June 2023

Park City Municipal Corporation

Community Wildfire Risk Assessment

Presented By

Alpine Forestry

Blue Mountain Environmental Consulting

The Ember Alliance

Sageland Collaborative

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1.0 Introduction

In This Chapter

1.1 Introduction

Communities in the wildland-urban interface (WUI) are increasingly vulnerable to wildfire as development expands further into surrounding natural areas. The desire to live on nature's doorstep draws people to places like Park City, Utah. Increasing numbers of people living in a natural habitat can present real challenges in mitigating the effects from natural disasters. In the case of wildfires across the nation, wildlands are burning more intensely, endangering lives, destroying homes and damaging valuable ecosystems that support wildlife and water resources.

It is not all bad news, however. Local officials from all levels of government, residents, and stakeholders can address this risk with a nationally recognized framework designed to help protect communities and the natural environment. It is through understanding and planning for the risks, that people can safely live, work, and play among this scenic environment.

To meet this challenge, the Park City Municipal Corporation (PCMC) set out to determine how wildfire could affect Park City. The Community Wildfire Risk Assessment (CWRA) helps us better understand the effects of wildfire, and plan a way forward to reduce some of its potential impacts.

The CWRA combines analysis of the community and environment to determine specific risk factors for the Park City Area. Ultimately, this helped produce specific recommendations to address the inherent risks of wildfire

Figure 1-0-1. Landowners work together to clear logs and branches from a tree thinning meant to reduce threat to a nearby home

ABBREVIATIONS

CWRA

Community Wildfire Risk Assessment

HVRA

High Value Resources and Assets

PCFPD

Park City Fire Protection District

PCMC

Park City Municipal Corporation

QWRA

Quantitative Wildfire Risk Assessment

WUI

Wildland Urban Interface

How did we get here?

The Human Influence and Expansion of Wildland-Urban Interface (WUI)

Park City is situated in a diverse landscape where its urban area is nestled against the Wasatch Mountains. The town was built here after thousands of years of use and management by the Shoshone and Ute Native American tribes. Fires were allowed to burn naturally and benefited the Native Americans through increased hunting and foraging and travel corridors. In the 19th century, settlers moved to the area for the rich mining opportunities. This eventually gave way to tourism in the mid to late 20th century.

Recreation is boundless with summer and wintertime activities drawing in more people each year. Due to its popularity and scenic setting, the urban areas have expanded across the landscape. The topography around Park City varies from gentle to steep terrain where a mixture of low to high density housing has been built within canyons and along ridgetops. Ski resort infrastructure spans the slopes around town. A large amount of this urban growth occurred in the last 30 years. This has spurred the preservation of open space for recreation and preservation purposes. Along with this, a need to manage these lands for fire protection has arisen.

A high percentage of wildfires in the western region of the US involve homes, businesses, and critical services (e.g. power lines). With a significant population, and a large proportion of landscape in the wildland-urban interface (WUI) intermix, even small wildfires can threaten structures and increase the risk and complexity for firefighters (National Strategy). Not only are fires in the WUI harder to control for firefighters, but there are more ignitions and letting natural, beneficial fires burn becomes impossible (Radeloff et al. 2018).

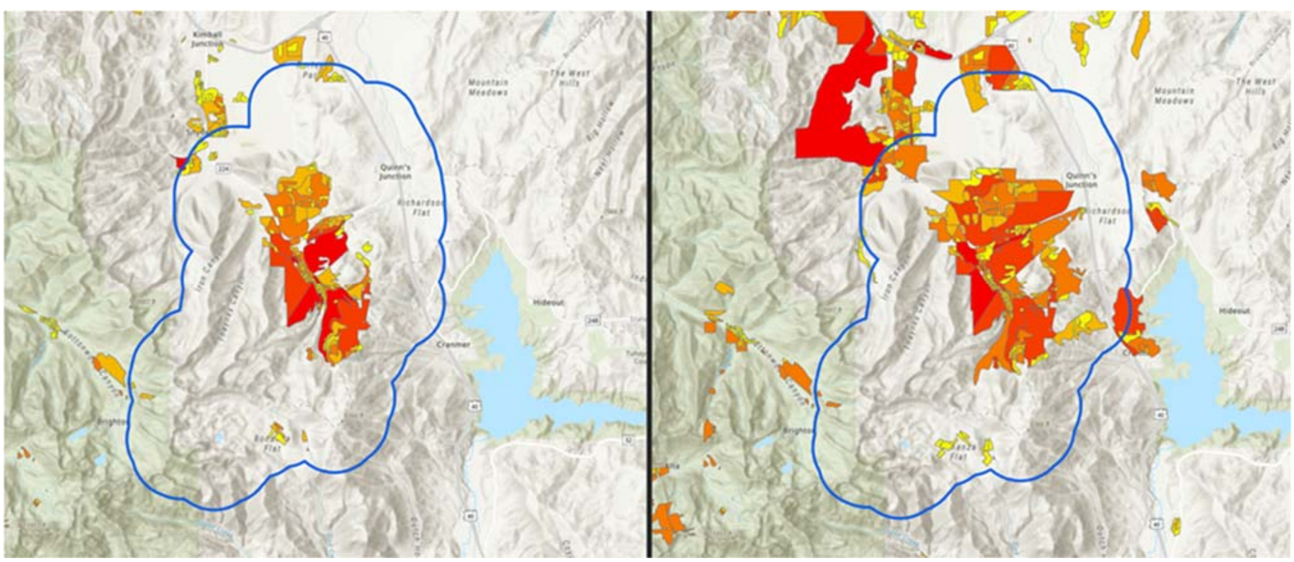

Figure 1-0-2. Park City's wildland-urban interface has expanded over 6,000 acres from 1990 (left) to 2020 (right).

Using data produced by Radeloff et al. 2022, the WUI within the risk assessment boundary (the blue line on the map) has increased by almost 6,000 acres during the period of 1990 to 2020. The 2022 Pre-Disaster Mitigation Plan projects that Summit County population growth will exceed another 20,000 people by 2050, many of which may choose to live in or near Park City. This information follows the national trend of more people choosing to live in the wildland-urban interface in the future.

Changes to Forests, Shrubs and Grassland Ecosystems

Many different types of vegetation surround Park City. Similar to other mountain towns in the western U.S., human use and development has changed forests. The resistance (the ability to resist or avoid change) and resilience (the ability to bounce back from change) of these ecosystems have adapted in a relatively small amount of time. The introduction of non-native species, such as cheatgrass, have increased the amount of damage from fire to sagebrush. Homes and recreation (e.g., trails and ski runs) fragment forests, shrub lands and grasses.

In the case of forests around Park City, past management from grazing, mining and timber removal has changed the types of trees and their density. This has resulted in a smaller average tree size as many large trees were cut down in the past. These practices, combined with a century of wildfire suppression, allowed surface fuels to build up in the form of both living and dead trees and shrubs in denser conditions.

The removal of natural fire from the landscape has led to the growth of small conifers under aspen, changing the way aspen and fire interact. In the past, fire acted as a natural method for thinning forests or removing them entirely (also known as a “stand-replacing” or “high-severity” fire). Some of the vegetation types around Park City naturally burned at high intensities with a longer time between fires. This was especially true in portions of conifer forests and some aspen groves. Unfortunately, allowing this full range of natural fire severity is now impossible with the increase in the wildland-urban interface and recreational use of the area. (The National Strategy, Fire Behavior Report, Treasure Hill Mgmt Plan).

The widespread changes to these forests have increased their susceptibility to insects and disease. Many of the insects are native but are now causing more extensive tree mortality than what was seen in the past (The National Strategy, Treasure Hill Management Plan, Fire Behavior Report, Implementation Report).

Shrub and grass vegetation types have experienced an increase in fire frequency, contributing to a rise in invasive species such as cheatgrass. This has further altered fire regimes and led to other ecosystem impacts (The National Strategy). These areas may still have an impact on nearby forests by carrying fire upslope into the trees. Declines in sagebrush due to increasing fire frequency means less forage for wildlife, a reduction in water holding capacity, and an overall reduction in biodiversity among other concerns (USU Extension Services, 2014).

What does all of this mean for our community?

While it is known that fires benefit ecosystems in their natural regimes, wildfires today are often more threatening than beneficial to communities. Impacts to communities and ecosystems include:

- threats to human health, safety, and infrastructure
- increased erosion potential,
- changes to vegetation,

- impacts to wildlife habitat,
- degradation of water quality and supply
- cost of suppressing and cleaning up after wildfires

The cost to a community to react to and recover from a wildfire can be significant. Revenue is lost as business is interrupted and portions of the population lose their livelihoods. It takes time, money and materials to rebuild as shown in other places (Mulholland, 2022; Senz, 2021). The Congressional Budget Office cited multiple studies that range from 30 million to hundreds of millions of dollars to rebuild post wildfire. These costs include insurance payments, federal assistance, or personal funding (Congressional Budget Office).

Multiple fires in the region and around Park City destroyed hundreds of structures and burned over 200,000 acres in recent years (Fire and Fuels Report, Sediment Delivery). Fire suppression costs have skyrocketed over time. The most recent data from the Parley's Canyon fire in 2022 indicates that it cost three million dollars to suppress a 541-acre fire (Fire Behavior Report).

Figure 1-0-3. Fires not only threaten human communities but also wildlife habitat and other resources.

There are other serious indirect costs associated with wildfire to water supply, wildlife habitat, and human health.

Water resources for Park City and nearby communities rely on a large portion of this area for fresh, safe drinking water. Hundreds of millions of dollars have been spent in other communities on repairing damaged water supplies and rebuilding infrastructure from fire damage and post-fire debris flows (Sediment Report).

Wildlife habitat surrounds the town and other human infrastructure (homes, businesses, hospitals, schools, power lines, resorts, places for recreation, etc.). Important mammal, bird, fish, and amphibian species make this area their home. While fire can have a positive impact on habitat, many fires today threaten it. For example, patchy fires may create foraging habitat for ungulates (e.g., deer, moose). On the other hand, the loss of large trees during a severe fire can reduce available nesting habitat for certain types of birds.

Smoke from wildfires often emit a significant amount of pollutants. This can impact all people during a wildfire event, but is often more problematic for people with underlying health conditions. Steps can be taken to reduce this impact to all of us, especially our most vulnerable populations.

Park City faces many challenges in the event of a wildfire. There are numerous resources, assets, and people potentially at risk. However, there are also proven strategies to proactively plan for and prepare the city and surrounding landscape should a fire occur.

What can we do about the threat of wildfires?

Wildfires may cause unwanted effects to the things people care about, also known as “values.” As such, it is critical to identify where fires are most likely to be the most intense, and how they may spread across a community. Information from past fire incidents and modeling programs can help explore these unknowns and identify what “values” are threatened. Once this is understood, steps can be taken to protect threatened values from wildfire using best available science and active community education and engagement.

Listed below are the individual CWRA reports with their associated goals and objectives that, when combined, provide a wider view of potential wildfire impacts to Park City. These reports describe pre-fire and post-fire mitigation strategies to prepare the city for an unplanned fire event.

1.2 How to Use This Document

This document includes sections that give an overview of areas of particular risk due to wildfires, and includes an Executive Summary, Background, Methods, Findings and Recommendations. Use The Table of Contents hyperlinks to navigate to areas that you find of particular interest. Information is presented at a broad level and not necessarily applicable at the smallest scale.

Below is a brief overview of sections and their information.

Resilient Landscapes – the potential effects of wildfire to the human environment and natural resources in and around Park City.

- Avalanche Terrain Assessment
- Post-Fire Erosion
- Stream Conditions

Fire-Adapted Communities – knowledge and perceived risk of wildfire and its impact to the Park City Community.

- Community Survey Results

Suppression Response – existing resources and their ability to respond in the event of a wildfire.

- Suppression Response Summary

Wildfire Risk Assessment – prioritizing wildfire risk in the project area

- Quantitative Wildfire Risk Assessment Process

Planning and Resources – Action steps to be taken to lessen risk in the community.

- Implementation Planning
- Implementation Guidelines

Appendices

Avalanche Terrain Assessment

Avalanches are slides of snow, rock, ice and soil that naturally occur in the mountains. However, loss of trees and vegetation can affect how often and where they occur. The goal of this report was to determine where wildfire, or removal of trees and vegetation, would likely influence avalanche activity around the community.

The objectives included:

1. Mapping locations and the extent of potential avalanche release areas (PRAs) and avalanche paths (hazard areas) around the project area.
2. Incorporating potential release areas into the Quantitative Wildfire Risk Assessment (QWRA) to understand the additional risk to the community following a wildfire.
3. Identifying areas that would need further analysis prior to forest management activities and post wildfire.

Figure 1-0-4. The force of an avalanche carrys snow and other debris, damaging anything in its path. Credit: Sawtooth Avalanche Center.

Post-Fire Sediment Delivery

The threat of wildfire does not end once the fire is out. The primary goal of the sediment delivery report is to understand the likelihood of flooding and erosion after a fire and where it may occur.

The objectives included:

1. Determining the impacts caused by flooding and erosion to residents, managers, and emergency responders.
2. Identifying the most at-risk areas and values within the project area.
3. Prioritizing and recommending locations that would benefit from proactive fuel treatments to lessen flooding or erosion impacts.

Figure 1-0-5. The effects of fire may continue long after the flames are extinguished.

Stream Health Condition

The streams, rivers, and wetlands in our watersheds are some of our most prized assets because they supply water for drinking, recreation and wildlife. The primary goal is understanding which streams and rivers are at risk for high-intensity wildfire and impacts.

The objectives included:

1. Locating areas of greatest importance (Highly valued resources and assets) to include in the QWRA,
2. Determining which water resources and habitats may benefit from mitigation.
3. Recommending responsible implementation strategies to prevent damage during wildfire.

Figure 1-0-6. East Canyon Creek.

Community Survey

The community survey provided insight and understanding of residents' views on wildfire risk and mitigation strategies. Community engagement and education empowers residents, stakeholders, and city managers alike to thoroughly plan for wildfire.

The objectives of the survey included:

1. Assessing knowledge of wildfire preparedness among residents.
2. Identifying the challenges and opportunities for mitigating hazards both around individual homes and across the WUI.
3. Determining the level of resident preparedness in the event of an evacuation.
4. Providing recommendations for further educational resources, materials, and outreach.

Figure 1-0-7. Park City Fire Department firefighters.

Wildfire Suppression Response

Safe and effective wildfire response is one of the central goals of the nation-wide wildfire strategy. Local fire departments have a big role in ensuring the response to a wildfire follows this approach.

The objectives included:

1. Assessing and summarizing the ability of the Park City Fire Protection District (PCFPD) to respond to a wildfire.
2. Developing recommendations based on industry standards and lessons learned from other fire districts in the western United States.

Quantitative Wildfire Risk Assessment (QWRA)

Fire Behavior

City managers need a proactive plan for how fire may impact the city to strengthen their emergency response strategies. The primary goal of the fire behavior report was to understand how fire can ignite and move through the area.

Figure 1-0-8. A surface fire burns through the understory of a forest.

The objectives included:

1. Analyzing and modeling where fires may ignite, how they spread, and the potential impacts to resources.
2. Rating which areas have the lowest to highest risk of fire based on model simulations.
3. Using the results to guide the Quantitative Wildland Risk Assessment (QWRA).

Fire has two sides: it can be a negative force on some things while positive for others. The QWRA helps us better understand how fire either threatens or benefits community assets and natural resources within the project area.

The objectives included:

1. Identifying important community features, also known as “Highly Valued Resources and Assets.” These typically provide essential services or hold a high intrinsic value, such as critical infrastructure and natural resources.
2. Map and rank High Value Resource or Assets (HVRA) so city managers may plan, prioritize, and implement effective wildfire mitigation strategies across a large area.
3. Determine the extent of whether fire either positively or negatively impacts or has a neutral impact on highly valued resources and assets (HVRAs) in the community.
4. Use this information to help prioritize fuel treatments.

Implementation Planning and Guidelines

The National Strategy calls for the use of fuel treatments to reduce flammable vegetation around communities. Doing so may lower fire intensity and subsequently the loss or damage of homes and businesses. The goal is to prioritize PCMC-owned lands where immediate mitigation is needed, and identify other areas where treatments could be considered in the future.

The objectives included:

1. Prioritizing areas for treatment on Park City-owned land to reduce risk in the community and surrounding area.
2. Developing maps for land use planners, fire personnel, emergency managers, resorts and homeowner associations showing areas of importance.

3. Identifying wildfire mitigation strategies and industry best practices for community members to address fire risk across multiple vegetation types common to Park City.
4. Listing potential grant opportunities to fund wildfire mitigation projects.

BEFORE	AFTER
	
	

Figure 1-0-9. Landscapes showing before and after fuel reduction treatment.

Other Resources - Education and Project Communications

This risk assessment also includes other valuable educational information and communication resources.

A community that has the most current wildfire risk information in their area is more likely to be prepared in an emergency. Identifying knowledge gaps within the community, based on community meetings and the community survey, help inform PCMC on how to target future outreach and education.

The objective was to:

1. Provide links to information from subject matter experts to help citizens better prepare for wildfire.

StoryMap

Figure 1-0-10. The CWRA StoryMap provides an overview of the project for anyone to view online.

This web-based resource provides a visual story of project development and findings for the public to access.

The objectives included:

2. Creating a web page that provides updates and key findings during project phases.
3. Developing an understandable and engaging interactive tool where the public can interact with, and better understand the project.
4. Providing an educational resource that could be expanded, updated, and improved through all stages of the project.

1.3 National Cohesive Wildland Fire Strategy

How do we determine risk?

