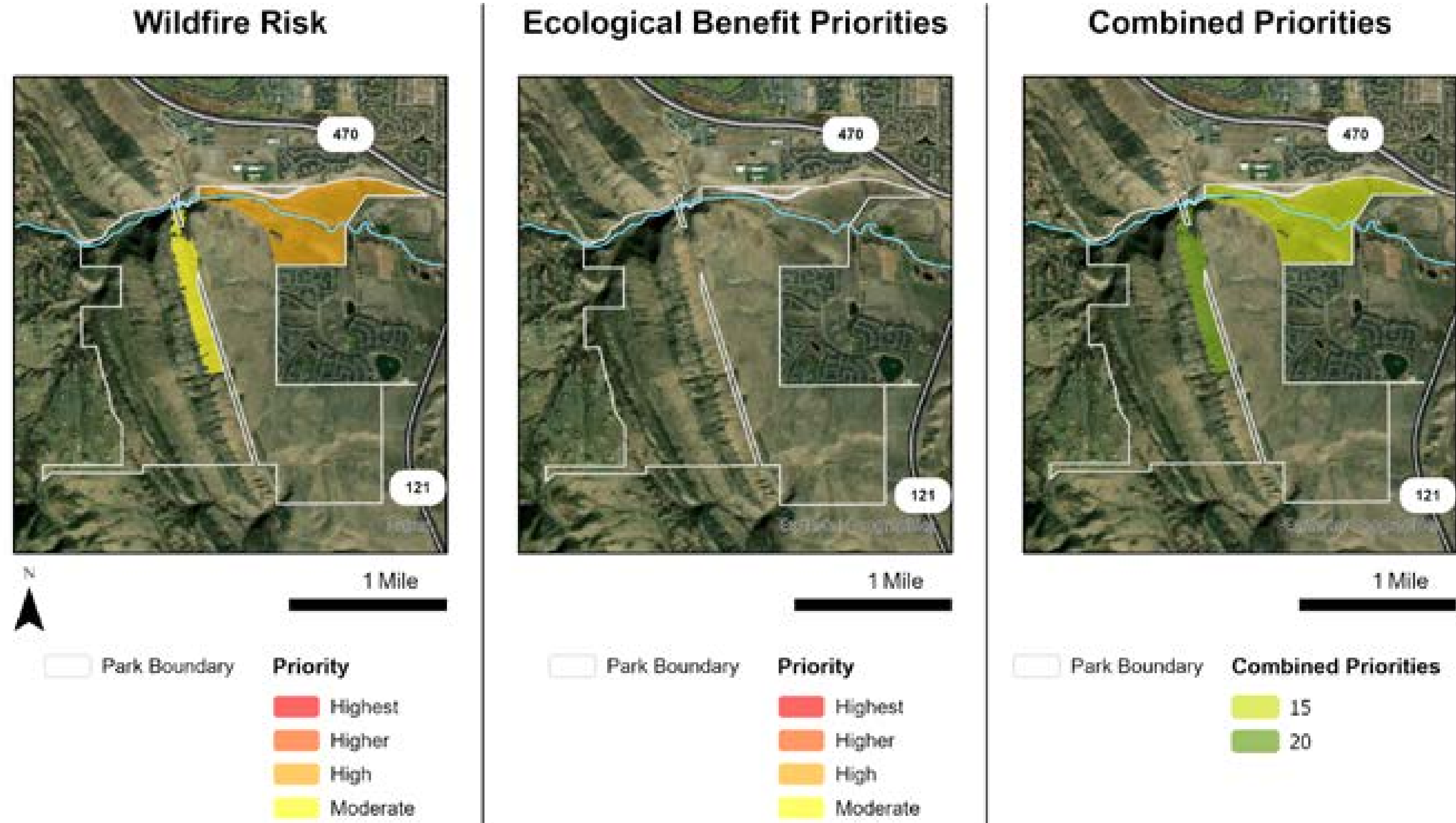


Figure E13. Lair o' the Bear Park priorities

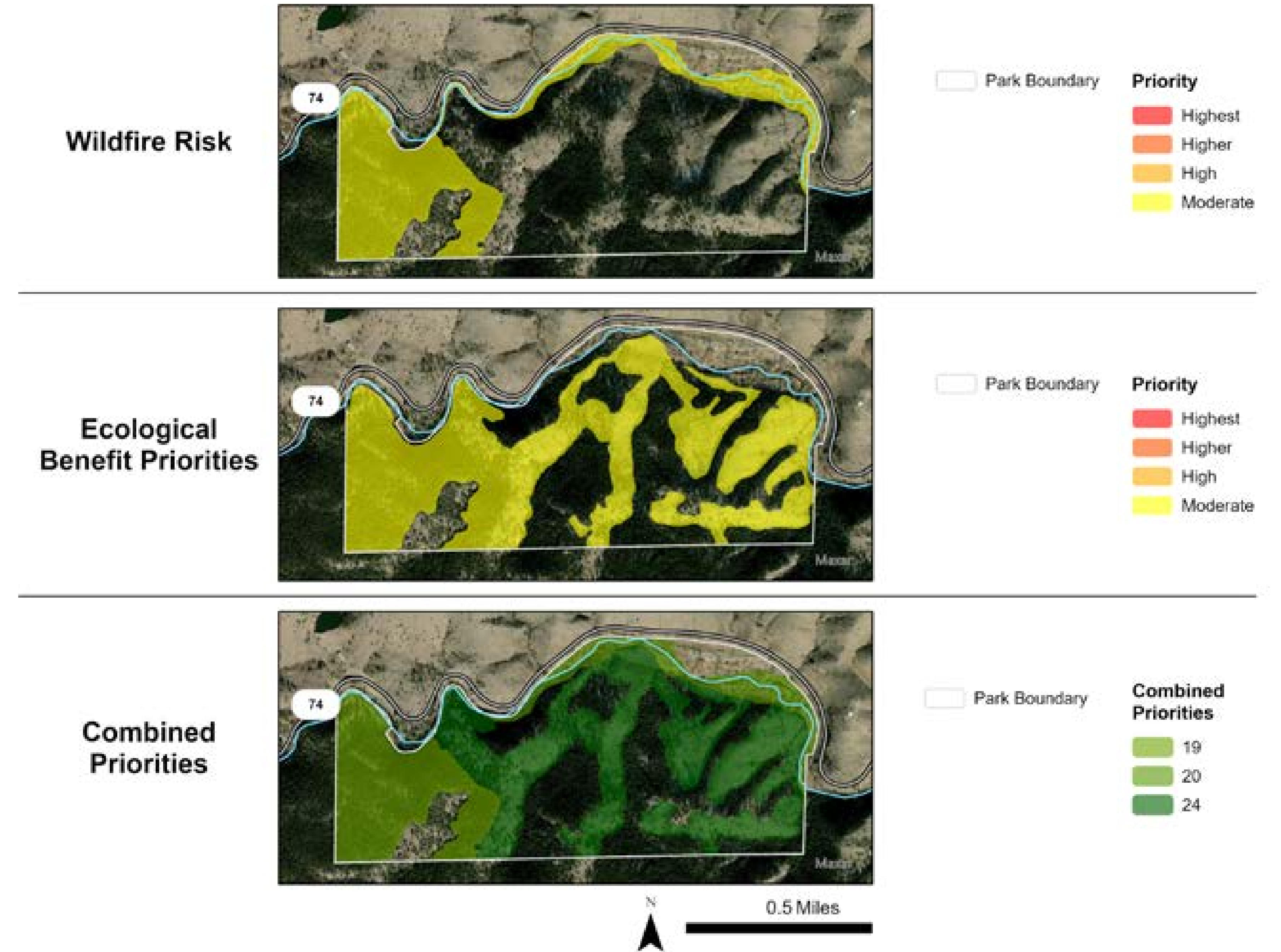


Figure E14. Lippincott Ranch Property priorities

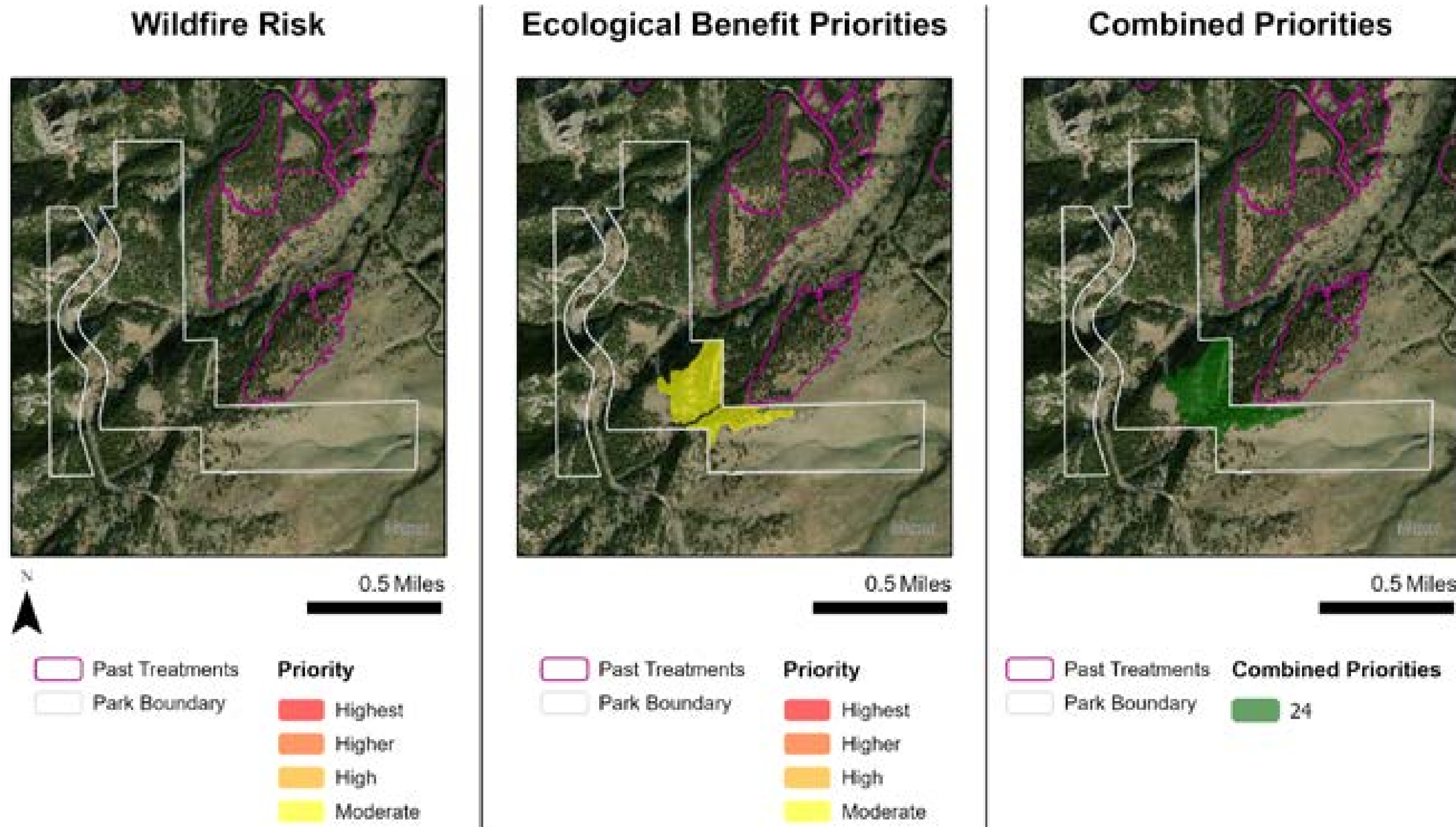