There is always some level of wildfire risk when communities are located within surrounding wildlands. This wildfire risk assessment follows the framework provided by the National Cohesive Wildland Fire Management Strategy (The National Strategy) to highlight ways in which local government and residents can make their community safer.

The National Strategy draws upon decades of research and lessons learned from wildfire incidents and outcomes across the USA. Developed by government and non-government organizations, it recognizes how wildfire activity is changing over time and provides insight on how communities can prepare themselves. It describes a variety of mitigation strategies developed from reputable scientific findings, many of which have been tested by wildfires.

The National Strategy encourages collaboration among all stakeholders across all landscapes, using best science, to make meaningful progress towards three goals:

1. Creating Resilient Landscapes
2. Creating Fire Adapted Communities
3. Promoting a Safe, Effective, and Risk-based Wildfire Response.

Congress saw this need due to the lack of a comprehensive plan to address the threat of fire throughout the nation. The vision of this strategy is to:

"Safely and effectively extinguish fire when needed; use fire where allowable; manage our natural resources; and collectively, learn to live with wildland fire."

Resilient Landscapes

Summit County, Utah, is listed as a high priority for broad scale fuels management as well as for community planning and coordination in the National Strategy. Communities with an increased threat of wildfires must manage the forest and vegetation around them. This is particularly important for communities located in the WUI with fire-adapted native vegetation. To be effective, fuel treatments must reduce wildfire intensities under the conditions most likely to result in destruction.

The three primary means of managing fuels are:

1. Prescribed fire
2. Managing wildfire for ecological purposes and resource objectives
3. Non-fire treatments involving mechanical (e.g. thinning trees), biological (e.g. grazing), or chemical methods (e.g. use of herbicides)

Treatments can be coordinated by themselves or in combination, depending on management objectives and resource availability.

Fire-Adapted Communities

Community wildfire risk is a combination of the frequency and extent of wildfires and distribution and density of homes and other structures. Another risk factor is the susceptibility of certain people ("social groups") that may experience a higher probability of death or impacts to health, financial loss, or disruption of livelihood (FEMA). There are many programs emphasizing the importance of reducing combustible materials within the vicinity of buildings. Reducing the likelihood fire will burn next to vegetation is also one of the best ways to reduce losses. Residents and business owners can take many actions, but it is the collective action of the community as a whole that can be most effective.

The wildfire risk mapping for Summit County demonstrates a need for combining individual defensible space actions with overall community planning. Addressing these two areas is essential to reducing the loss of buildings and infrastructure that provide crucial services to the local population.

Opportunities:

1. Updating building codes
2. Reducing the chance of fire starting in the first place
3. Continued education and resources to help community members plan for a wildfire.

Safe, Effective, Risk-based Wildfire Response

Coordinating a safe and effective response to wildfire is essential. Fire department response is the last line of defense and action after a fire has started. The organized response of emergency responders is a complex, nationwide issue that is constantly being adapted to meet the challenges of each incident.

To prepare, communities are encouraged to consider:

1. Preparing for large, long-duration wildfire
2. Protecting structures and targeting ignition prevention

Park City is considered to be at "very high risk" of wildfire, higher than 93% of communities in the US (wildfirerisk.org). There is a need and an opportunity to explore tactics used in suppression and containment of fires in this area. Effective action could lead to enhanced ecological benefits, reduced firefighting costs, and perhaps less direct risk to firefighters.

1.4 Project Area

This Community Wildfire Risk Assessment (CWRA) covers approximately 33,000 acres around the Park City urban core and Bonanza Flat. The project area is located in western Summit County, much of which falls within the response area of the Park City Fire Department.

The project area covers the lands around what is called the "Park City Urban Core." Models for fire behavior and spread have not been fully developed for urban areas, but the assessment does use the most up-to-date available information to determine fire behavior in natural vegetation types and WUI surrounding the city.

The primary purpose of this risk assessment is to determine how the following either affect, or are affected by, wildfire within this area:

- Critical city services
- Social, economic, and ecological values
- Post-fire sediment delivery
- Avalanche hazards
- Emergency access, response, and human safety

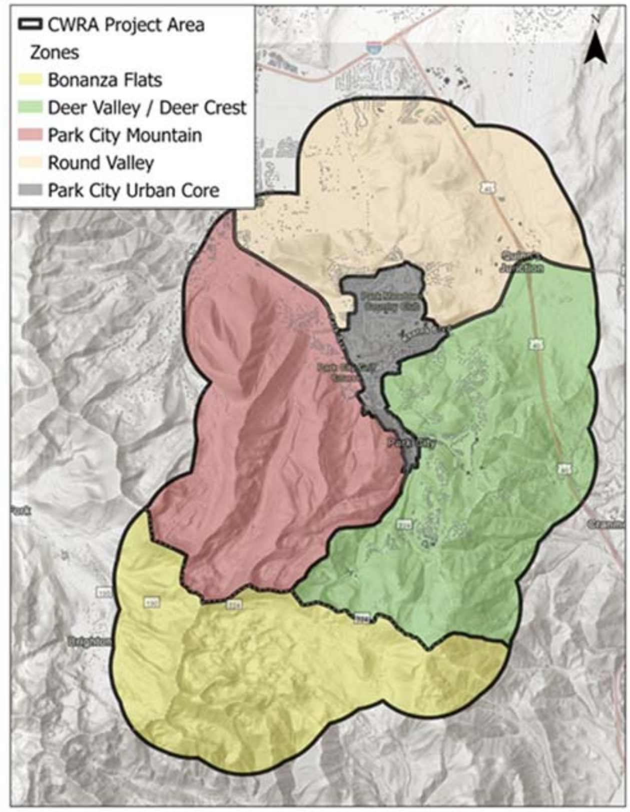

Figure 1-0-11. The CWRA project area with project zones identified.

The report also provides information about fuel treatments, a review of wildfire suppression and response and educational resources.

1.5 Local Climate

The Park City area tends to have hot and dry summers with minimal precipitation. There can be occasional rain from monsoons, but this moisture quickly evaporates due to the high temperatures and low humidity. The winter months bring most of the area's precipitation in the form of snow. Flooding can be a concern in the months of May and June due to snow melt.

Like many mountainous areas of the west, climate change is causing average low temperatures to elevate, which increases wildfire risk. Drought has been a concern in this area, as well. The loss of snowfall combined with continuing drought will contribute to increased wildfire risk over the next decade and for years to come.

Figure 1-0-12. Park City depends on snowfall for many reasons, notably recreation and drinking water. (Photo of Park City Resort).

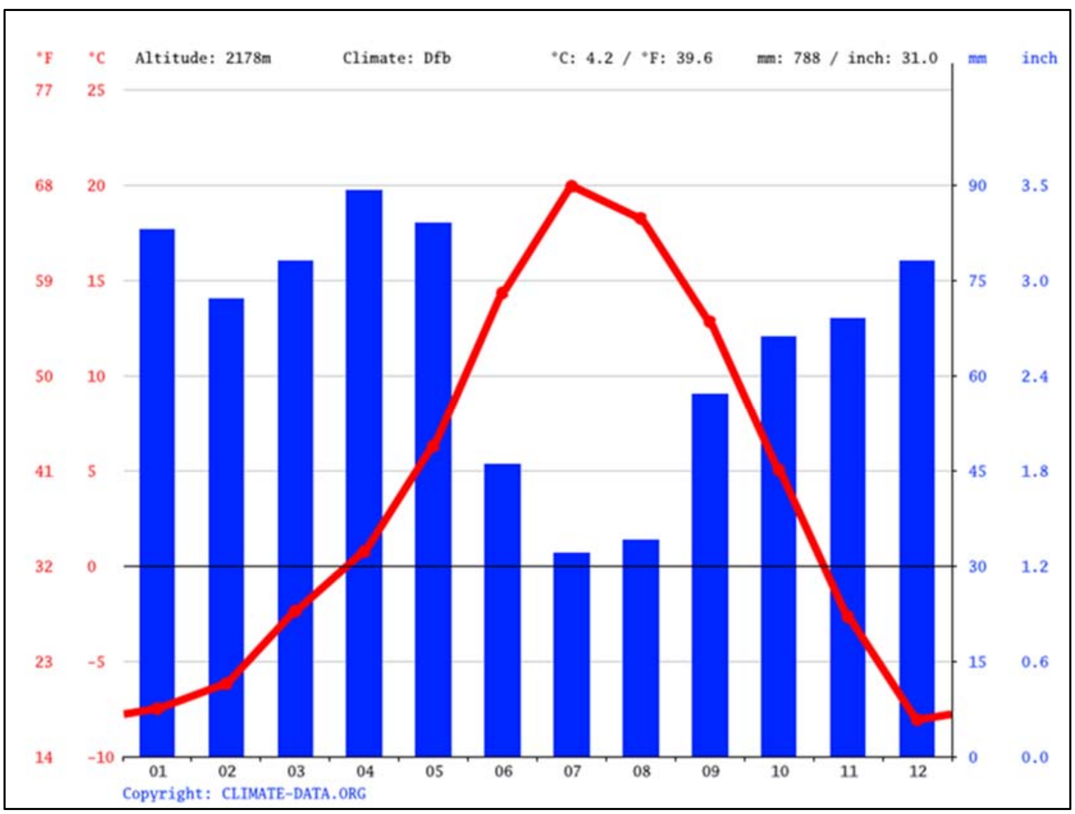

Figure 1-0-13. Average temperature and precipitation for Park City, Utah.

Of special note is how the climate may be impacted by changes to water levels in the Great Salt Lake. Snowfall in the Wasatch is enhanced by “lake effect” snow. While the southern Wasatch around Big and Little Cottonwood Canyons receive the greatest impact, it does enhance snowfall in the Park City area as well. Researchers at Brigham Young University recently released a report showing the lake at 37 percent of its former volume. Drought brought on by climate change and overconsumption is contributing to rapid declines in the lake level. According to this report drafted by more than 30 scientists from 11 universities, unless drastic action is taken to cut the amount of water used by the state, the lake will go completely dry within five years (Kaplan & Dennis, 2023).

1.6 Project Team

The Consultants who worked on this project and produced this report consist of four organizations with extensive expertise and experience in wildfire analysis, ecological sciences and forestry. They include the following organizations.

ALPINE FORESTRY

Alpine Forestry is uniquely situated to address the threat facing the Northern Utah mountain community. They possess more than 100 years of experience specializing in fire and emergency response, forestry and GIS mapping. Their detailed, systematic approach to their work provides communities and homeowners with relevant recommendations and quality results. Their mission is to assist homeowners and community members with producing a healthier forest while mitigating the risks of wildfire. Alpine played a critical role in fire behavior modeling and avalanche risk with the CWRA.

The Alpine forestry staff includes:

- David Telian – Co-owner, Fire and Fuels Specialist, Suppression Response and Implementation Planning
- Matt Castellon – Co-owner, Fire and Fuels Specialist, Suppression Response and Implementation Planning
- Reba Broyles – Logistics and Technical Review
- Robby Young – Avalanche Specialist and GIS analyst, Avalanche Terrain Assessment
- Alan Spadafora -- Operations Manager and GIS analyst, Implementation Planning
- Katharine Napier-Janz – Forester, Implementation Planning
- Brad Washa – Consulting Fire and Fuels Specialist, Fire Behavior Report, Quantitative Wildfire Risk Assessment

Blue Mountain Environmental Consulting (BMEC) provides services in resource management, conservation planning and wildfire mitigation. Their goal is to achieve project outcomes in an efficient and responsible manner by providing scientific expertise within a regulatory framework. They seek to help property owners and managers achieve their goals and outcomes while sustaining the environment. BMEC coordinated most of the planning for the final report by leading the communications and outreach for the CWRA.

The BMEC staff working on this project includes:

- Matt Tobler – Director, Planning and Report Production
- Leslie Brodhead – Wildfire Mitigation Specialist, Community Engagement Lead
- Brett Haberstick – Wildfire Specialist, Suppression Response
- Amy Randell – Technical Writer, Report Production

The Ember Alliance (TEA) is a nonprofit dedicated to socially just fire management and community engagement that supports people, landscapes, and the planet. TEA consists of the Resilient Communities and Forests team and the Fire Operations Team. The TEA team has over 70 years of combined fire experience and wide-ranging knowledge and technical expertise, including wildfire pre-planning, fire behavior modeling, fire adapted communities, collaborative decision-making, outreach and education, design and implementation of fuel treatments, and forest ecology. TEA played an important role in coordinating impacts to post-fire landscapes, human health risks and community survey feedback.

The ETA staff who assisted include:

- Brianna Baker – Program Director, Project Coordinator
- Stacy Armbruster – Program Manager, Community Survey Coordinator
- Meg Matonis – Senior Wildfire Analyst, Post-fire landscapes
- Kenzie Hartt – Wildfire Analyst, StoryMap Coordinator

Sageland Collaborative is a non-profit organization that facilitates conservation in Utah of wildlife habitat and open lands. Their philosophy includes addressing obstacles to effective conservation through providing data based on science. They believe wildlife and its habitat can be conserved when data informs decision-making by stakeholders and other decision makers. Sageland provided critical data to the CWRA on stream side habitats.

The Sageland Collaborative staff includes:

- Janice Gardner – Conservation Ecologist, Stream Condition Surveys
- Rose Smith-Stream - Ecologist, Stream Condition Surveys

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2.0 Resilient Landscapes

In This Chapter

2.1 Avalanche Terrain Assessment

Executive Summary

The identification of potential avalanche release areas is necessary to account for elevated or newly created avalanche hazard following wildfire or forest management activities. Avalanches and wildfire have a relationship within the forested and subalpine mountain environments; both have the ability to alter landscapes and cause forest fragmentation, where the occurrence of one natural disturbance may potentially alter the magnitude and frequency of the other (Bebi et al., 2009).

Forest structure can offer protection from avalanche release, both mechanically through anchoring plant stems and through localized thermodynamic influences on snowpack processes (Bebi et al., 2001), also known as a 'protective effect.' Forest fragmentation by fire has shown over recent history that it can increase the frequency and/or magnitude of avalanche events, in examples both studied (Germain & Hetu, 2005; Campbell et al., 2019) and observed. In communities that reside within the mountain environment where avalanches are possible, the introduction of new or additional avalanche hazard through forest fragmentation or destruction may prove to elevate the avalanche risk to adjacent infrastructure and to public safety. For this reason, the identification of potential avalanche hazard is an integral part of this Quantitative Wildfire Risk Assessment (QWRA).

Figure 2-0-1. An avalanche within the project area (Homelite - 2019).

Goals and objectives of this avalanche hazard indication assessment include:

1. Develop geospatial datasets that identify avalanche potential release areas (PRAs) and avalanche paths (hazard areas) for forest management and silvicultural planning.
2. Develop geospatial datasets of the release areas and hazard areas to trigger a hazard analysis if forest management activities are desired, or if a fire were to occur in the future.
3. Incorporate applicable PRAs into the QWRA that may introduce additional risk to the community in a post-fire setting.

In total, 249 active PRAs and their corresponding avalanche paths / hazard areas were identified within the PCMC project area (33,074 acres). An additional 208 PRAs were identified that possess some level of 'protective effect' from forest and vegetation composition. The areas are stored as geospatial data and displayed in the maps contained within this assessment. Where community habitation, infrastructure, or high-use recreation areas may be vulnerable to additional avalanche hazard in a post-fire setting, the corresponding PRAs were incorporated into the Highly Valued Resources or Assets (HVRA) datasets as inputs to the QWRA

Background

Wildfire risk assessments and fuels treatments have, historically, remained independent of avalanche hazard assessments within the United States. However, with continued and/or accelerated development in mountain communities in recent years, combined with the growing risks of wildfire associated with long-term drought conditions and climate change (USGCRP, 2018), it is important to view natural hazard management practices through a multi-hazard field of view. Avalanches, wildfire and forest-altering management practices all can alter forested landscapes, increase forest fragmentation and subsequently change the frequency and magnitude of other interacting natural hazards.

Figure 2-0-2. Aerial view of forest destruction and fragmentation resulting from frequent avalanche activity.

Interaction of avalanches and forest composition has garnered attention in research, most frequently regarding the risks to economic resource loss in the timber harvesting industry, as well as within the role of public safety as 'protection forest' management practices are being used as mitigation measures for mountain communities, most notably in the European Alps (Brang et al., 2006). Much of what has been studied and is widely accepted has been developed for these other purposes listed above; however, a foundational forest-avalanche interaction knowledgebase can be applied across forest management practices with a variety of desired project outcomes.

Figure 2-0-3. Post-fire wet slab avalanche that impacted an unoccupied home (Sawtooth Avalanche Center).

Structural Support of the Snowpack – Tree stems of adequate durability and arranged with sufficient stem densities may provide structural support against snow slab release within release areas. Durable tree stems also affect flow velocities and play a role in debris detrainment within tracks and runouts of active avalanche paths for small- and medium-sized avalanches, up to threshold impact pressures (Bartelt & Stockli, 2001). In addition, recently developed Avalanche Terrain Exposure Scale (ATES) methodologies have proposed forest categories based on both stem densities and spacing (Campbell & Gould, 2016). Following wildfire, stem densities may retain some of their protective effect on avalanche release; however, as stems decompose, the protective effect is lost over time prior to forest regeneration. For hazard indication mapping at a landscape scale, stem-density data is difficult to quantify at the necessary resolution and is more easily incorporated into the hazard analysis phase of an assessment at the avalanche path/slope scale.