Figure E15. Lookout Mountain Preserve priorities

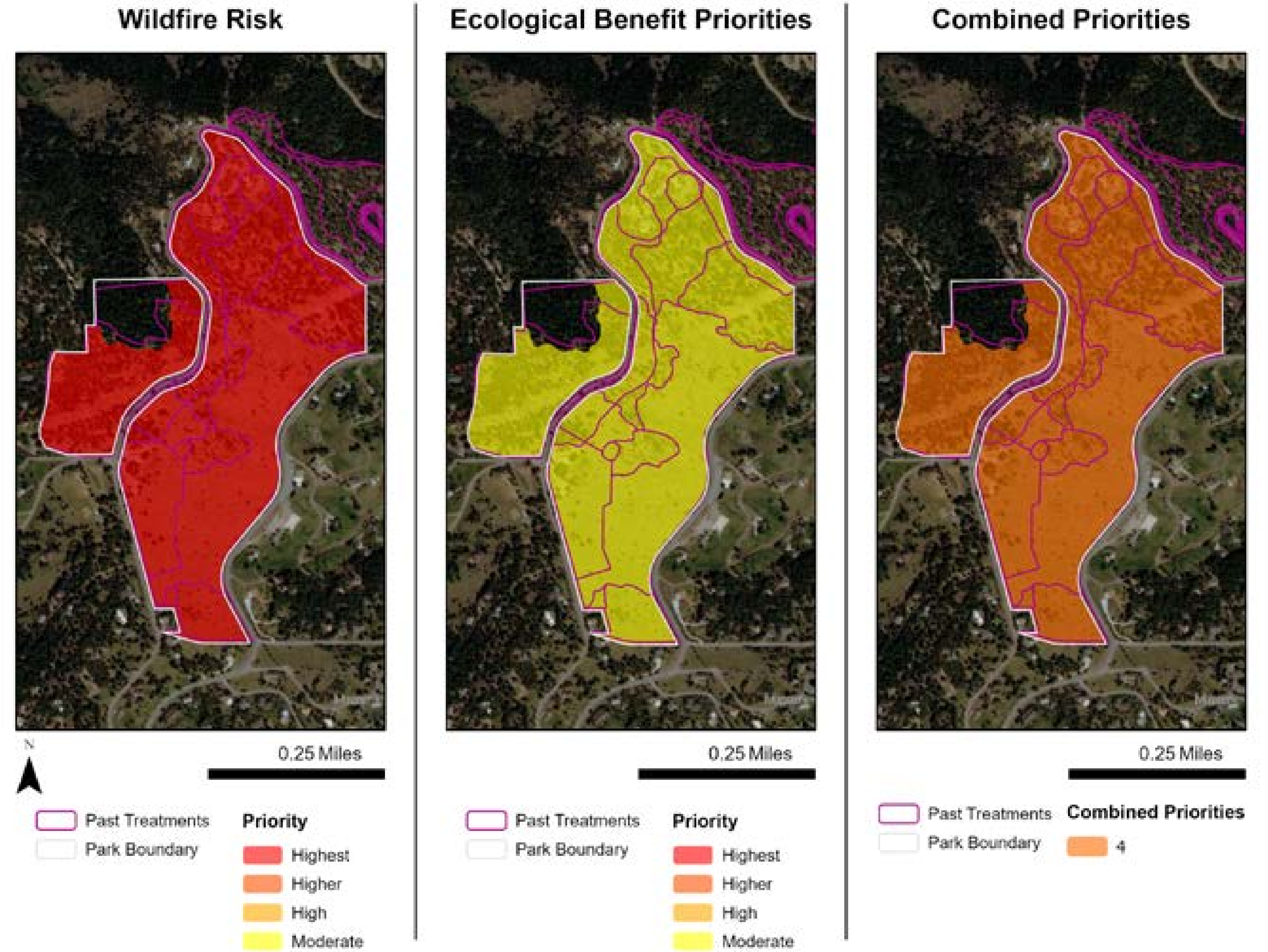


Figure E16. Matthews/Winters Park priorities

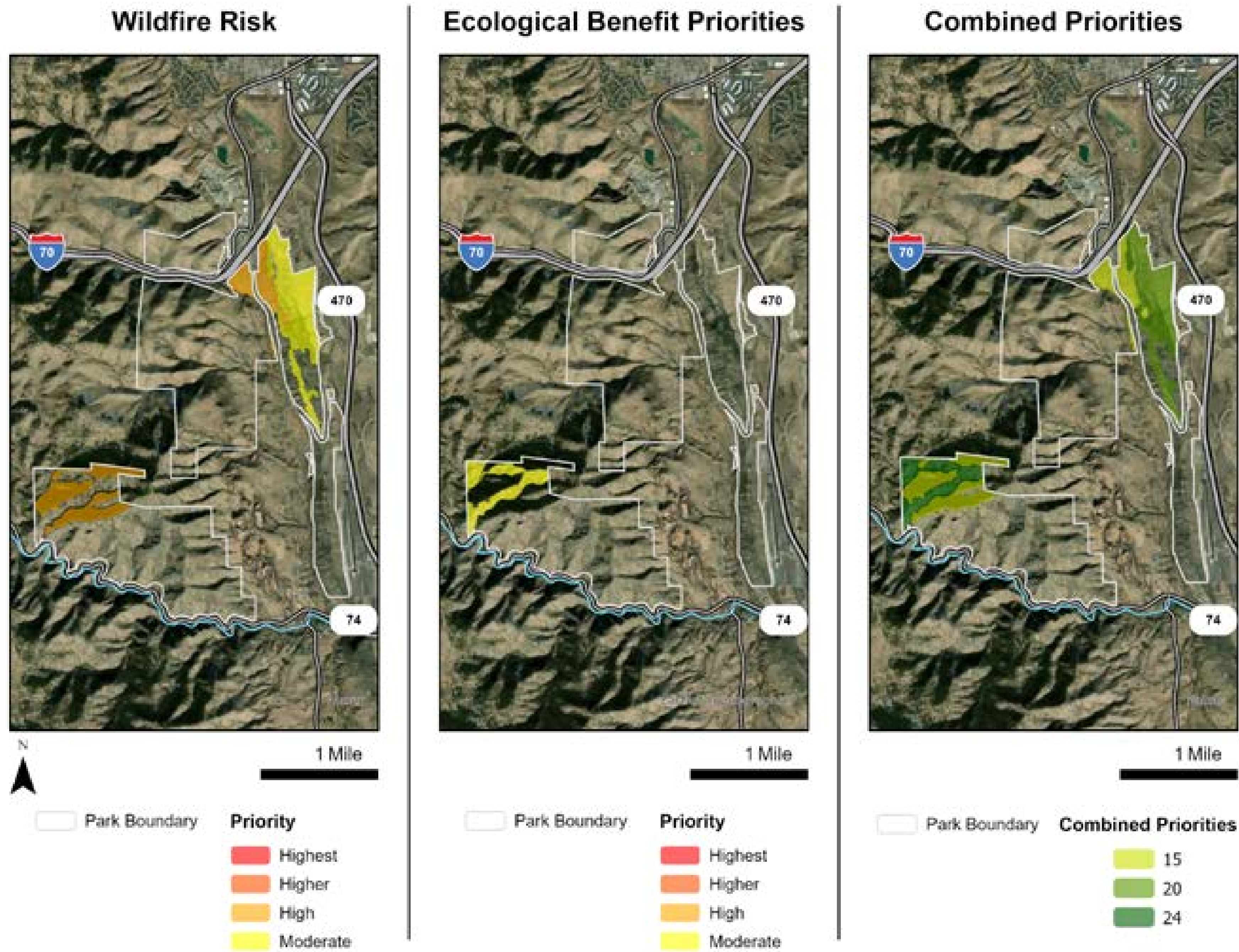