Canopy Cover - Criteria for 'protection-forests' used as mitigation methods to protect life and infrastructure are also determined by percentage of canopy cover, and criteria for protection have been proposed and implemented (Table 2-1). Where sufficient canopy cover is present, localized thermodynamics within and above the snowpack surface is affected by forests and their canopy cover. Sufficient canopy cover (%) results in less snow accumulation on the ground and a diminished ability to develop persistent weak snow grain types such as facets and surface hoar. For large-scale hazard indication mapping, canopy cover (%) is both quantifiable and easily obtained through remote sensing techniques. European protective forest management offers numerous correlative guidelines between canopy cover (%) and 'protective effect' for both total canopy cover for all tree species (TCCP) and for only evergreen species (WCCP) (Table 2-1).

Table 2-1. For all tree species, total canopy cover percentage (TCCP) and for evergreen species (WCCP) offering 'high' levels of protection according to NaiS European protective forest management guidelines (Frehner et al., 2005).

Guideline	NaiS	SFP	GSM-N
Level of Protection	"high"	"high"	"high"
Slope	TCCP	TCCP	WCCP
≥30°	>50%	>50%	>50%
≥35°	>50%	>50%	>50%
≥40°	>50%	>50%	>70%

While stem and canopy criteria may be implemented in assessing a forest's protective efficacy against avalanching, the complex interactions between ecological condition, snowpack complexities and meteorological conditions will result in variability in the 'protective effect.' The datasets created within the scope of this project are primarily focused on PRAs, where the prevention and limitation of avalanche initiation (release) by vegetation and forest composition is the most efficient and important protective effect that forests provide against avalanche hazards.

Methods Overview

A generalized framework for assessing avalanche hazard is shown in Figure 2-0-4, in accordance with the Canadian Avalanche Association Avalanche Hazard Assessment Framework (CAA, 2016), with 'Hazard Identification' being performed for the PCMC QWRA. The following data sets and modeling processes were utilized to identify *potential release areas* and *avalanche paths*:

- Written and Oral Avalanche History
- Climatology
- Snowpack Analysis
- Modeling Process 1: Development of Potential Release Datasets
    - Terrain Modeling – Digital measurements of terrain parameters
    - Forest Canopy

        - Multi-Resolution Land Characteristics Consortium
        - Tree Canopy Cover (%)
        - Normalized Difference Vegetation Index
    - Ground Roughness / Vegetation Height
        - Landfire (EVH)
        - Vegetation Height (VHM)
- Modeling Process 2: Avalanche Hazard Area Indication
- Hazard Area Runout Modeling (TauDEM)
- Numerical Dynamic Modeling (RAMMS)

(For the PCMC QWRA project area, as in much of North America, historical avalanche records, dynamic model calibration and long-term documentation of snow and weather information is limited and presents challenges for high-confidence modeling of avalanche hazard when methodologies are used in isolation. However, with digital mapping techniques and the combination of the above methodologies avalanche hazard identification within the project area is possible at the regional scale (1:15,000).

Detailed methods are available here

Figure 2--0-4. Generalized framework for Avalanche Hazard Assessment (CAA, 2016).

Key Findings

All the geospatial datasets (shapefiles) identified within this hazard identification are intended to trigger a subsequent hazard analysis based upon the hazard assessment framework, Figure 2-0-4 (CAA, 2016), where forest health, fuel reduction or silvicultural activities are proposed. In addition, the datasets produced here within may provide further guidance or indication of need for an avalanche hazard assessment in a post-fire setting, if future fire were to occur within the project area. The datasets developed in this assessment are organized into the following four categories:

1. Potential Release Areas (Active) – PRAs that have been determined to be sufficient for avalanche release based on a digital and manual delineation outlined in the Methods Overview section. Many of these PRAs have been validated as 'active' based on observed and recorded avalanche occurrences and consultation with local avalanche professionals.
2. Potential Release Areas (Forest-Protected) – PRAs that meet slope and terrain curvature criteria but possess forest canopy cover >50%. Canopy cover is largely a result of conifer forest; however, some areas of mixed deciduous and conifer were considered to meet this criterion. While forest avalanching is possible, a significant reduction in frequency is notable (McClung, 2001; Schneebeli & Bebi, 2004).
3. Potential Release Areas (Roughness-Protected) – PRAs that meet slope and terrain curvature criteria but possess robust hardwood shrub ground cover at heights that, on average, exceed expected design release depths (drel). These areas are very infrequent or inactive avalanche release areas, that typically require anomalous or atypical snowpack conditions to allow for avalanche release.
4. Avalanche Hazard Areas – When PRAs were categorized as 'Active,' modeled track and runout areas were identified utilizing topographical runout and/or numerical runout modeling.

While the recommended outcome is the same for all four (4) categorical datasets; guidance and methodology for a subsequent avalanche hazard analysis may differ based on this initial categorization.

Potential Release Area Datasets

PRA datasets are displayed spatially in the Avalanche Hazard and Release Area Indication Maps. Naming criteria includes a location ID, PRA 'qualifier' and a unique numerical ID that matches the ID of its associated avalanche hazard area, if applicable. An alphabetical sub qualifier is used when more than one PRA are located within the same avalanche hazard area. For example, a forest-protected PRA with no associated avalanche hazard area will contain a location ID and a numerical ID (>250), i.e., THYNPRA312. An active PRA in a large avalanche hazard area containing multiple PRAs will contain all the naming criteria shown in Table 2-2 (i.e., SNKPRA30b).

Table 2-2. PRA naming workflow.

<table>
<tr><th colspan="2">LOCATION ID</th><th>PRA</th><th>UNIQUE NUMERICAL ID</th><th>ALPHABETICAL ID*</th></tr>
<tr><td>Big Cottonwood Canyon</td><td>BCC</td><td rowspan="16">PRA</td><td rowspan="16"># (1-249) - Matching Associated Avalanche Hazard Area

(250-458) - Forest / Roughness Protected</td><td rowspan="16">a-z</td></tr>
<tr><td>Bonanza Flats</td><td>BNZ</td></tr>
<tr><td>Caribou Basin</td><td>CAR</td></tr>
<tr><td>Daly/Empire Canyon</td><td>DALY</td></tr>
<tr><td>Deer Valley Resort</td><td>DV</td></tr>
<tr><td>Iron Canyon</td><td>IRO</td></tr>
<tr><td>Lavina Creek</td><td>LAV</td></tr>
<tr><td>Mayflower Resort</td><td>MAY</td></tr>
<tr><td>Ontario Canyon</td><td>ONT</td></tr>
<tr><td>Park City Mountain Resort</td><td>PC</td></tr>
<tr><td>Pine Creek</td><td>PIN</td></tr>
<tr><td>Snake Creek</td><td>SNK</td></tr>
<tr><td>Thaynes Canyon</td><td>THYN</td></tr>
<tr><td>Silver Creek Corridor</td><td>SIL</td></tr>
<tr><td>Drain Tunnel Creek</td><td>DRN</td></tr>
<tr><td>White Pine Canyon</td><td>WP</td></tr>
</table>

* *Optional when >1 PRA lies within same Avalanche Hazard. Area*.

A complete tabular list of avalanche hazard areas and PRAs are included in Section 2.2.

Avalanche Hazard Area Indication

Avalanche hazard areas are displayed spatially in the Avalanche Hazard and Release Area Indication Maps and are provided naming criteria (Path ID) with a locational identifier and a unique numerical ID organized from west-east (ex. MAY225). Where a known avalanche path or area has a formal name, that name is used in place of the path ID in the maps. Named paths are also provided a unique path ID within the geospatial dataset attributes.

Table 2-3. Avalanche Hazard Area naming workflow.

LOCATION ID		UNIQUE NUMERICAL ID
Big Cottonwood Canyon	BCC	# (1-249)
Bonanza Flats	BNZ	
Caribou Basin	CAR	
Daly/Empire Canyon	DALY	
Deer Valley Resort	DV	
Iron Canyon	IRO	
Lavina Creek	LAV	
Mayflower Resort	MAY	
Ontario Canyon	ONT	
Park City Mountain Resort	PC	
Pine Creek	PIN	
Snake Creek	SNK	
Thaynes Canyon	THYN	
White Pine Canyon	WP	

Limitations and Uncertainty

Weather and Climate: Weather and climate, injecting uncertainty into any assessment by nature, are two primary factors affecting avalanche behavior. The effects of recent climate change on avalanches have been a topic of recent avalanche research (Bellaire et al., 2016; Eckert et al., 2013; Sinickas, 2016) and records from recent history show a shortening of winter seasons and a decrease in snowpack depths, particularly at lower elevations, with Park City particularly susceptible to early snowpack-related climatological change given its elevation (Steenberg, 2014). These trends are expected to continue and a change in avalanche behavior is anticipated. Whether this alters or eliminates avalanche hazard in lower-elevation areas of the project area is very difficult to project, and incorporation of anticipated climatological changes was not performed in this assessment.

Avalanche Hazard Mitigation Programs: The project area includes some or all of three ski resorts that actively perform avalanche mitigation activities as part of their operation. While information gathered from local avalanche mitigation activities was incorporated into this assessment, the identification of avalanche hazard areas was done as part of a project-wide systematic approach, and considerations of avalanche mitigation programs were omitted. Avalanche mitigation operations are typically only performed during a specific operational period, and as occurred during the COVID-19 shortened ski season of 2020, may be suspended during the winter season. Observed avalanche path extent, vegetation and trim line observations and other pertinent data for avalanche hazard identification may be altered due to the frequency of mitigation work performed and the assumed associated reduction in large-magnitude event frequencies.

Terrain: Numerous PRAs and avalanche hazard areas identified within the project area are unlikely or very infrequent producing release areas due to the ground roughness provided by hardwood shrub ecosystems and snow-supply limitations. In above-normal snowpack conditions these areas may become active as deep snowpacks smooth terrain and depths exceed vegetation height. Temporally, this may only occur over centuries. The changes in individual slope characteristics due to this winter snowpack coverage are difficult to evaluate and inject uncertainty into this assessment and will continue in later phases of hazard analysis and evaluation, if performed.

Resolution: Given the scale, resolution and size criteria of the PRA dataset, small slopes were omitted from this analysis. Terrain traps, cutbanks and other small avalanche hazard areas may pose a risk to humans in extreme conditions and may have been omitted due to geographical scale and extent of this project.

Validation

Previous region-wide avalanche hazard mapping efforts have not been performed within the project area. Avalanche path identification has been performed as part of avalanche mitigation documentation within the operational footprints of the Park City ski areas. While consultations with local avalanche professionals have broadly supported PRA-detection efficacy, digital (pixel-scale) validation of the delineation methods is not possible; the ski areas within the project area do not have PRAs mapped in geospatial datasets. Qualitative validation of PRAs with these local experts was performed between June and August of 2022, and included avalanche technicians at Deer Valley, Park City and Brighton ski resorts. Formal names of avalanche paths (avalanche hazard areas) were also synchronized with local ski-area nomenclature based on these personal communications.

Outside of this project, validation of the auto-generative methodologies used in this assessment is ongoing as large-scale avalanche hazard mapping techniques are being continually refined across regions of North America, Europe and Asia.

Recommendations and Conclusion

Under the scope of this project, the potential for avalanche hazard is outlined utilizing authoritative digital resources, covering a large area (33,074ac) where field surveys would prove to be time-exhaustive and costly. The datasets produced will allow for more thoughtful and responsible forest management planning, all working towards the goal of building more fire-resilient communities while minimizing additional risk from interacting avalanche hazard. As part of the PCMC QWRA, avalanche hazard area and PRA geospatial datasets serve as an indication of potential hazard and are intended to trigger subsequent hazard analysis where desired forest management treatments and avalanche hazard/release areas spatially overlap. The same recommendation applies to the project area in a post-fire setting if wildfire were to occur; particularly where changes in avalanche behavior are anticipated near community values and resources.

Forest management activities and wildfire share similarities in how they may affect the forest-avalanche relationship. Further hazard analysis in the event of planned silvicultural treatments or wildfire should be performed at higher resolution, at the PRA/hazard area scale and should evaluate anticipated or observed changes to:

- PRA size resulting from deforestation or stem density reduction
- Anchoring stem density (by species) within a PRA
- Canopy cover (%) within a PRA
- Wind-loading index resulting from deforestation adjacent to PRAs
- Ground roughness provided by hardwood shrub ecosystems
- Forest conditions affecting flow regimes and detrainment potential in track and runout areas

- Dynamically simulated runout extent, flow heights, velocity and impact pressures prior to and following forest alteration (Campbell et al., 2019).

Methods Detail

Written and Oral Avalanche History

Historical avalanche events offer valuable information about individual avalanche paths that can be integrated into large-scale hazard indication mapping. Within the PCMC project area, recorded avalanche events and their spatial extent, if known, were used to validate the project-wide digital methodologies, validate snowpack and snow-supply calculations (particularly at low and mid elevations), and in some instances help refine avalanche hazard area extent based on known impacts to historical structures.

Figure 2-0-5. Written and oral avalanche history. Photo credit (Park City Historical Society and Museum).

Park City underwent rapid development in the late 1800s due to precious metal mining strikes, and because of town expansion and mining infrastructure development, much of the forest and vegetation was removed to accommodate construction and for burning firewood. Historical photos during this era are plentiful, all showing nearly bare hillsides around the historical district of Park City and up adjacent canyons (Empire, Ontario, Walker and Webster among others). Rapid growth, deforestation and a deficit of avalanche knowledge resulted in numerous buildings impacted and many lives lost during the early part of Park City's mining history. As a result, written records of avalanche events in the area are plentiful; however, reference to spatial extent is minimal and therefore PRA and path extent derived from historical records is only relevant for a small percentage of the avalanche paths within the project area. Additionally, widespread deforestation has made avalanche path delineation difficult to discern based on the forest characteristics typically found in avalanche hazard areas. Indicative stem densities, species diversity and historical tree damage records within old-growth stands have been altered by deforestation, masking many of the signals of historical avalanche occurrences that predate the mining-boom of the late 1800s.

Limited path information may be inferred by locating historical structures and sites that were impacted using a variety of resources including historical photography, Sanborn Insurance Maps (University of Utah, Marriott Library; 1889, 1900, 1907), US Census Records and Park Record newspaper archives (since 1880). A summary of notable events, some of which have validated refined Avalanche Hazard Area extent include:

Jan 1, 1884	Treasure Hill	Residence of T.A. Clark impacted on Woodside & 3rd Ave (now 5th). Citizens warned about cutting trees on Treasure Hill. (PRA identification codes PCPRA372, PCPRA370)
Feb 18, 1884	Ontario Canyon	Mrs. Harris & 3 children (Reich family) were killed, multiple homes destroyed (Unknown PRA on the West side of Ontario Canyon, where terrain has been significantly altered)

March 1884	McHenry Canyon	Mine buildings destroyed at the Hawkeye Mine & Lowell Shaft (DV235, DV245)
Jan 21, 1886	Empire Canyon	Mr. & Mrs. Peterson killed in their home
Jan 30, 1886	Thaynes Canyon	Near the Crescent Mine, 6 miners swept into Thaynes Canyon below, 4 killed (PC124)
Jan 7, 1888	Caribou Gulch	Avalanches at Himalayan and Rochester Mine buried 3 miners, 1 (Joe Baxter) killed
	Anchor Mine	Bunkhouse and half of the boarding house swept into canyon below, sweeping away half the men in an active card game in the boarding house (Daly Bowl / Chutes). DALY MINE (#1); Engine room impacted with one injured (DV183 - Lady Morgan Area)
Feb 19, 1897	Woodside Gulch	Silver King Mine boiler room smashed, 2 buried and survived (Berg's Bowl North)
Mar 12, 1897	Empire Canyon	Daly Mine (#1) hit, destroying two (2) bunkhouse and a boarding house, burying 9 miners, 4 killed. (DV-183 - Lady Morgan Area)
Jan 31, 1903	Empire Canyon	Hillside behind Quincy Mine released, destroying the hoist, burying nine (9) miners and killing three (3). Avalanche wrapped around the 'prow' towards the Daly West Mine, and nearly hit the Little Bell Mine to the south. (DVPRA353)
Dec 29, 1916	Empire Canyon	Francis Trythall killed collecting firewood near the Daly West mine
Mar 10, 1916	Park City	Alma Kimball killed while attempting to 'blast' cornice above the Crescent Mine Road (PC178, PC180 - Rocky Point)
Feb 10, 1949	Empire Canyon	Herbert Savage buried and killed 'just above the last home in Empire Canyon (DALYPRA374)
Dec 31, 1965	Park City	Three (3) buried while inbounds skiing at Park City Mountain (Treasure Mountain), 1 killed (PC179 - Berg's Bowl North)
Feb 18, 1984	Big Cottonwood Canyon	Skier (Lane) buried and killed (BCC14 - Lane's Leap)
Mar 19, 1985	Park City	One skier buried and killed after out-of-bounds skiers ducked into closed area and triggered wet slab avalanche on open terrain below (PC168 - Gobbler's Knob)
Feb 17, 1986	Big Cottonwood Canyon	Snowboard (Brad Lindsey) buried and killed, Utah's first snowboarder avalanche fatality (BCC2 - Brighton Hill)
Feb 26, 2004	Empire Canyon	One snowshoer caught, carried and killed. (DALY194)
Mar 3, 2004	Empire Canyon	Close call with snowboarders in the path immediately adjacent to the Feb 26 fatality, with debris reaching the roadway (DALY197)
2002, 2007, 2012	Park City	Three notable wet slab avalanche cycles along the Crescent Ridge including Gobbler's Knob (PC168) and Rocky Point (PC180) reaching modern observed extents, altering vegetation. (Sauer, 2014)
Jan 2017	Iron Canyon	Numerous avalanches triggered on a buried surface hoar layer within Iron and White Pine Canyons; most notably occurring as low as 6600

feet above mean sea level. (Iron Bowl #2 – IRO106 & Sharp's Bowl – IRO69)

Climatology

The PCMC project area lies within the Northern Mountain Utah Climate Division (#5). The climate is categorized as humid continental, with warm to hot summers and cold (sometimes severe) winters with significant snowfall. Categorically, the region is considered wet all year; however, due to the seasonal positioning of the polar jet stream, northern Utah receives more precipitation during winter months as strong Pacific storm systems pass through the region from the northwest (Gillies & Ramsey, 2009). These factors have led to the Wasatch Range (and Park City) becoming notorious with abundant snowfall and winter recreation, specifically alpine skiing. Subsequent development of the region has been driven by the demand for mountain recreation since the post-mining era began.

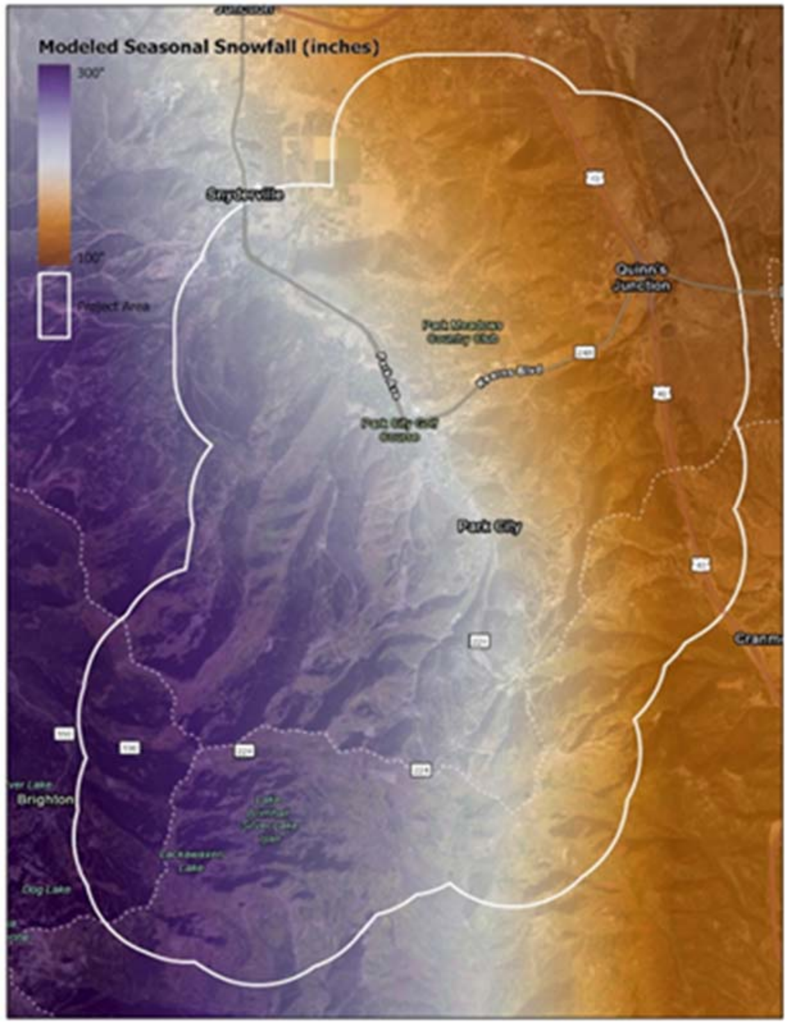


Figure 2-0-6. Modeled seasonal snowfall. Created from data sourced from the National Gridded Snowfall Analysis program; resampled to 50m GRID using cubic interpolation for visual efficacy. Data derived from existing snowfall data observations as well as quantitative precipitation estimates from forecasting models (water year 2009-present).

Local climatology plays an important role in snowfall amount and distribution, and subsequent avalanche behavior (frequency and magnitude). The project area, while relatively small in aerial coverage, sees a marked change in seasonal precipitation amounts (specifically winter snowfall) from the western boundary to the east due to an overall decrease in elevation, as well as its positioning within the rain/precipitation shadow of the greater Central Wasatch Mountains. Avalanche behavior varies as a result. As an intermountain snow climate, the Wasatch Range exhibits the avalanche characteristics of both a maritime and continental climate from year to year, and often within a single season. Early season snowfall often develops into weak faceted snow, occasionally resulting in persistent avalanche failure planes near the ground surface persisting into the latter part of the winter season. In winters of average or above average snowpack conditions, early-season weak layers typically become dormant, strengthened through metamorphism, compression and insulation under a strong and deep overlying snowpack. Given the lesser snowfall of the Park City area, early-season weak snow development tends to persist for longer periods than the central portion of the range, just a few kilometers to the west.

Snowpack

Figure 2-0-6 shows a modeled visual representation of seasonal snowfall accumulations derived from the National Oceanic and Atmospheric Administration's 'National Gridded Snowfall Analysis.' This program incorporates observed snowfall data as well as quantitative precipitation estimates derived from forecasting models (NOAA, 2022). While data included in this dataset covers the previous 13 water-years, it is noted that the drought conditions currently in place across Utah result in an underestimation of seasonal snowfall totals; however, useful derivation of local climatology related to precipitation decrease per unit elevation was still inferred from this data.

Table 2-4 summarizes the location and snow depth data from three (3) snow observation sites utilized in this assessment. As is the case in most of North America, long-term snowfall data is not available. These three sites do not meet the minimum number of sample years (n=30) preferred for a long-term extreme value statistical analysis; however, additional data points within the sample period were used in the statistical analysis of the Thaynes Site to meet the 30-year criteria. Given the period, and the scope of this project, nearly 30 years of record provide confidence in a 30-year estimation, with greater uncertainty in the estimation of a 100-year snow supply (presumably underestimated).

From these sites, design avalanche release depths were calculated using a Gumbel extreme-value distribution of annual maximum three-day change in height of snow (ΔHS3), to determine release depths (drel) at 30- and 100-year intervals (Salm et al., 1990). While a frequency analysis for individual avalanche paths was not considered in this hazard indication assessment, calculated release depths at designated elevation bands will incorporate a more accurate depiction of runout extent by elevation in the 'Hazard Indication Maps' produced here within; specifically, those that were modeled dynamically where release depth inputs effect avalanche runout extent (Section 2.2.3.5). In addition, estimated release depths allow for a maximum destructive potential (release mass and volume) calculation, used further to filter out PRAs that are not large enough to be deemed harmful to humans or infrastructure (<D2). Design release depths calculated from each snow observation site were averaged and spatially categorized by elevation as shown in Table 2-5.

Table 2-4. Snow observation site summary.

SITE	ELEVATION (FT/M)	SNOW DEPTH (M)	
		Annual Maximum Average	Range of Annual Maximum
Parleys	7,585/2,312	1.17	0.8 – 1.56
Brighton	8,766/2,671	1.51	1.0 – 2.62
Thaynes	9,230/2,813	1.65	0.9 – 2.83

Table 2-5. Calculated design release depths (d_{rel}) for the Project Area at different elevation bands. All design release depths are slope-adjusted to 28 degrees and presumed to be leeward.

		PARLEYS SUMMIT (7,585 FT)	BRIGHTON (8,766 FT)	THAYNES (9,230 FT)	AVERAGE
Return	Elevation (ft)	Design (m)	Design (m)	Design (m)	Design Depth (m)
30-year	< 7,500	0.97	0.82	0.74	0.84
	7,500 – 8,500	1.12	0.96	0.89	0.99
	8,500 – 9,500	1.37	1.21	1.13	1.24
	> 9,500	1.61	1.46	1.38	1.48
100-year	< 7,500	1.14	0.97	0.89	1.00
	7,500 – 8,500	1.28	1.12	1.04	1.15
	8,500 – 9,500	1.53	1.36	1.28	1.39
	> 9,500	1.78	1.61	1.53	1.64

Modeling Process 1: Potential Release Area (PRA) Delineation

Automatic PRA delineation has been the subject of recent avalanche research, and methodologies have been proposed and refined by several practitioners including Magioni and Gruber (2003) and Buhler et al. (2013). While the foundational sequencing of GIS functions described throughout this area of work shares similarities, tailoring the process for the project scope, mapping scale/resolution and goals/objectives is warranted. In the case of avalanche hazard indication mapping for the PCMC QWRA, forest parameters were both categorically utilized and omitted in the auto-generation of PRAs, to further evaluate PRAs for the following scenarios:

1. Altered avalanche behavior in a post-fire setting (QWRA input)
2. Altered avalanche behavior for forest-management and silvicultural activity planning
3. Existing avalanche hazard areas under current forest/vegetation composition

For the scope and objectives of this project, the GIS-based PRA delineation workflow is outlined below (Figure 2-0-7).

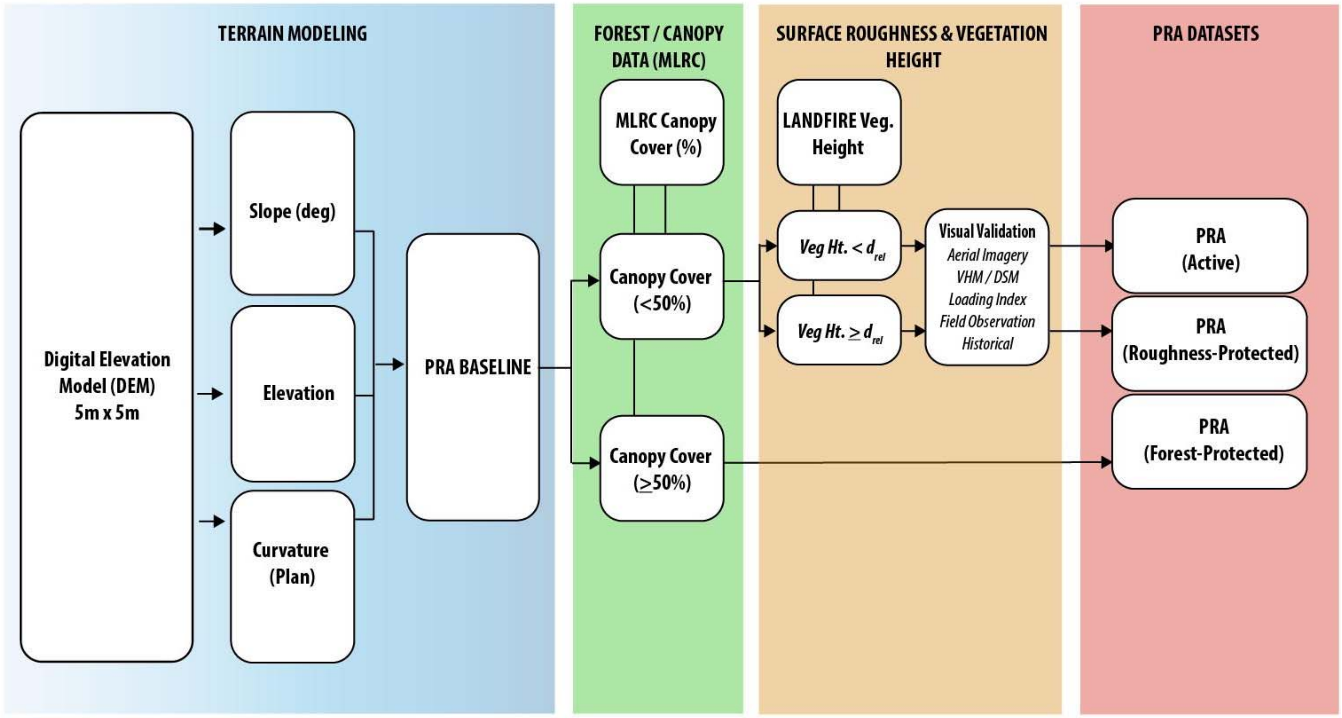


Figure 2-0-7. Simplified PRA-delineation workflow.

Terrain Modeling: 1-meter digital elevation models (DEMs) were used for terrain modeling within the project area. Utilizing ArcGIS Spatial Analyst, several other surface parameters were extracted, and raster datasets were generated including but not limited to:

- Aspect
- Slope angle
- Curvature (Plan and Profile)
- Pit-filled DEM
- Flow direction
- 5m DEM (resampled)

While 1-meter DEMs offer some of the highest resolution elevation data that is available, avalanche modeling (both dynamic and statistical) benefits from smoothed attributes of a 5-meter DEM to better represent a snow-covered landscape (where ground roughness is marginally subdued). Additionally, slopes derived from 5-meter DEMs reduce noise and limit additional digital processes to reduce small and insignificant terrain features that are insufficient for avalanche release.

Forest Canopy: Two (2) forest layers were acquired and/or developed for this assessment including *Multi-Resolution Land Characteristics Consortium (MLRC) and Normalized Difference Vegetation Index (NDVI)* which are discussed in detail below.

Multi-Resolution Land Characteristics Consortium (MLRC) – Tree Canopy Cover (%): Tree canopy cover (%) derived from remote sensing at 30-meter resolution by the MLRC (USGS et al., 2016) where different percentage classifications may be symbolized (or reclassified) to meet desired canopy percentage criteria. For the application of PRA identification, this layer was resampled (cubic interpolation to 5 meters) and reclassified to simple integer where '0' indicates <50% canopy cover and '1' indicates >50% canopy cover; as per NaiS European protective forest management guidelines –Total Canopy Cover Percentage for all tree species (Frehner et al., 2005) This dataset was used in calculations during the auto-generative delineation of the PRA dataset.

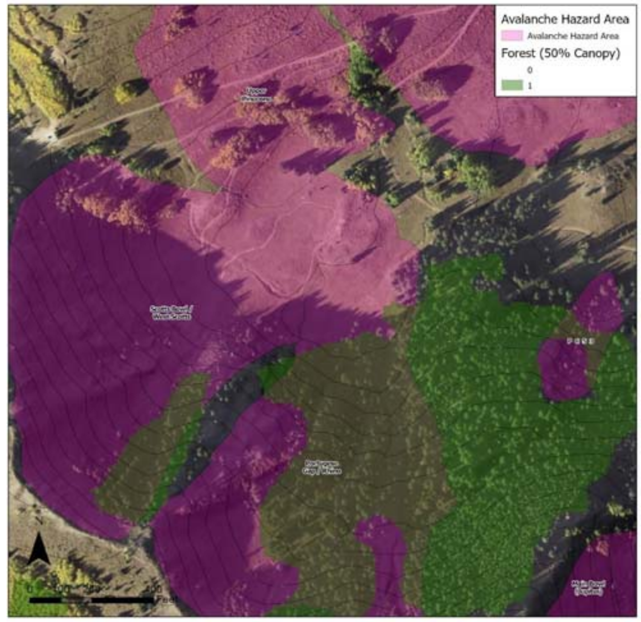


Figure 2-0-8. Avalanche hazard area. Resampled (5m) MLRC Canopy Cover Percentage (>50%).

Normalized Difference Vegetation Index (NDVI) – Normalized difference vegetation index (NDVI) is a dimensionless index used to display the differences between visible and near-infrared reflectance of vegetation (Weier & Herring, 2000). Using 4-band (RGB and near-infrared) NAIP imagery from the fall of 2018, reflectance ranges were identified that highlight conifer, deciduous and dense hardwood shrub; while omitting dry short grasses, non-burnable areas and short intermittent brush and herbaceous ground cover. This dataset was referenced as a high resolution (0.3m) to refine the MLRC canopy cover (%) data during the visual validation of the PRA-delineation process.

Ground Roughness/Vegetation Height: At mid and low elevations (<8,500 feet) within the project area, particularly on solar aspects (SW-S-SE), hardwood shrub/brush ecosystems are spatially continuous. Dominant species within these shrub forests are dense and durable hardwood including maple and Gambel oak (most abundant). While aerial coverage of hardwood shrub can be delineated digitally with high accuracy, its effectiveness on avalanche abatement is highly variable and difficult to quantify. One dataset evaluated in British Columbia showed that 90% of avalanching occurred in areas where vegetation height was less than 2 meters in height (McClung, 2001); however, localized snow-loading patterns and vegetation durability will result in localized variability.

What is broadly understood is that robust brush height and spatial continuity plays a significant role in the susceptibility to avalanche release, avalanche behavior (frequency and magnitude) and PRA-delineation through the introduction of ground/surface roughness. Ground roughness provided by robust hardwood shrub aids in the interruption of the development of a consistently stratified snowpack; however, when snowpack depths approach or exceed vegetation height, avalanching may become increasingly frequent. While not computed into the auto-generative portion of PRA delineation, brush height was incorporated into this assessment as part of the manual categorization and visual validation segment of PRA delineation. Where average brush height across a PRA exceeded the calculated design release depth (drel), PRAs were categorized as 'roughness-protected PRAs.' All assessments of ground roughness, vegetation height and the affected release areas were made manually for each individual affected PRA using high-resolution aerial imagery, DSM-derived vegetation height models (VHM) and field observations. The digital datasets utilized in the assessment of ground roughness as it pertains to brush/shrub conditions include the following:

<u>LANDFIRE Existing Vegetation Height (EVH)</u> – The LANDFIRE system is a shared program between the US Department of Agriculture, Forest Service and the US Department of the Interior, providing fire and land resource management data. Existing vegetation height (EVH) data is provided at landscape resolution (30m) and provides an average of brush height across PRAs delineated within the project.

Figure 2-0-9. Hardwood/Deciduous shrub ecosystems in Daly/Empire Canyon where hardwood shrub heights range from 0.8m (left) to over 2m (right).

<u>Vegetation Height Model (VHM)</u> – A portion of the project area is covered by 0.5-meter digital surface modeling (DSM) from the National Resource Conservation Service and the Utah Division of Emergency Management. Data from this DSM is utilized to estimate (relative) brush height and distribution, as well as identify the location and size of 'forest gaps' potentially excluded by the 30-meter resolution of the MLRC canopy cover (%) dataset utilized in PRA delineation.