Figure E17. Meyer Ranch Park priorities

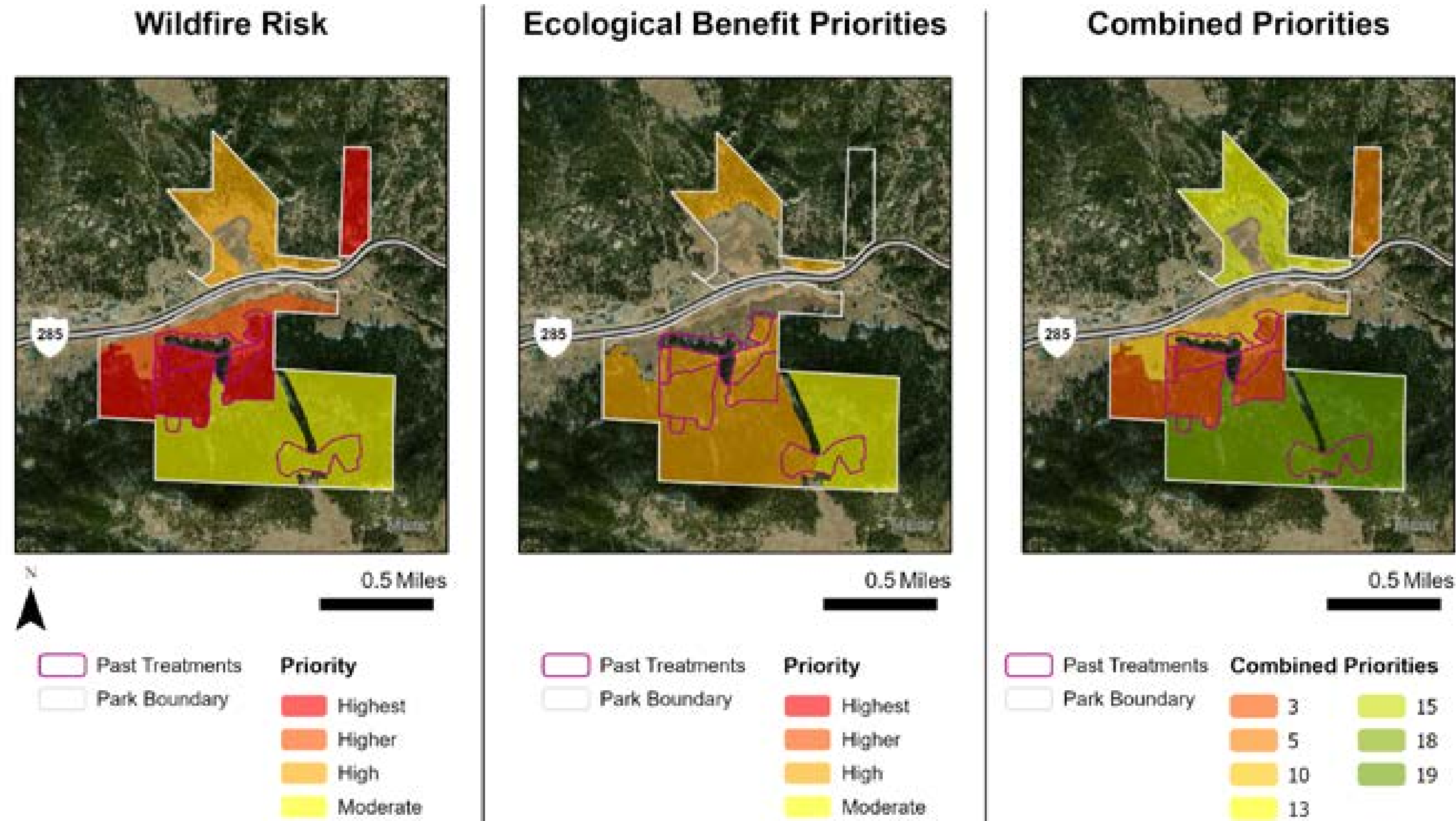


Figure E18. Mount Falcon Park priorities

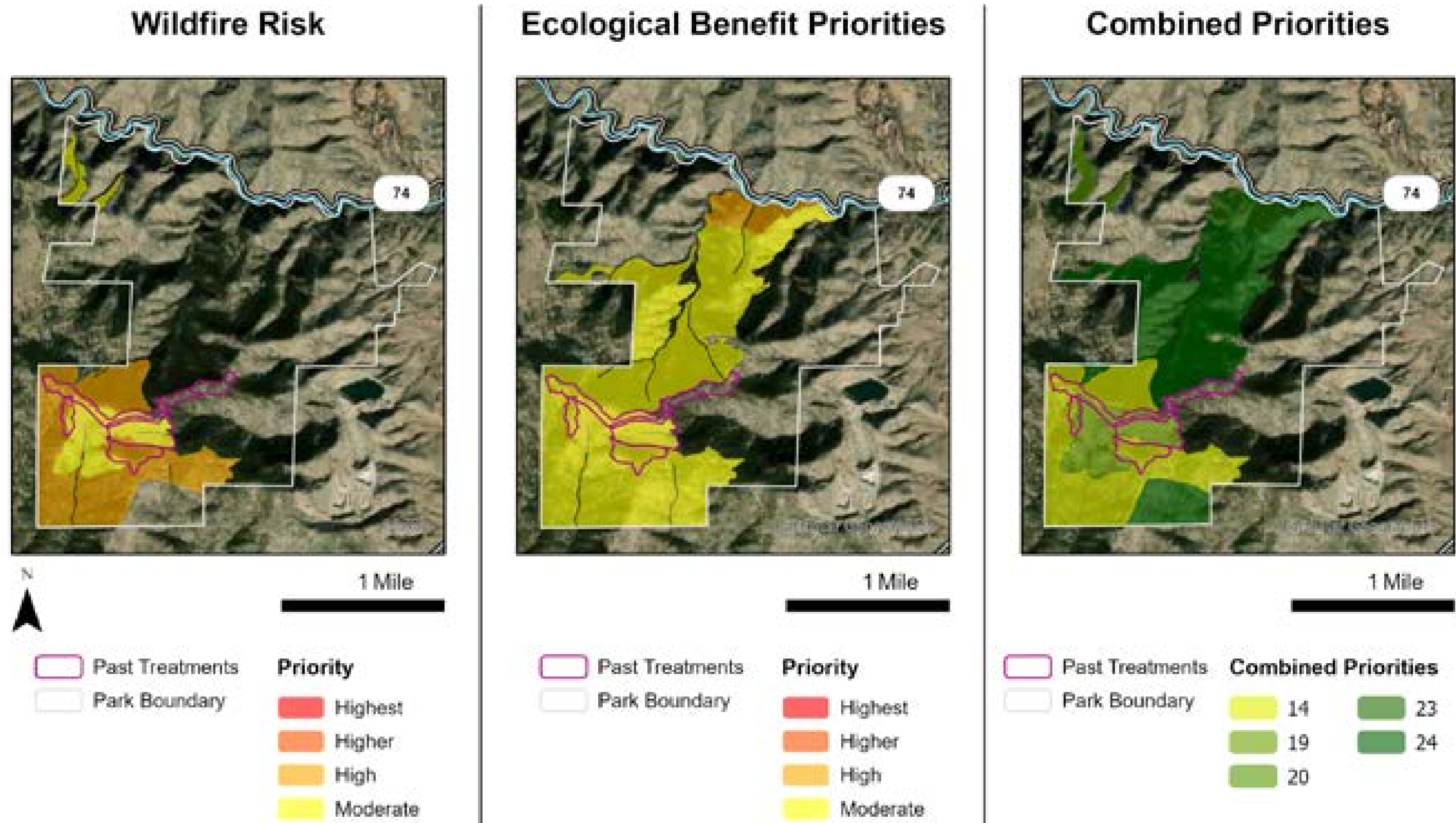


Figure E19. Mount Galbraith Park priorities