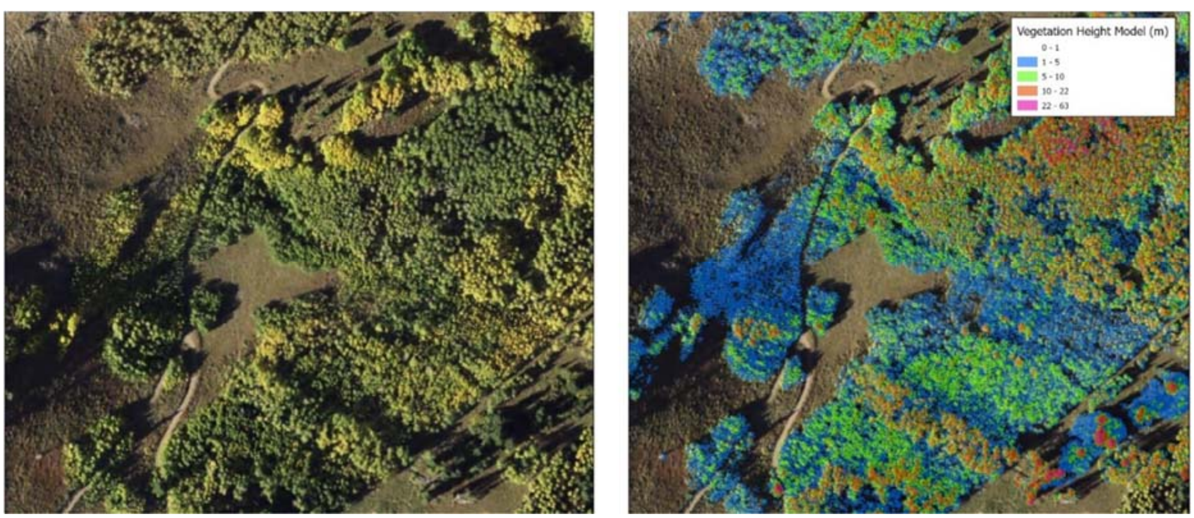


Figure 2-0-10. Vegetation height model (VHM) showing both the absence of ground cover/shrub in the PRA (upper left corner), as well as displaying varying age classes of deciduous forest; indicative of avalanche path trim lines as a product of frequency (Two Goons path – PC65).

In conclusion, a manual assessment was made within auto-generated PRAs comparing existing vegetation height to calculated design release depths (drel). Where average brush height exceeds drel, PRAs were categorized as 'roughness-protected." Within these PRAs, avalanche release is possible, but under atypical snowpack depths, or extreme conditions. Typically found at mid and low elevations within the project area, most of these shrub-dominated PRAs are infrequent avalanche-producers due to limitations and inconsistency in annual snow supply. These PRAs are included in the final PRA dataset as fuel treatments of hardwood shrub/brush could have a significant impact on avalanche frequency, and higher-resolution field analysis of these areas should be performed, accordingly.

Model Process 2: Avalanche Hazard Area Indication

Among PRAs categorized as 'active' through digital PRA-delineation (and visual validation), predicted avalanche hazard areas were identified utilizing both topographic-based runout angle modeling and dynamic numerical 2D-modeling. A simplified workflow for the development of avalanche hazard indication maps is shown in Figure 2-0-11.

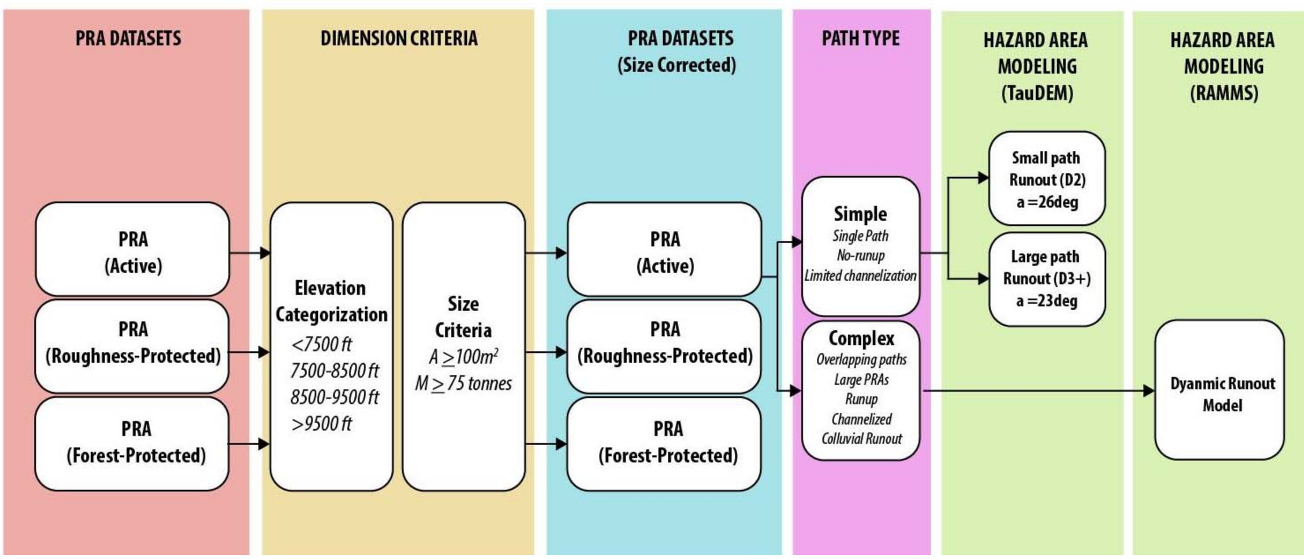


Figure 2-0-11. Simplified workflow for the development of avalanche hazard indication maps.

Hazard Area Runout Modeling (TauDEM): For hazard area runout modeling, the open-sourced GIS software 'TauDEM' was used. TauDEM is a hydrologic terrain-based analysis tool that identifies locations downslope from a PRA given a specified input alpha (runout) angle (Tarboton, 2013). Runout angles of 23 degrees and 26 degrees were used for paths with estimated release mass of ≥750 tonnes and <750 tonnes, respectively. TauDEM "D-Infinity Avalanche Runout" outputs are derived from raster datasets where individual pixels represent elevation, runout direction (angle) and a PRA-source GRID. This process does not account for flow velocity and momentum as debris mass moves over benched or uphill terrain features. Therefore, topographic runout modeling was only utilized for 'simple paths' with single or easily separated

PRAs, minimal terrain complexities or path overlap within the avalanche track and without run-up along lateral flanks or within the runout zone.

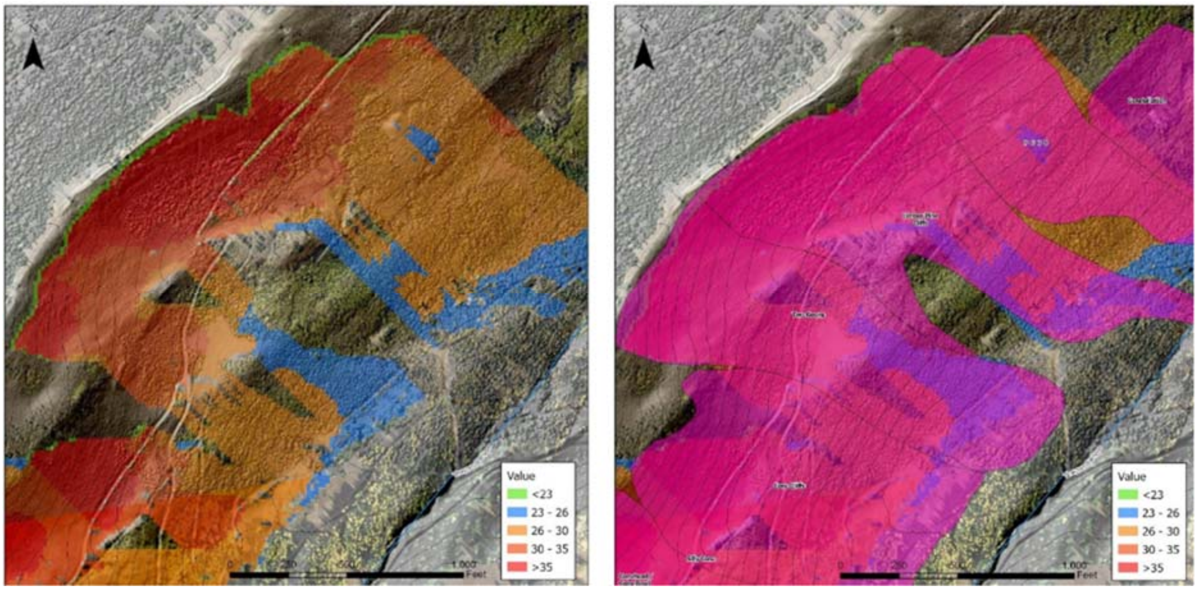


Figure 2-0-12. TauDEM runout angle dataset (left) showing the terminus of 23-degree runouts in blue. Overlayed Avalanche Hazard Areas shown (right).

Numeric Dynamic Modeling: ‘Complex’ paths include those with large PRAs; confined, gullied or split tracks; run-up and/or colluvial (fanned) runout zones. Where complex paths were mapped, RAMMS (Rapid Mass Movement Simulations) were utilized. RAMMS is a commercial product developed by the WSL Swiss Institute for Snow and Avalanche Research SLF (Christen et al., 2010) and provides modeled mass movement data including depth-averaged velocity, flow heights, impact pressures, momentum and overall extent. RAMMS is most often used in engineering, planning and avalanche hazard analysis; however, it may also be used in scenarios where vegetation and surficial characteristics and oral and written histories are insufficient to determine path extent (CAA, 2016). To achieve the objective of hazard indication mapping, path extent (envelopes) was extracted from RAMMS simulations and integrated into the avalanche hazard area dataset.

Regional calibration for numerical modeling in North America is lacking; however, indirect calibration of input friction parameters (Jamieson et al., 2018) of known avalanche events within the region was utilized for modeling paths within the project area. Two avalanche events lying just outside the project area were used in this exercise; Pointy Peak (2020) and Dutch Draw (2005), both evaluated be 30-year return period avalanches with known release dimensions. Using this indirect calibration method is intended to provide a more representative and useful modeled outcome than either topographical runout modeling or dynamic modeling with global friction parameters calibrated to the continental snow climates of Switzerland, in which calibration has been extensively refined. Modeled avalanche runout extents (shapefiles) were exported from RAMMS into the ArcGIS platform and integrated into the avalanche hazard area dataset, as shown in avalanche hazard indication maps provided with this assessment.

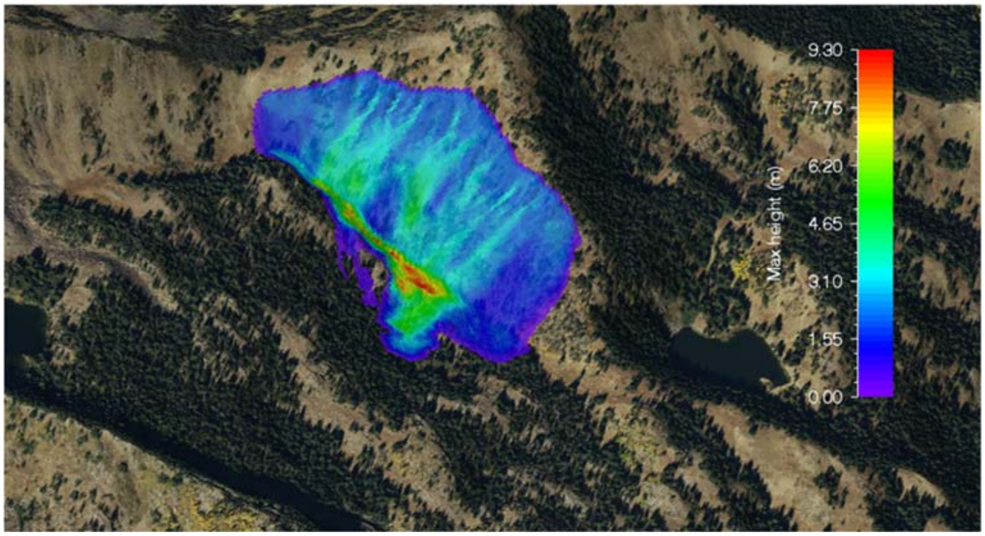
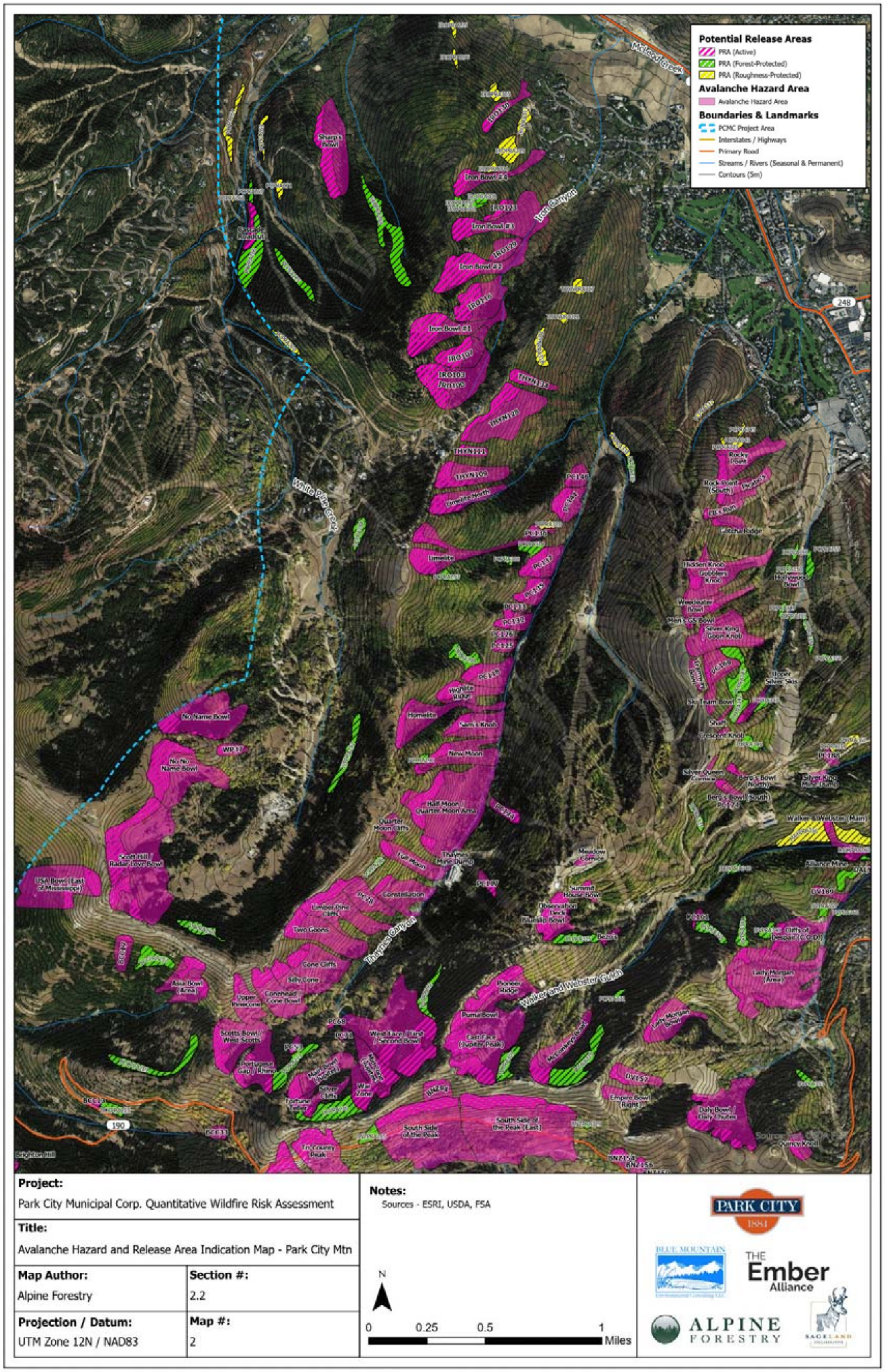


Figure 2-0-13. 10420 (Southeast) dynamic model results, depicting a runout envelope with Max Height of flow (m).