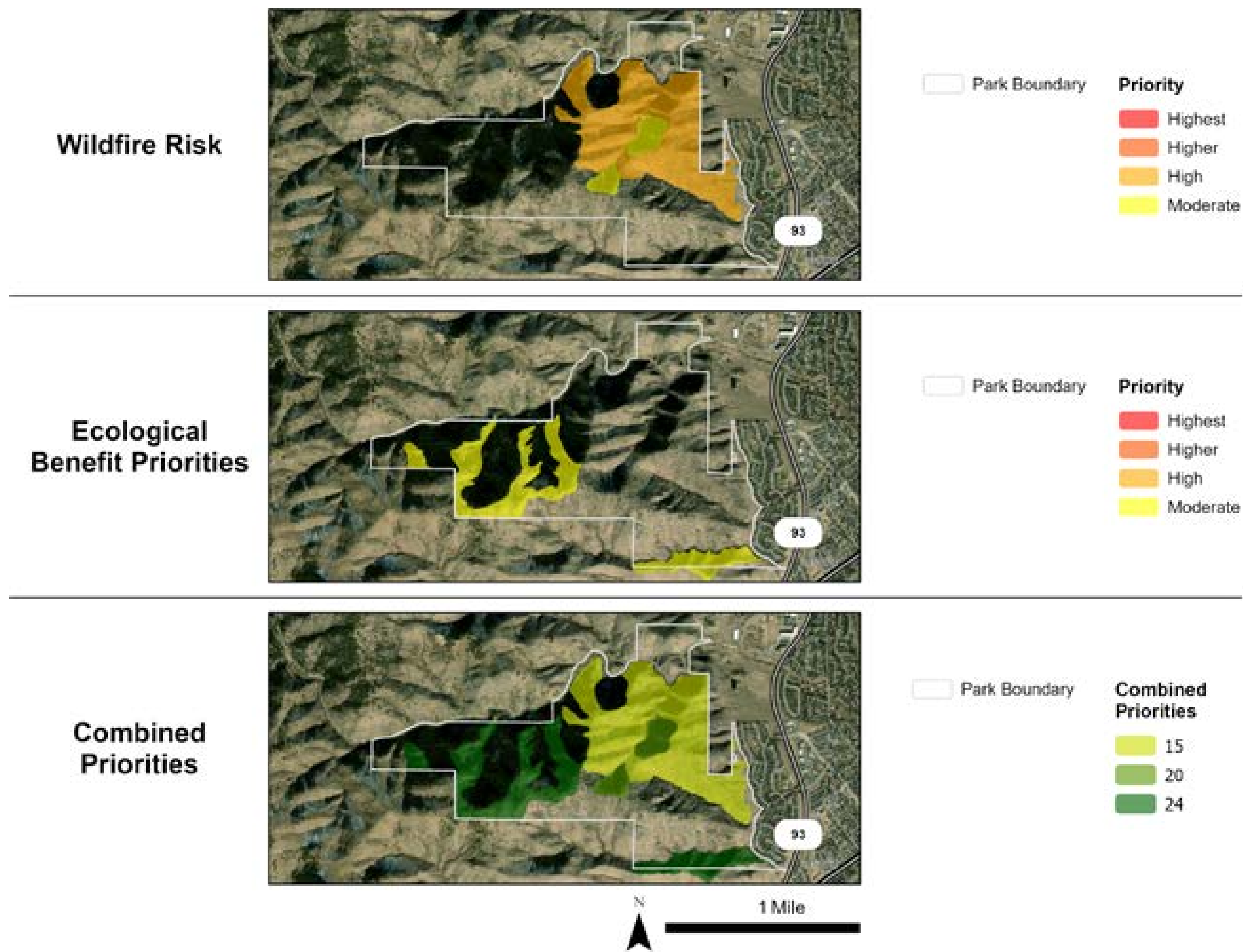


Figure E20. Mount Lindo Park priorities

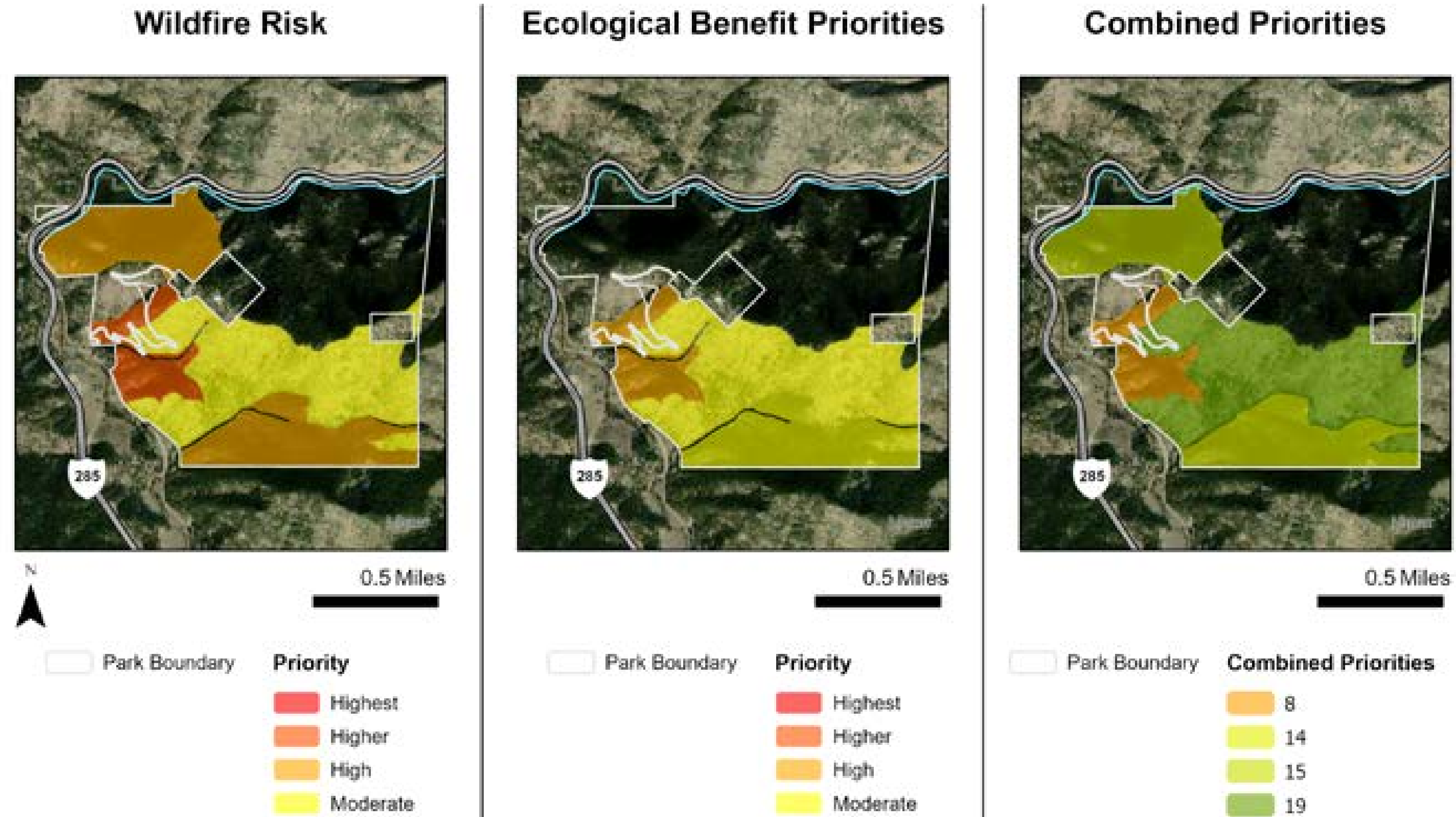


Figure E21. North Table Mountain Park priorities

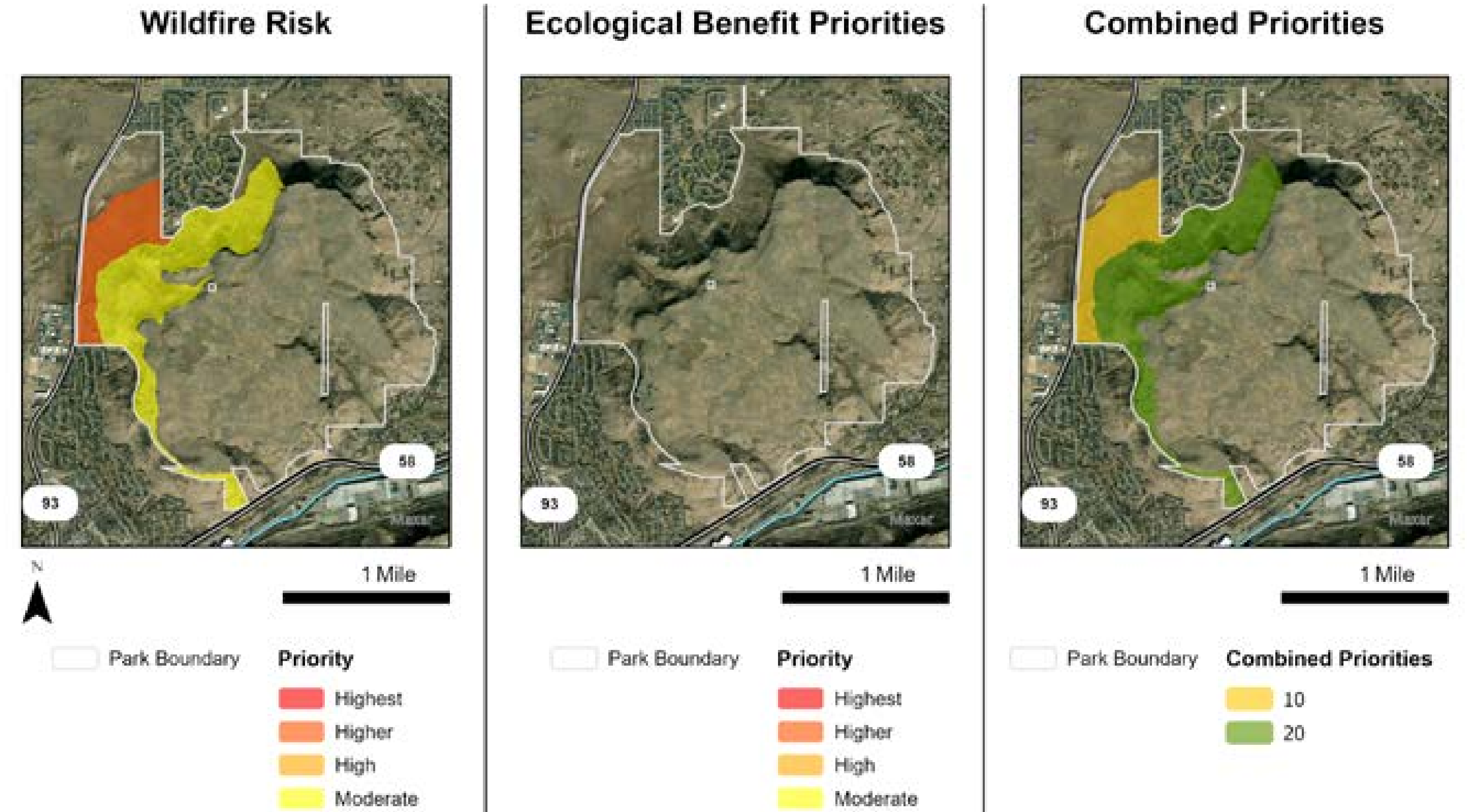