Maps


Potential Release Areas
PRA (Active)
PRA (Forest-Protected)
PRA (Roughness-Protected)
Avalanche Hazard Area
Avalanche Hazard Area
Boundaries & Landmarks
PCMC Project Area
Interstates / Highways
Primary Road
Streams / Rivers (Seasonal & Permanent)
Contours (5m)
McLeod Creek
Iron Canyon
White Pine Creek
Thaynes Canyon
Walker and Webster Gulch
Project:
Park City Municipal Corp. Quantitative Wildfire Risk Assessment
Title:
Avalanche Hazard and Release Area Indication Map - Park City Mtn
Map Author:
Alpine Forestry
Section #:
2.2
Projection / Datum:
UTM Zone 12N / NAD83
Map #:
2
Notes:
Sources - ESRI, USDA, FSA
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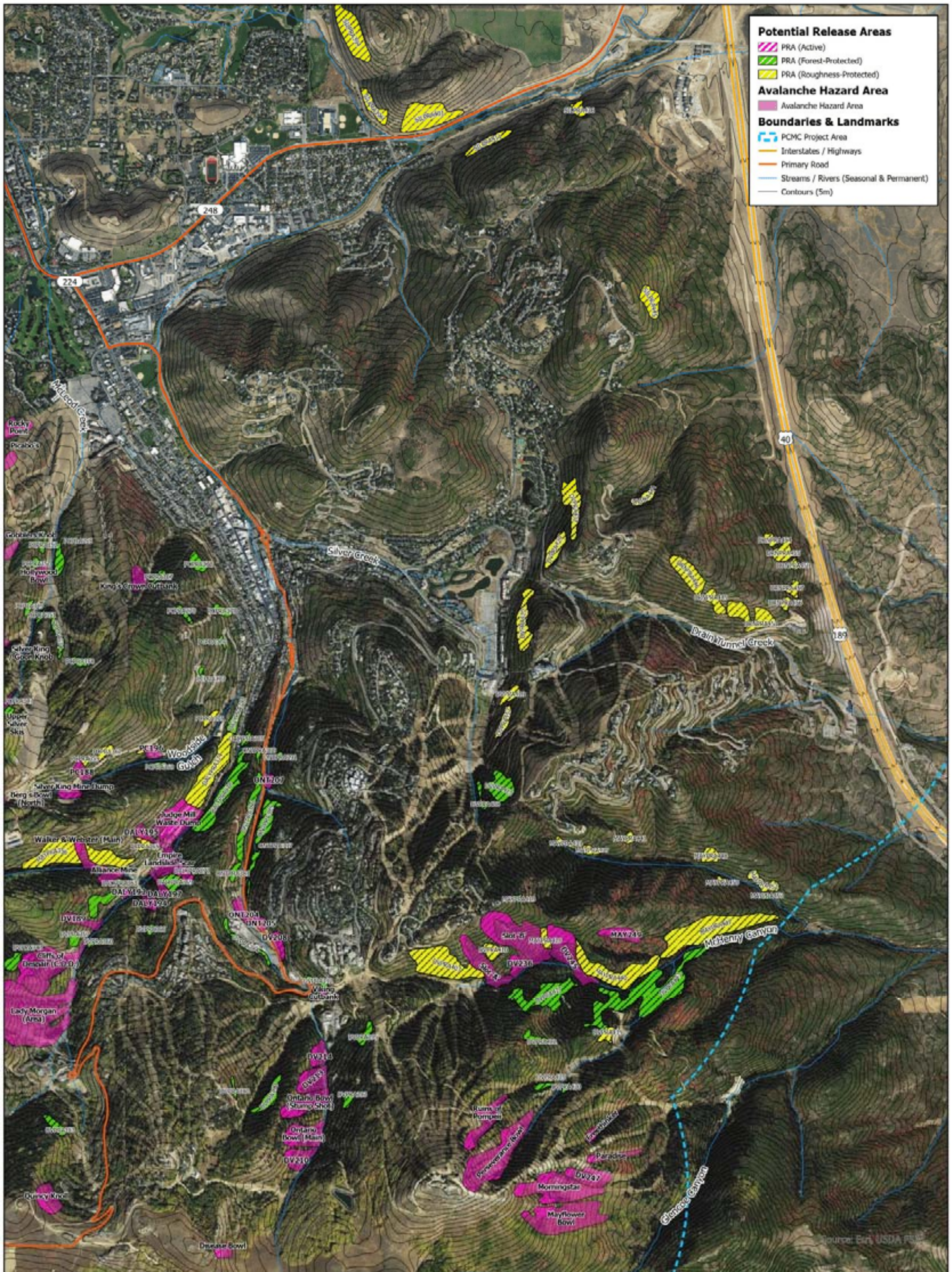
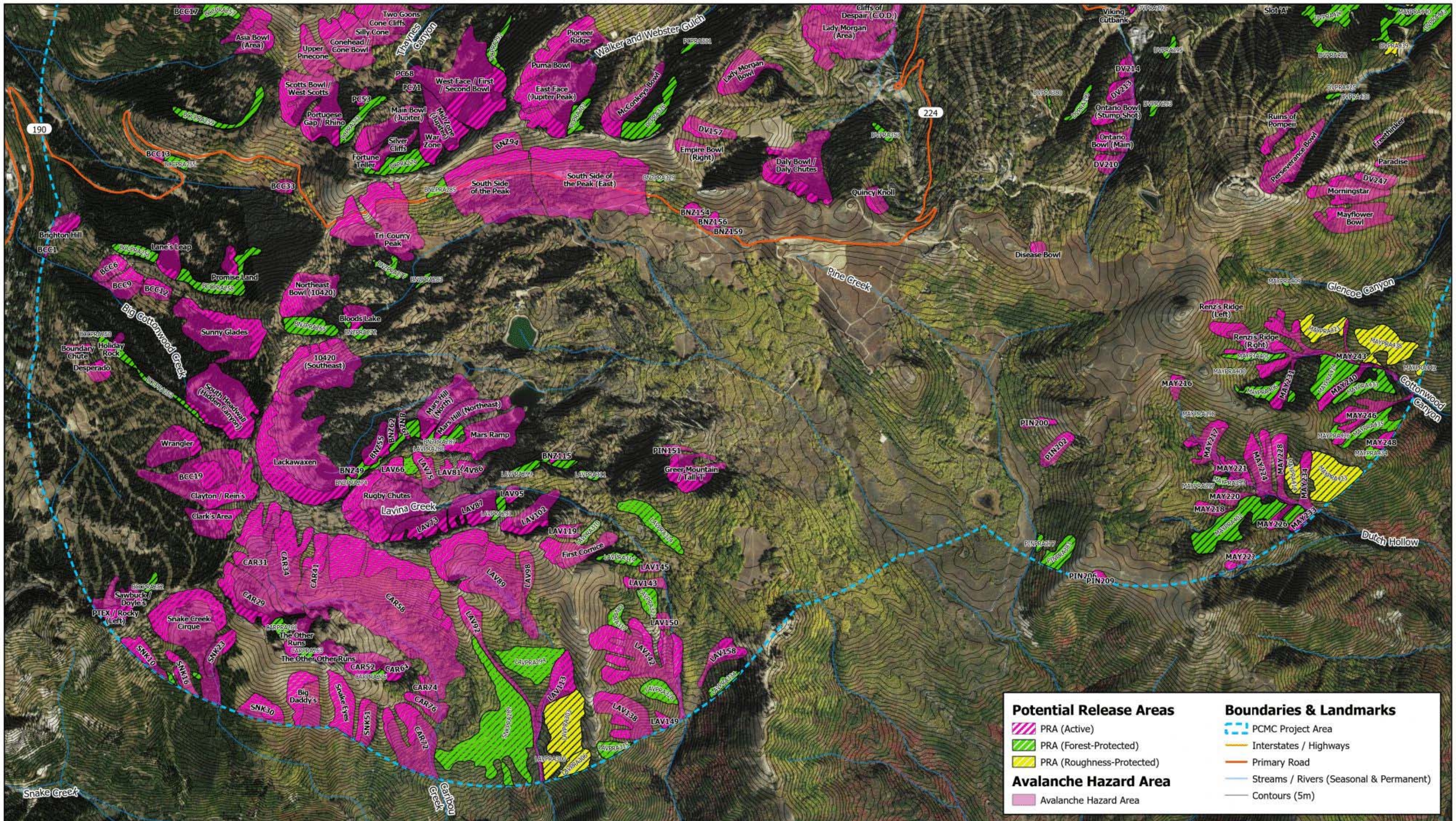


Project:		Notes:
Park City Municipal Corp. Quantitative Wildfire Risk Assessment		Sources - ESRI, USDA, FSA
Title:		
Avalanche Hazard Indication Map - Deer Valley / Deer Crest Zone		
Map Author:	Section #:	
Alpine Forestry	3.3	
Projection / Datum:	Figure #:	
UTM Zone 12N / NAD83	14	

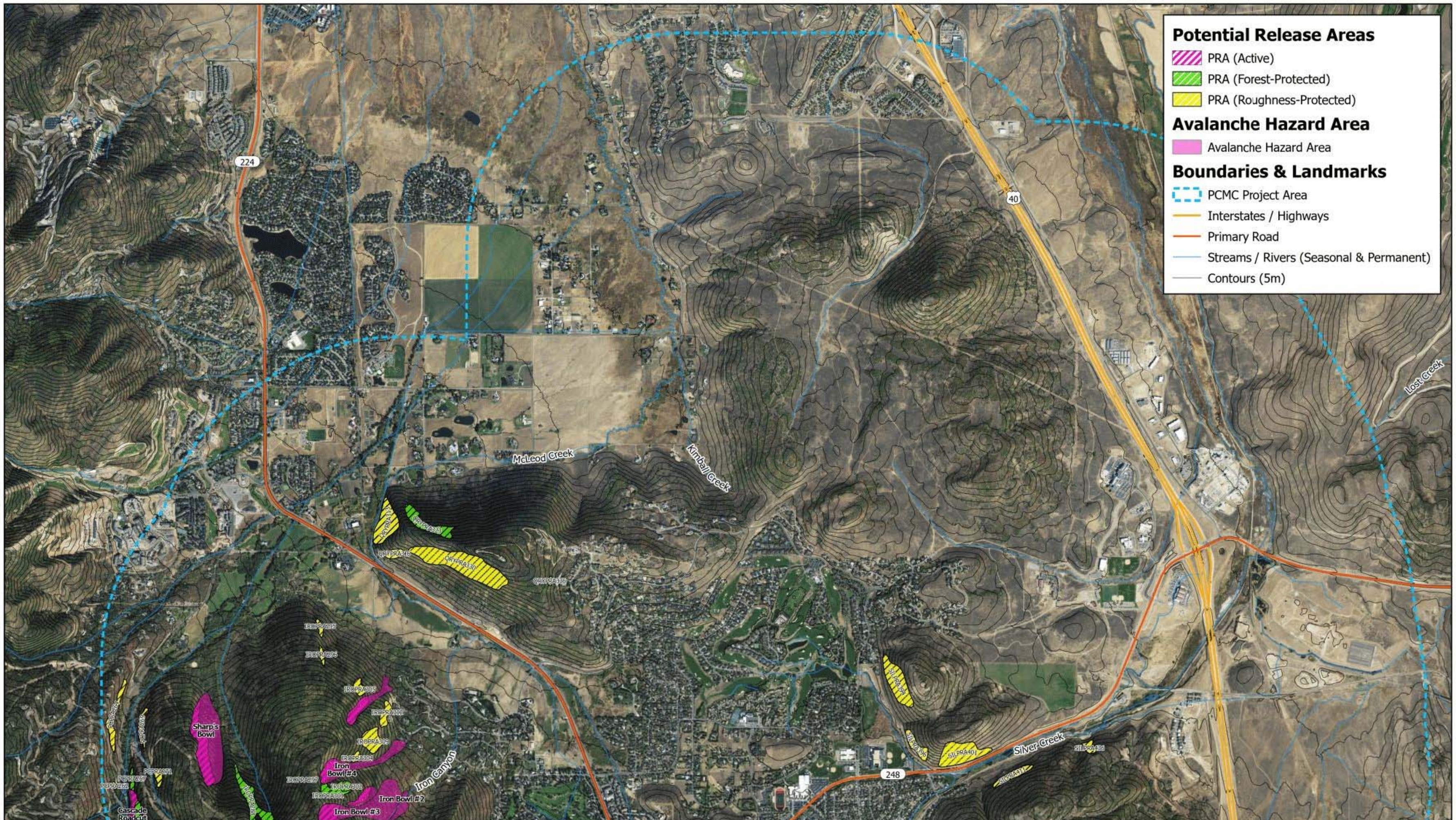
N

0 0.25 0.5 1 Miles



Project:	Map Author:	Section #:	Notes:
Park City Municipal Corp. Quantitative Wildfire Risk Assessment	Alpine Forestry	2.2	Sources - ESRI, USDA, FSA
Title:	**Projection / Datum:**	**Map #:**	0 0.25 0.5 1 Miles N
Avalanche Hazard and Release Area Indication Map - Bonanza Flats	UTM Zone 12N / NAD83	1	

PARK CITY 1884 · THE Ember Alliance · ALPINE FORESTRY · BLUE MOUNTAIN · SAGELAND



Project: Park City Municipal Corp. Quantitative Wildfire Risk Assessment	**Map Author:** Alpine Forestry	**Section #:** 2.2	**Notes:** Sources - ESRI, USDA, FSA
Title: Avalanche Hazard and Release Area Indication - Round Valley	**Projection / Datum:** UTM Zone 12N / NAD83	**Map #:** 4	0 0.25 0.5 1 Miles N

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2.2. Post-Fire Sediment Delivery

Executive Summary

This assessment quantified the potential for destructive sediment delivery following a wildfire, identified values at risk to post-fire sediment and suggests proactive measures to mitigate impacts. Results from this assessment fed into recommendations for proactive fuel treatments to mitigate wildfire and post-fire impacts as described in chapter 6.0 Planning and Resources.

Impacts of wildfires do not end once the flames are extinguished. Intense rainfall events can result in flash floods, erosion, sediment delivery and debris flows the first few years following a wildfire (Neary et al., 2005). Erosion and sedimentation are natural processes that shape streams, transport soil and nutrients across a landscape and create diversity in stream and riparian habitats. However, extreme post-fire sediment delivery and debris flows can damage and destroy homes, community assets, infrastructure, fisheries and riparian vegetation. A localized thunderstorm after the 2018 Dollar Ridge Fire east of Park City triggered debris and mud flows that caused significant damage to homes, roads, bridges, reservoirs and fisheries (Hardy, 2018). About 50 people needed to be rescued from the Camelot Resort and Timber Canyon area in Duchesne County when they became trapped from flooding and mudflows (Canham, 2018).

There are numerous homes, community assets and infrastructure in the Park City area, and watersheds in this part of Utah are especially important for the delivery of clean surface drinking water (Mack et al., 2022). Assessing the potential for post-fire sediment delivery to damage these values can help residents, managers and partners in the Park City Municipal Corporation to identify areas most likely to experience damage and to plan for actions to mitigate impacts. We modeled potential sediment delivery using the Water Erosion Prediction Project (WEPP) under current unburned conditions and potential post-fire conditions.

The probability of sediment delivery (the likelihood that any amount of sediment is deposited after rainfall events) could be 3 times greater the first year following wildfire in the Park City area compared to current, unburned conditions, and the magnitude of sediment delivery (the amount of sediment that could be dislodged from hills and transported into streams during intense rainstorms) could be 20 times greater after wildfires. About 1,560 homes and businesses in the area (12% of all addresses) occur in watersheds with a high risk of damage from post-fire sediment delivery. Water infrastructure in the area have a high risk of damage from post-fire sediment, which is particularly concerning given the importance of watersheds in this part of Utah for the delivery of clean drinking water. Numerous springs, water tanks and water points of distribution are in at-risk areas, as well as 40% of the length of pipelines, 15% of canals and ditches and 54% of streams and rivers.

There is also a significant risk of post-fire sediment delivery to recreation infrastructure and heritage resources in the Park City area. Almost all the Brighton Ski Resort in the study area could experience post-fire sediment delivery, as could over 50% of Deer Valley Resort and Park City Mountain Resort and almost 70% of the length of ski lifts. Over 45% of the length of trails in the study area and 11 trailheads have a high risk of post-fire sediment due to their location on steep slopes with high burn probabilities. Historic structures at Thaynes Mine, California-Comstock Mine, Jupiter Mine, Alliance Mine and Silver King Mine are at risk of post-fire sediment delivery.

Proactive planning and activities to mitigate the impacts of wildfires and post-fire sediment are key components of becoming a fire-adapted community. Proactive management actions include stream restoration, which improves the health and resilience of streams so they can dissipate flood waters and store sediment, and fuel treatments, which reduce fire intensity and extent. Fuel treatments recently completed on Treasure Hill could reduce fire severity and potentially reduce the likelihood and magnitude of post-fire sediment delivery into the downtown area of Park City. Watersheds in Iron Canyon, Thaynes Canyon, Walker and Webster Gulch, along Crest Ridge, and around Bald Mountain and Bald Eagle Mountain could especially benefit from fuel treatments given their high potential to deliver sediment to homes and community assets after wildfire. The city, water and utility providers, residents and business owners should also develop plans to protect lives and property in the case of large post-fire flooding and sedimentation events.

Immediate and long-term action to address potential post-fire sediment are important for protecting values at risk across the Park City area. Climate change makes immediate action even more imperative as the future is likely to include more frequent, large, high-intensity wildfires and extreme rainfall events (Sankey et al., 2017; Touma et al., 2022).

Background

Impacts of wildfires do not end once the flames are extinguished. Intense rainfall events can result in flash floods, erosion, sediment delivery and debris flows the first few years following a wildfire (Neary et al., 2005). According to the Utah Geological Survey: “Debris flows are one of the most dangerous post-fire hazards because they can be life threatening, move rapidly and strike with little warning” (Giraud & McDonald, 2013).

Wildfires kill vegetation that anchor soil in place and intercept rainfall, and they consume surface litter and organic matter that serve as a sponge absorbing rainfall and slowing the overland movement of water. Extreme heating from wildfires can break apart clumps of soil, known as aggregates, thereby reducing the stability of the soil and its ability to absorb water and resist erosion. Wildfires occasionally result in hydrophobic soils that repel water and exacerbate post-fire erosion. When hydrophobic conditions develop, they are usually isolated to portions of the burned area that experienced prolonged heating, and the organic compounds that cause water-repelling conditions break down within months to a couple years after a wildfire (Binkley, 2020; Huffman et al., 2001). Research suggests that post-fire sediment delivery is related to the loss of surface cover to a greater degree than to the formation of hydrophobic soils (Larsen et al., 2009).

DEFINITIONS

Debris flow

A fast-moving landslide made up of a mixture of water-saturated rock, soil and debris with a consistency similar to wet cement.