Figure E22. Pine Valley Ranch Park priorities

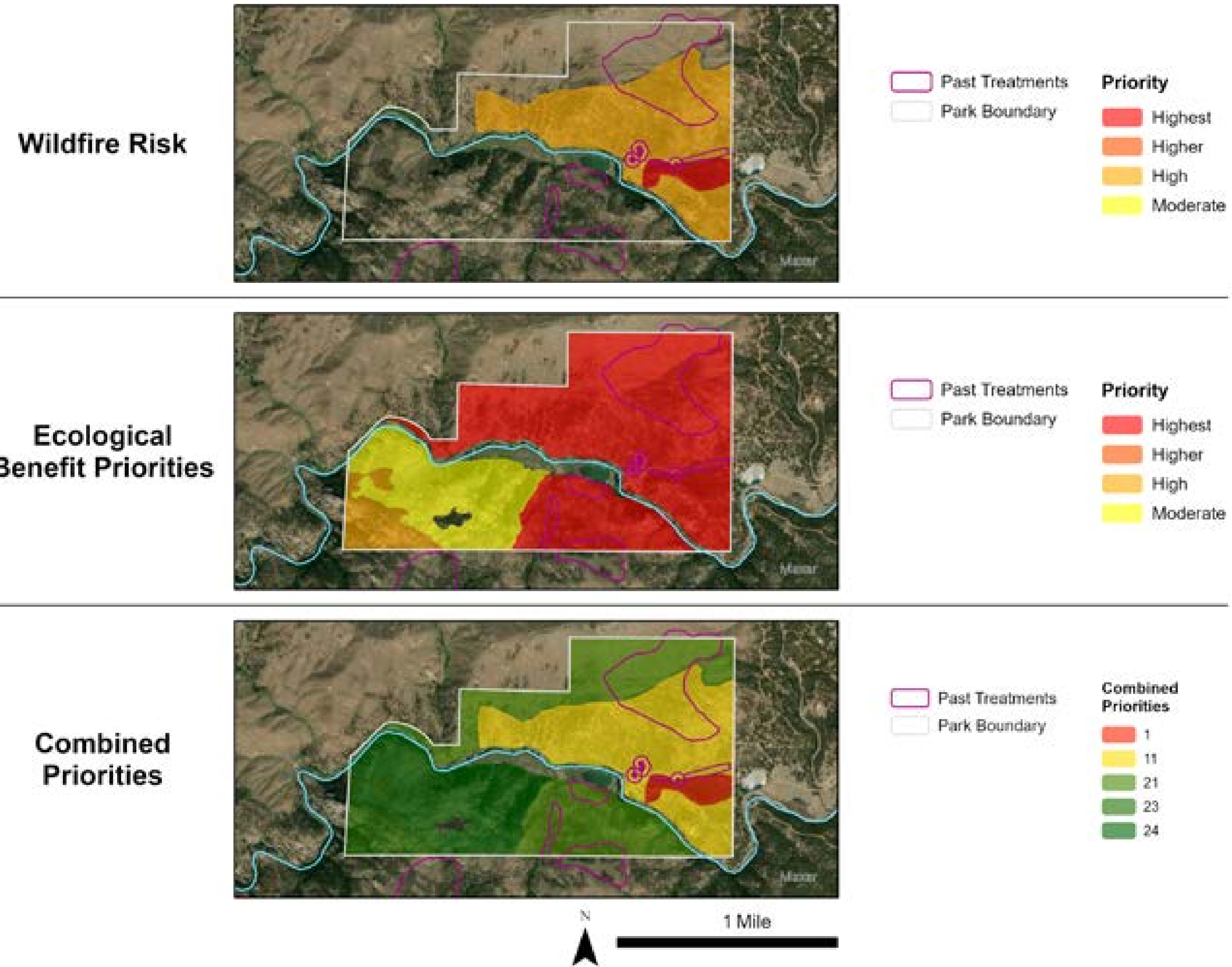


Figure E23. Reynolds Park priorities

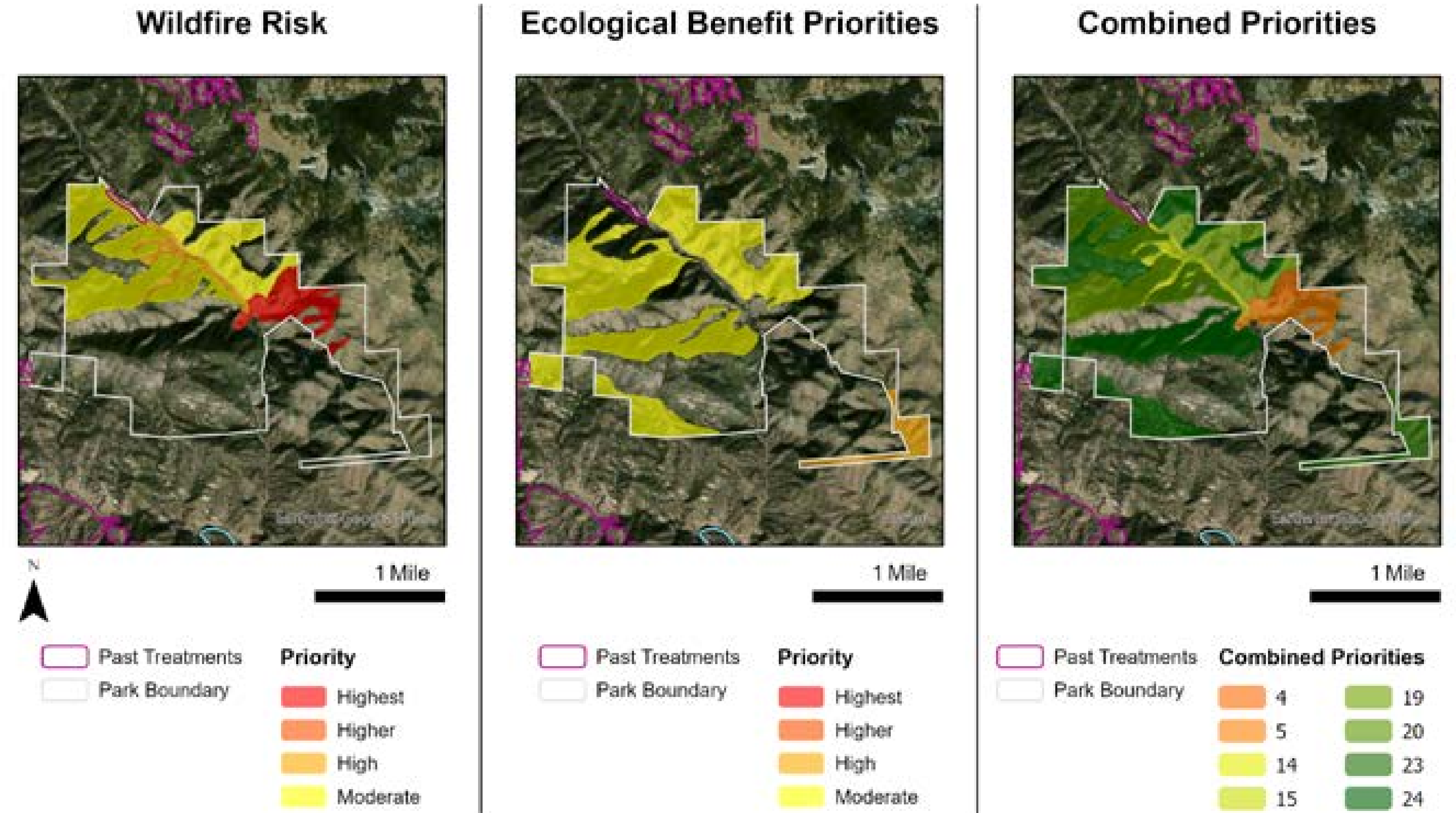


Figure E24. South Valley Park priorities