Erosion

Detachment and transport of soil and rock due to gravity, water or wind.

Sediment delivery

Movement of soil into streams. Rates of sediment delivery are less than rates of erosion. Variation in topography and other barriers can stop the downhill movement of soil before it enters a stream.

Watershed

Area of land where all precipitation falling in that area drains to the same location.

The severity of post-fire sediment delivery is related to the size of the area burned, amount of ground cover consumed, time since wildfire, slope, soil characteristics and rainfall intensity (Neary et al., 2005). Climate change has lengthened the fire season in the western United States and driven larger, more intense wildfires (Parks et al., 2016). The occurrence of high-intensity rainfall events following on the heels of large wildfires is likely to increase across the western United States in the coming decades (Sankey et al., 2017). The percentage of extreme fire weather conditions followed within one year by extreme rainfall events in northern Utah could increase from about 30-40% today to 70-80% in the mid-20th century (Touma et al., 2022).

Erosion and sedimentation are natural processes that shape streams, transport soil and nutrients across a landscape and create diversity in stream and riparian habitats. According to Trout Unlimited, post-fire sediment can severely damage fisheries, but "Riparian areas are incredibly resilient … When viewed in the long term (10 to 20 years post-fire), it is clear that fires can deliver benefits to fisheries by introducing large numbers of logs and tree roots, as well as adding in-stream gravel contributing to habitat diversity" (Prettyman, 2018). However, extreme post-fire sediment delivery and debris flows can damage and destroy homes, community assets, infrastructure, fisheries and riparian vegetation. Numerous post-fire debris flows and sedimentation events have occurred along the Wasatch Range in the past 30 years, causing damage to roads, homes, water infrastructure, power plants and fisheries (Figure 2-0-14, Table 2-6).

The 2018 Dollar Ridge Fire burned over 57,000 acres and damaged or destroyed 438 structures, including primary and secondary residences, camper trailers, vehicles and outbuildings. On July 22, 2018, a localized thunderstorm producing 1-3 inches of rainfall over a 2-hour period triggered debris and mud flows that damaged homes, roads, bridges, Starvation Reservoir and fisheries (Hardy, 2018). About 50 people needed to be rescued from the Camelot Resort and Timber Canyon area in Duchesne County when they became trapped from flooding and mudflows (Canham, 2018). Drinking water quality was impacted and required expensive updates to the Duchesne County Water Treatment Plant to remove contamination from post-fire debris (Central Utah Water Conservancy District, 2021). Sediment and ash from the fire also decimated the brown trout population in the Wild Strawberry River—a designated Blue Ribbon Fishery (Murray, 2019).

Post-fire debris flows triggered by intense rainfall in the years following the 2012 Seeley Fire were also particularly destructive. Debris flows caused damage to and closures of State Route 31. Sediment buried the Huntington/Cleveland Irrigation Company's headgate and clogged sprinkler lines and caused the PacifiCorp-Huntington Power Plant to shut their water intake for several days. Impacts to water quality were observed as far as 50 miles downstream, and fisheries were decimated, including the endangered razorback suckers due to ash-clogged gills (Giraud & McDonald, 2013).

Emergency response, mitigation measures and sediment removal after major flood events carry a hefty price tag—sometimes even exceeding the cost of wildfire suppression. Costs are borne by federal agencies, state agencies, municipalities, water providers, homeowners and other parties. Federal requests for mitigation activities by Burned Areas Emergency Response teams (BAER)[1] ranged from less than $15,000 following smaller and/or lower-severity fires in areas with fewer values at risk to over $1 million following larger wildfires with a greater potential to trigger post-fire damages for wildfires along the Wasatch Range. Utah's Watershed Restoration Initiative has contributed between $42,000 and $1.4 million per project for aerial

[1] BAER teams are interagency teams of specialists, including hydrologists, soil scientists and biologists, formed after wildfires to analyze post-fire conditions and undertake emergency stabilization action to prevent loss of life and damage to property, critical infrastructure, natural resources and other values at risk.

seeding, invasive weed control and erosion mitigation after wildfires in central and northern Utah (**Appendix B, Table B.2.4.1**). Notable expenses for post-fire mitigation include:

- **2018 Dollar Ridge Fire:** Over $30 million in funding from the U.S. Forest Service, Federal Emergency Management Agency (FEMA), Utah's Watershed Restoration Initiative, Utah Drinking Water Board, Utah Permanent Community Impact Fund Board and Central Utah Water Conservancy District to update the Duchesne Valley Water Treatment Plant to remove post-fire sediment and debris, conduct aerial seeding, spray invasive weeds and repair damaged trails (Central Utah Water Conservancy District, 2021; Hardy, 2018; Mathis, 2019). Mitigation costs significantly exceeded the $18.2 million spent on wildfire suppression for the Dollar Ridge Fire (Hardy, 2018).

- **2018 Pole Creek and Bald Mountain Fires:** Over $11.3 million in funding from the U.S. Forest Service, USDA Natural Resources Conservation Service and Utah's Watershed Restoration Initiative for debris removal, stream bank protection, aerial seeding and invasive weed management (Curtis, 2019; Edgel, 2019; Hardy & Waterman, 2018a). Suppression costs for the Pole Creek and Bald Mountain Fires ($40.3 million) were significantly greater than the cost for mitigation measures due to the large size and complexity of these incidents (Hardy & Waterman, 2018a).

- **2012 Dump Fire:** $3.7 million in funding from the USDA Natural Resources Conservation Service and Utah's Watershed Restoration Initiative to restore and strengthen over a mile of open channels, construct erosion control structures and conduct aerial seeding (Bullock, 2013; C. Jones, 2013). Mitigation costs exceeded the $1.5 million spent on wildfire suppression for the Dump Fire (Vaughn, 2012).

- **2012 Quail Fire:** $1.85 million in funding from the USDA Natural Resources Conservation Service, Alpine City and Utah's Watershed Restoration Initiative to alter and expand sediment basins in response to post-fire debris flows and conduct aerial seeding (Allred, 2014). Mitigation costs exceeded the $1.1 million spent on wildfire suppression for the Quail Fire (Condrat, 2012).

Understanding the potential for post-fire sediment is important to plan and undertake proactive measures to protect the community. There are numerous values at risk of damage from post-fire sediment in the Park City area, including homes, schools, medical facilities, utility infrastructure and ski area infrastructure. Watersheds in this part of Utah are especially important for the delivery of clean drinking water (Figure 2-0-15). Debris flows and sedimentation after large, high-severity wildfires could threaten the delivery of clean water to tens of thousands of residents. Watersheds in the Park City area provide drinking water to almost 40,700 residents within the watersheds and 91,000 to 195,000 residents downstream of the watersheds (Mack et al., 2022).

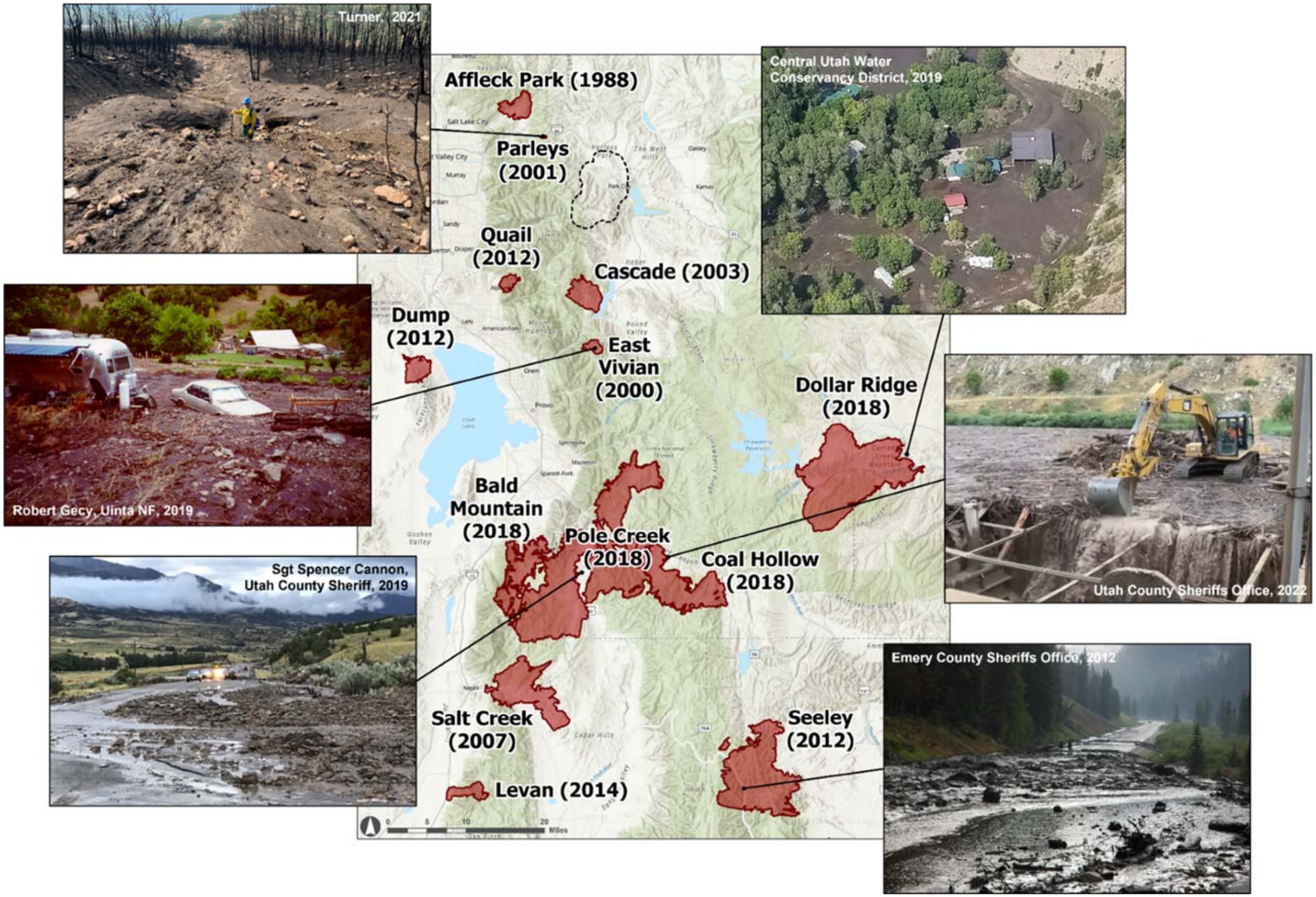

Figure 2-0-14. Numerous wildfires along the Wasatch Range have resulted in major debris flow and sedimentation events. Sources: Fire perimeters from the National Interagency Fire Center. Base maps from Utah County, Utah Geospatial Resource Center, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, BLM, EPA, NPS, and NGA.

Table 2-6. Description of post-fire debris flows and sedimentation events following wildfires along the Wasatch Range (see Figure 2-0-14 for fire perimeters). Soil burn severity and predicted sediment yield are provided for wildfires that triggered the response of Burned Areas Emergency Response teams to analyze post-fire conditions and undertake emergency stabilization action. For comparison, sediment yields are typically 0-2.5 tons/acre/year in undisturbed watersheds across the western United States (Neary et al., 2005).

FIRE DESCRIPTION	SOIL BURN SEVERITY	PREDICTED SEDIMENT 1-YEAR POST FIRE	OBSERVED POST-FIRE DEBRIS FLOWS AND SEDIMENTATION
Parleys Canyon Fire Aug 14-21, 2021 158 acres	Unburned: 23% Low: 25% Mod: 52% High: <1%	0.23 tons/acre	Thunderstorms on August 18, 2021, caused a flash flood and deposited debris within 75 feet of Interstate 80. Source: (Turner, 2021)
Pole Creek Fire Sept 6-Oct 7, 2018 103,545 acres **Bald Mountain Fire** Aug 24-Oct 3, 2018 21,218 acres	Unburned: 14% Low: 41% Mod: 41% High: 4%	2.5 tons/acre	Flooding on July 26, 2019, crossed US Highway 89. Flooding on August 8, 2019, damaged US Highway 89 and 4 miles of US Highway 6, where about 3-5 feet of debris were deposited. Flooding triggered evacuations of residents in Loafer Canyon and damaged at least a dozen homes. Sediment impacted the quality and quantity of irrigation water provided by Strawberry Water Users Association to farms near Payson, UT. Source: (Hardy, 2018; Harris, 2022; Roberts, 2019)
Coal Hollow Fire Aug 4-Sep 6, 2018 29,912 acres	Unburned: 9% Low: 28% Mod: 52% High: 11%	1.4 tons/acre	Thunderstorms on August 12 and 13, 2022, caused flooding and debris flows at Mill Fork and Dairy Fork in Spanish Fork Canyon and triggered the need for debris removal by UT County Public Works. See videos of flooding at Mill Fork: https://www.youtube.com/watch?v=I-BZXFXVIe8 Source: (Burt, 2022; Natharius & Meccariello, 2018)
Dollar Ridge Fire July 1-30, 2018 57,897 acres	Unburned: 22% Low: 47% Mod: 28% High: 3%	2.7 tons/acre	Thunderstorms on July 22, 2018, triggered debris flows and sedimentation that damaged homes, roads, bridges and fisheries. About 50 people needed to be rescued in Duchesne County after becoming trapped by floodwaters. Drinking water quality was impacted and triggered a $28.5 million project to update the Duchesne County Water Treatment Plant. Sediment and ash also decimated the brown trout population in the Wild Strawberry River—a Blue Ribbon Fishery. Source: (Canham, 2018; Central Utah Water Conservancy District, 2021; Hardy, 2018; Murray, 2019)
Levan Fire July 24-Aug 8, 2014 4,313 acres	Unburned: 16% Low: 22% Mod: 41% High: 20%	10.3 tons/acre	Thunderstorms on July 29, 2014, caused a flashflood and debris flows along a 12-mile stretch of State Route 28, washed out a campground and flooded residents' basements near the town of Levan. Source: (Davidson, 2014; Goodell, 2014; Penrod, 2014)
Quail Fire July 3-July 11, 2012	Unburned: 0% Low: 93%	10.2 tons/acre	Four extreme flooding events occurred after thunderstorms on July 5, July 20, August 22, and

2,091 acres	Mod: 7% High: 0%		September 7, 2013. The mudslide on August 22, 2013, damaged several homes in Alpine, UT, and forced emergency evacuations. See a video of extreme flooding in Alpine, UT: https://www.youtube.com/watch?v=LkJruU92mwo Source: (Allred, 2014; Condrat, 2012; Mecham & Winslow, 2013)
Seeley Fire June 26-July 18, 2012 48,050 acres	Unburned: 34% Low: 20% Mod: 30% High: 15%	6.3 tons/acre	Intense rainfall and flooding occurred on July 7, 16, 30 and 31, 2012, and September 1, 2012, and July 16 and 19, 2013. Flooding and debris flow on July 7, 2012, caused serious damage to State Route 31, powerlines, coal mines, trails and recreation sites. Sediment buried the Huntington/Cleveland Irrigation Company's headgate and clogged sprinkler lines. Debris flows in Huntington Creek caused PacifiCorp-Huntington Power Plant to shut their water intake for several days. Impacts to water quality were observed as far as 50 miles downstream. Fish died in the Price and San Rafael rivers due to ash-clogged gills, including endangered razorback suckers. Source: (Chatel, 2012; Giraud & McDonald, 2013)
Dump Fire June 21-25, 2012 5,507 acres	No BAER report produced	No BAER report produced	Thunderstorms on September 1, 2012, caused flash flooding, mudslides, major damage to 5 homes and moderate damage to 20 homes. Source: (Park, 2012)
Salt Creek Fire July 19-29, 2007 24,659 acres	Unburned: 11% Low: 12% Mod: 57% High: 20%	11.6 tons/acre	Thunderstorms on July 25 and September 5, 2007, resulted in flash floods in the town of Fountain Green. Source: (Hales, 2007; Pope & Higginson, 2007)
Cascade II Fire Sept 23-Oct 6, 2003 7,828 acres	Unburned/low: 36% Mod: 46% High: 18%	7.1 tons/acre	Heavy rainfall on July 14, 2004, resulted in mud and debris flows in Lower Bear Canyon, lower Thomas Canyon and Little Provo Deer Creek. The Central Utah Water Conservancy District Water Treatment Plant was forced to switch water sources and temporarily close Canyon Meadows Water System. Debris damaged a recreation site and road on the Uinta-Wasatch-Cache National Forest. Source: (Pope, 2004)
East Vivian Fire July 26-Aug 11, 2000 1,753 acres	Unburned: 0% Low: 40% Mod: 46% High: 14%	1.6 tons/acre	Intense thunderstorms on August 31, 2000, produced flooding and debris flows down the South Fork Provo River and into properties in Vivian Park. Source: (Gecy, 2000; Pope, 2002)
Affleck Park Fire Sept 2-7, 1988 5,600 acres	Not reported	7.1 tons/acre compared to 1.1 tons/acre pre-fire	Thunderstorms on June 9, 1989, caused flooding and debris flows in Freeze and Brigham Canyons and damaged homes and businesses along Emigration Creek. Source: (DuMont, 1990; Nelson & Rasely, 1988)