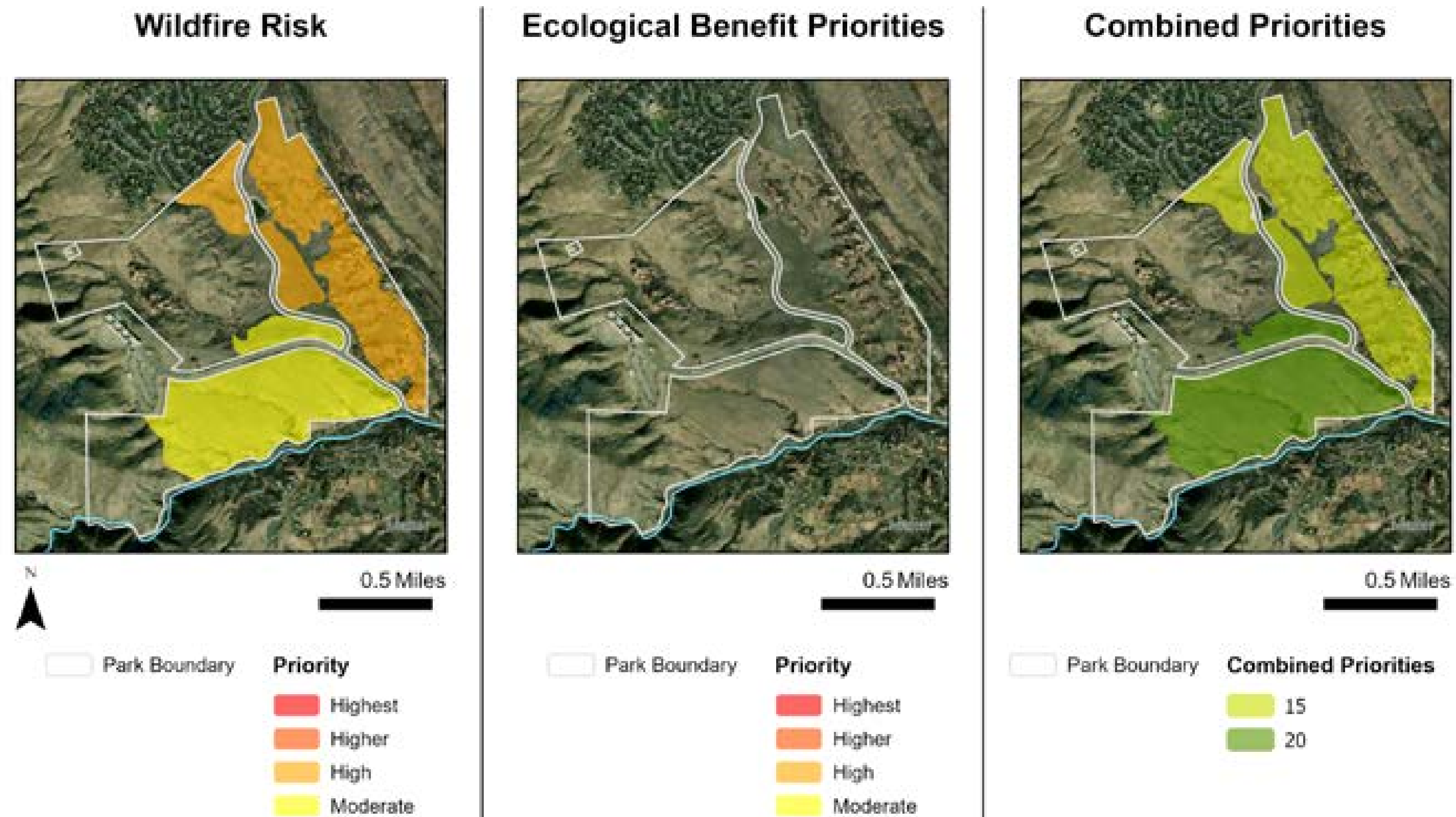


Figure E25. White Ranch Park priorities

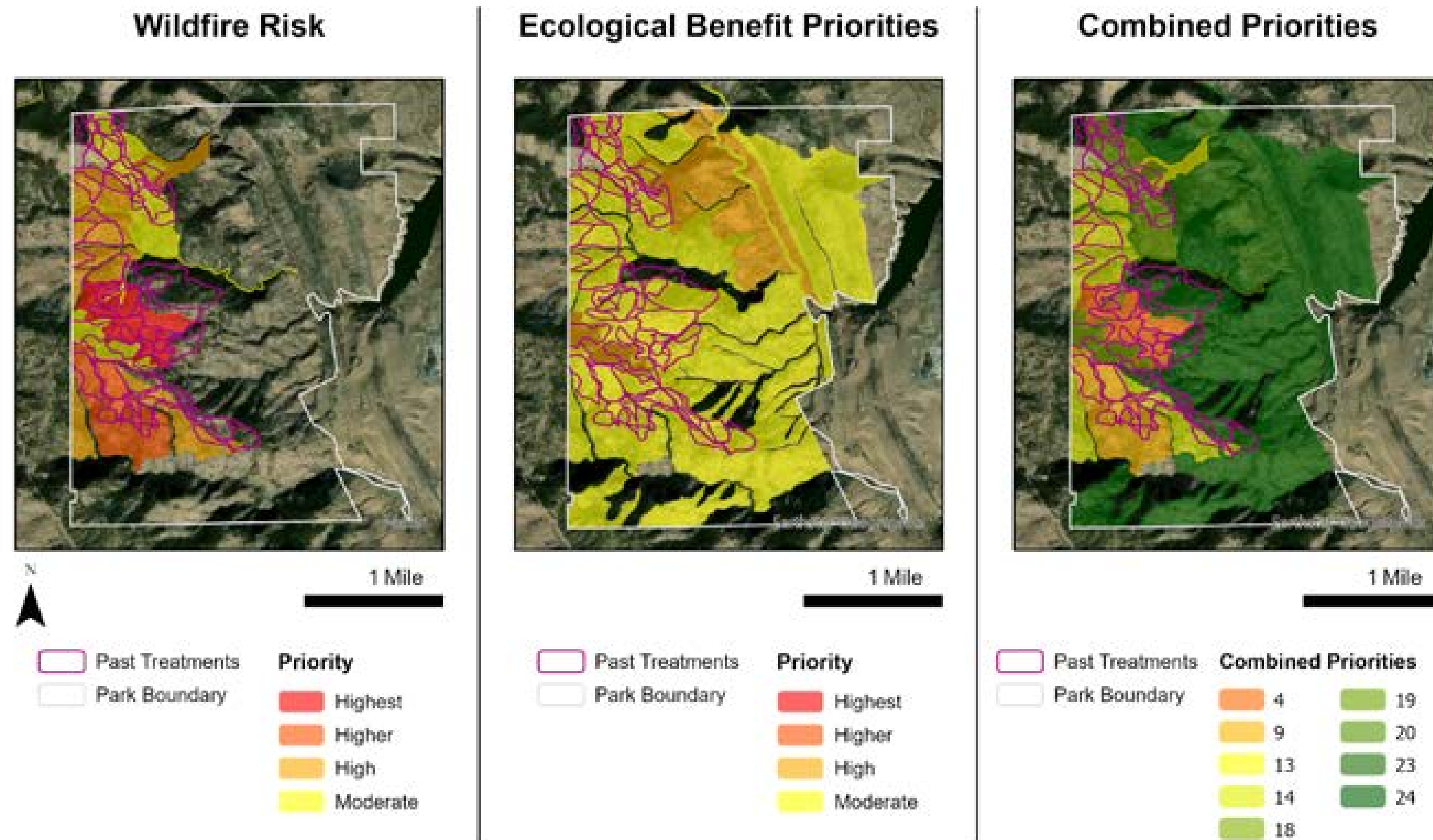
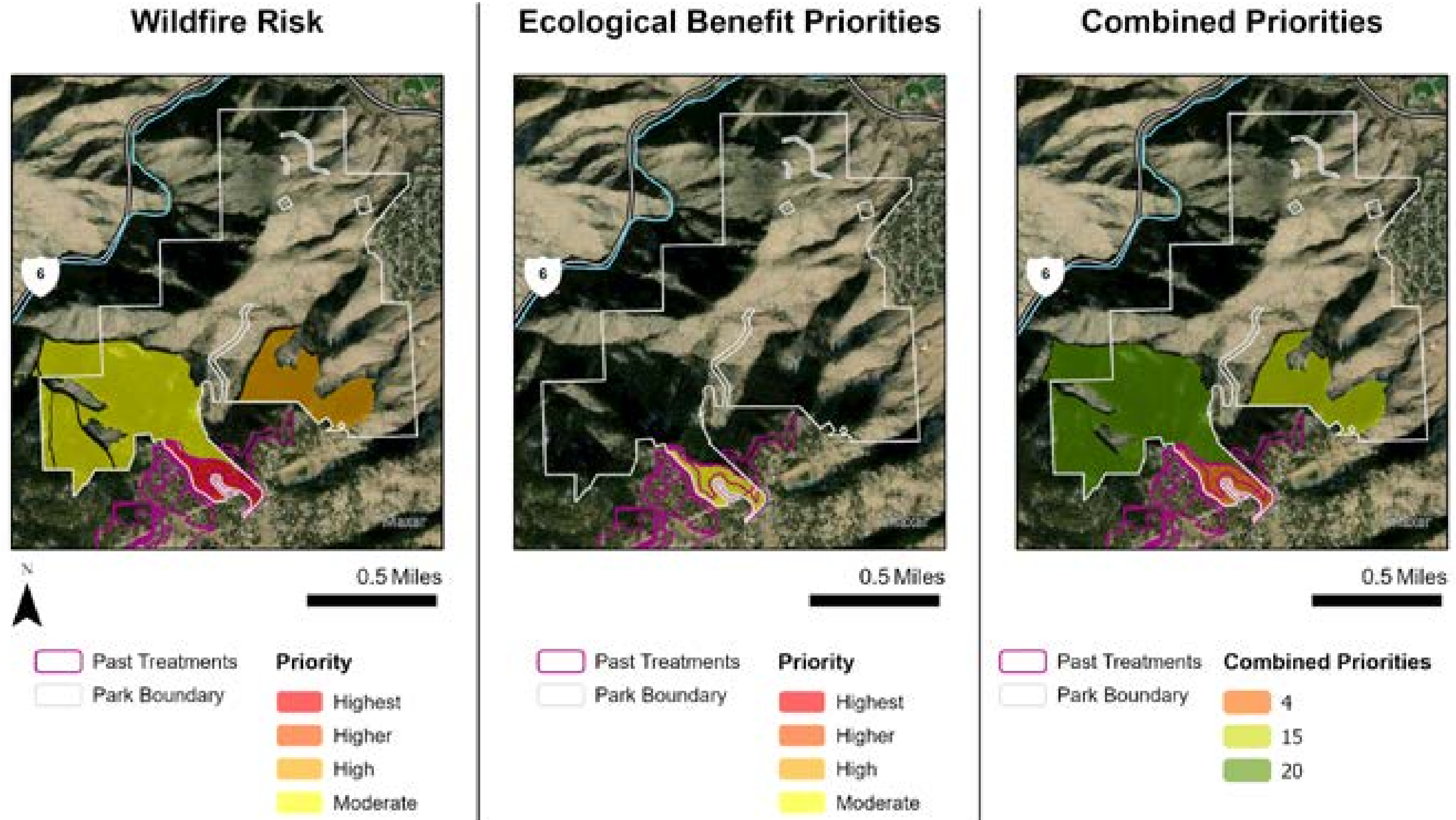


Figure E26. Windy Saddle Park priorities



Overlook of the North Fork of the South Platte River at Pine Valley Ranch Park.

Back cover: An old growth tand of ponderosa pine at White Ranch Park. This area was managed with multiple treatements of mechanical thinning and prescribed fire in the 1990's and 2000's creating an example of desired conditions for ponderosa pine ecosystems in Jefferson County.

JEFFERSON

COUNTY COLORADO

Open Space