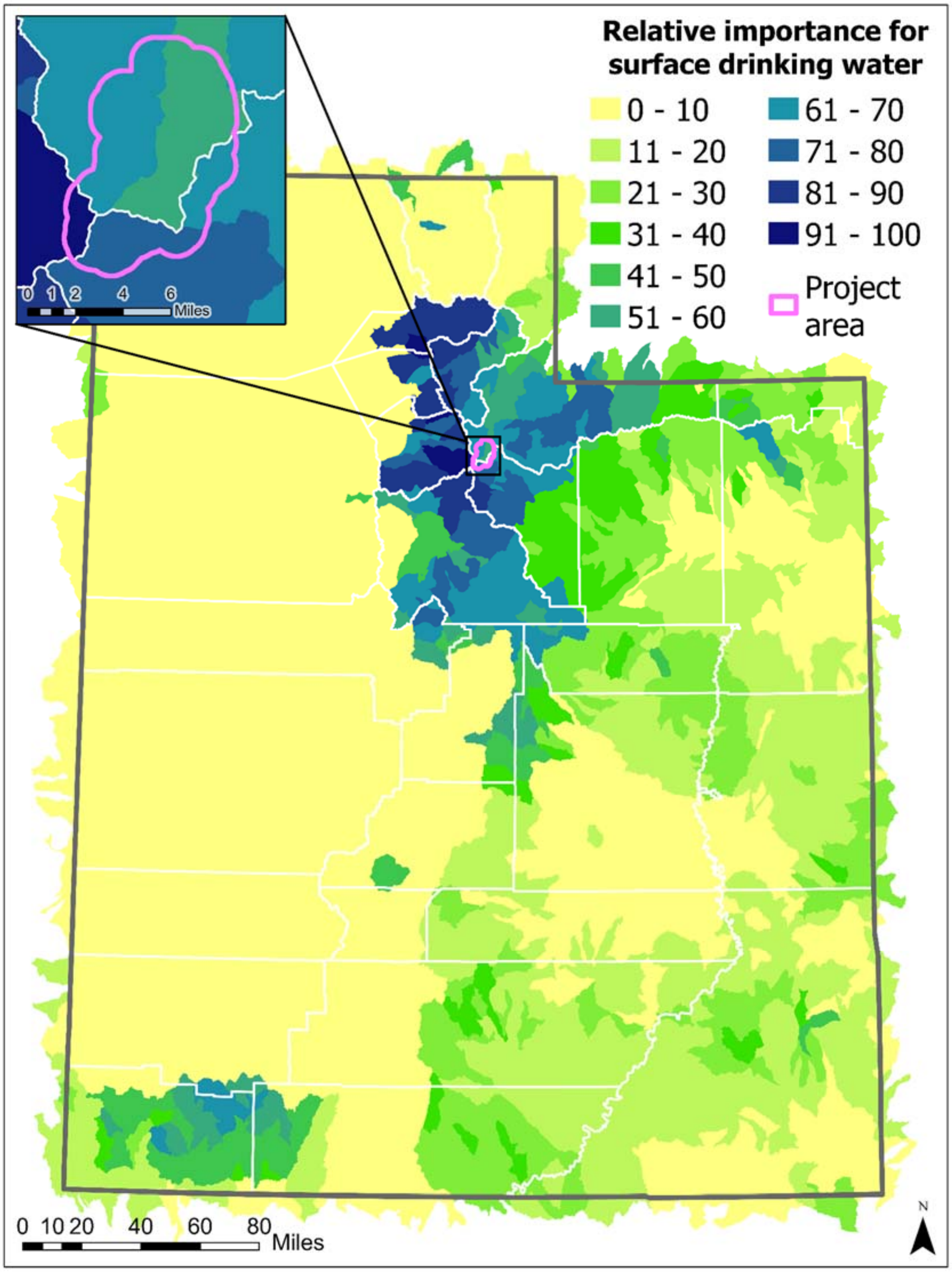

Figure 2-0-15. Relative importance of watersheds for producing clean surface drinking water in the state of Utah according to the Forests-to-Faucets 2.0 assessment by the U.S. Forest Service (Mack et al., 2022). Values indicate the relative importance of watersheds compared to all watersheds in Utah. For example, the Headwaters of Big Cottonwood Creek watershed in the southwest portion of our study area has a relative importance value of 93, meaning it is more important for providing clean surface drinking water than 93% of watersheds in the state.

Methods

Assessing the potential for post-fire sediment delivery can help residents, managers and partners in the Park City Municipal Corporation to identify areas most likely to experience damage and to plan for actions to mitigate impacts. We focused on sediment delivery instead of erosion because movement of soil into streams can cause greater post-fire damage than erosion itself. We modeled potential post-fire erosion and sediment delivery using the Water Erosion Prediction Project (WEPP) version 2.0 (Elliot & Hall, 2010). WEPP models sheet and rill erosion but not landslides, channel erosion or debris flows. Inputs to the model include vegetation type, burn severity, surface cover, soil texture and slope.

We modeled sediment delivery under current unburned conditions and potential post-fire conditions following the approaches of Elliot et al. (2016) and Miller et al. (2011) to classify soil burn severity based on predicted flame lengths. The post-fire scenario assumed that fires burned every portion of a watershed under extreme (97th percentile) fire weather conditions—a reasonable assumption given that the sizes of watersheds delineated for this analysis (5 to 4,620 acres) are within the size range of wildfires along the Wasatch Range that resulted in post-fire sediment (160-103,500 acres) (Table 2-6). See chapter 5.0 Wildfire Risk Assessment for a description of fire behavior modeling for this project.

We modeled sediment delivery under 50 random weather conditions based on historical observations from the two closest National Weather Service cooperative stations available through Rock:Clime (the weather prediction model incorporated into the WEPP modeling framework). These stations were at Silver Lake Brighton, which is 0.3 miles west of the study area, and the Snake Creek Powerhouse, which is 2.5 miles south of the study area (Figure 2-0-23). We present results for average predictions from all 50 weather scenarios and for 1-in-50-year weather conditions (i.e., conditions likely to occur once in every 50 years). See Appendix A for full details of modeling methodology.

Weather scenarios did not incorporate the potential for altered rainfall intensity with climate change. Climate change is likely to make large, high-intensity wildfires and extreme rainfall events more likely and therefore could result in greater sediment delivery than predicted here (Sankey et al., 2017; Touma et al., 2022). However, spatial patterns in relative sediment delivery across the analysis area are likely to stay the same; topography and soil texture will not change for centuries to millennia, and dominant vegetation types are unlikely to change in the coming decades.

The risk of community values and infrastructure being damaged by post-fire erosion is based on intensity, exposure, likelihood and susceptibility. For our analysis, we quantified intensity as 1-in-50-year predictions of post-fire sediment yield, likelihood as the average conditional burn probability and exposure as the occurrence of values at risk within watersheds with high post-fire sediment yield (>315 tons/year) and high relative burn probabilities (≥33%). We did not assess the susceptibility of different community assets and infrastructure to damage from sedimentation. We compiled and validated the locations of community assets from various sources and utilized a similar categorization as that for the Qualitative Wildfire Risk Analysis (QWRA) as part of the broader project for Park City Municipal Corporation (see Table 2-16 for data sources and chapter 5.0 Wildfire Risk Assessment for a description of the QWRA process).

Key Findings

Predicted Sediment Delivery

The probability of sediment delivery—the likelihood that any amount of sediment is deposited after rainfall events—could increase significantly the first year following wildfire in the Park City area. The median probability of sediment delivery from watersheds was 9% under current, unburned conditions and rose to 38% the first year following wildfire (Table 2-7). Under current, unburned conditions, higher probabilities of sediment delivery occurred in steep watersheds including Red Pine Canyon, Dutch Draw and McDonald Draw in the northwestern part of the analysis area; Thaynes Canyon and the lower portion of Walker and Webster Gulch in the central part of the study area; the western side of Clayton Peak in the southeastern part of the analysis area; and on the eastern side of Bald Mountain in Wasatch Gulch, Pine Canyon, Glencoe Canyon and the top of Dutch Hollow in the eastern part of the analysis area (Figure 2-0-16).

The probability of post-fire sediment delivery could be particularly high across mountainous terrain in the southern portion of the analysis area. In addition to the canyons, draws and gulches mentioned above, probability of post-fire sediment delivery was elevated in West Monitor Flat, Iron Canyon and Ontario Canyon. The probability of erosion was slightly lower in the Bonanza Flat area due to shallower slopes.

The probability of post-fire sediment delivery remained low for watersheds in the northeastern portion of the analysis area, despite there being a moderate to high burn probability with moderate flame lengths in grass and grass-shrub vegetation. The likelihood of large rainfall events was lower across the northern portion of the analysis area and where slopes are shallower—both rainfall intensity and slopes are significant factors driving observed and predicted post-fire erosion.

The magnitude of sediment delivery—the amount of sediment that could be dislodged from hills and transported into streams during intense rainstorms—could increase dramatically the first year following wildfire in the Park City area. If average weather conditions occurred the year following wildfire, total post-fire sediment delivery from watersheds averaged 20 times higher than under current, unburned conditions (Table 2-7). If 1-in-50-year storms followed a wildfire, total post-fire sediment delivery averaged 28 times higher and up to 16,050 times higher. Under extreme weather conditions, 25% of watersheds in the study area could produce very high to extreme sediment delivery the first year following wildfire (>815 tons/year). About 60% of these watersheds also had high relative burn probabilities (≥33%), meaning they have a higher likelihood of burning and then delivering high post-fire sediment (Figure 2-0-16).

The highest total sediment yields the first year following wildfire were predicted for Thaynes Canyon (9,910 tons/year; 60% relative burn probability), Pine Canyon (8,870 tons/year; 40% relative burn probability) and the upper part of McHenry Canyon (6,240 tons/year; 45% relative burn probability). The average slope in these watersheds was about 40%. High-severity fire behavior was predicted to predominate in Pine Canyon and McHenry Canyon. Thaynes Canyon is a large watershed unit, so total sediment delivery was high regardless of the preponderance of low-severity fire behavior.

The size and shape of watershed units is driven by topography and the scale of analysis, so total sediment delivery on a watershed-scale cannot be compared between studies in different landscapes. We calculated per-acre sediment delivery to compare sediment predictions from our analysis to other findings in the western U.S. Under current, unburned conditions and 1-in-50-year storm conditions, per-acre sediment delivery rates were all less than 1.7 tons/acre/year in the Park City area. These values fall within observed erosion rates for undisturbed watersheds in the western United States (0 to 2.5 tons/acre/year) (Neary et al., 2005). Post-fire, per-acre sediment delivery exceeded 2.5 tons/acre/year for almost 50% of watersheds in the analysis area. The highest per-acre sediment delivery rate at the watershed-scale was 29 tons/acre/year. Erosion rates tend to be <8.0 tons/acre/year for 80% after wildfires (Binkley, 2020; Robichaud et al., 2000), but erosion rates can reach 165 tons/acre/year when extreme rainfall events follow high-severity wildfires on steep slopes (Neary et al., 2005).

Table 2-7. Watershed-scale predictions for the likelihood of sediment delivery across 50 years of random weather simulations and the magnitude of sediment delivery under unburned conditions and the first year following wildfire for average and 1-in-50-year weather conditions. For comparison, sediment yields are typically 0-2.5 tons/acre/year in undisturbed watersheds across the western United States (Neary et al., 2005).

	Probability of sediment delivery (%) Median (minimum-maximum)			Total sediment (tons/year) Median (minimum-maximum)			Per-acre sediment (tons/acre/year) Median (minimum-maximum		
Weather conditions	Unburned	1-yr post-fire	Ratio (post-fire: unburned)	Unburned	1-yr post-fire	Ratio (post-fire: unburned)	Unburned	1-yr post-fire	Ratio (post-fire: unburned)
Average	9 (0-76)	38 (0-84)	3 (1-65)	0.3 (0.138)	15.2 (0-769)	20 (1-429)	0 (0-0.4)	0.1 (0-1.5)	20 (1-433)
1-in-50 year	N/A	N/A	N/A	11.1 (0-720)	316.5 (0-9,907)	28 (0.1-16,047)	0.1 (0.0-1.7)	2.3 (0.0-29.4)	29 (0.1-30,261)

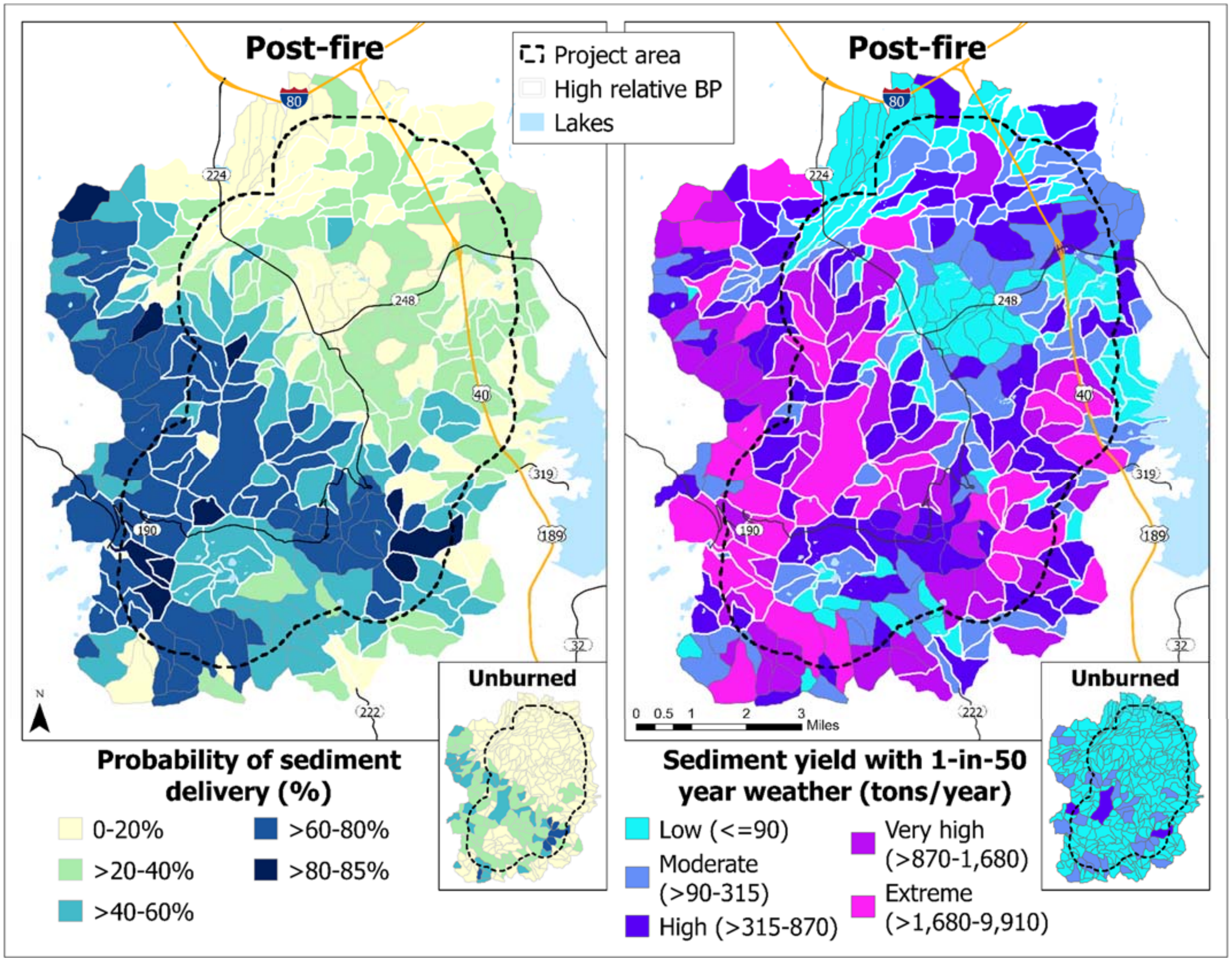

Figure 2-0-16. Figure 2.4.3. Watershed-scale predictions of the probability of sediment delivery (the percentage of 50 simulated weather scenarios that resulted in sediment delivery >0 tons/acre) and the magnitude of sediment delivery (tons/year) for unburned conditions and the first year following wildfire. Total sediment yield is presented for 1-in-50-year weather conditions. Watersheds outlined in white have relative burn probabilities (BP) ≥33%.

Values at Risk to Post-Fire Sediment Delivery

Post-fire sediment delivery triggered by severe rainstorms the first year following wildfires could cause significant damage to some homes, businesses, community values and infrastructure in the Park City area. We considered values with a high risk of post-fire sediment delivery to be those located in watersheds with a high relative burn probability (≥33%) and high magnitude of post-fire sediment delivery (>315 tons/year). Segments of streams/rivers and lakes downstream of watersheds with high potential post-fire sediment delivery were also identified as high risk because they could receive sediment from upper reaches.

Figure 2-0-17 and Figure 2-0-18 show the location of values at risk across the analysis area. Figure 2-0-19 shows the percentage of length of linear values at risk. Figure 2-0-20 shows the percentage of area of the Richardson Superfund Site and ski resorts at risk. Figure 2-0-25 shows the names and lengths of linear features exposed to post-fire sediment. Figure 2-0-29 shows the burn probabilities and potential sediment delivery for all values at risk included in this analysis. See Figure 2-0-24 for a reference map with the locations of topographic features (e.g., ravines, gulches, hills, and mountains) mentioned below, and Figures 2-0-25 – 2-0-28 for zoomed-in maps of values at risk in each project zone.

Homes and businesses - About 1,560 homes and businesses in the area (12% of all addresses) are in watersheds with a high risk of damage from post-fire sediment delivery. Homes and businesses with high risk of post-fire sediment delivery are located in or around Quarry Mountain, White Pine Canyon, Iron Canyon, Thaynes Canyon, McLeod Creek at the base of Crescent Ridge, Walker and Webster Gulch, Empire Canyon, Rossi Hill, Bald Eagle Mountain and north of Deer Valley Meadow.

Public safety - All fire stations, law enforcement buildings and courthouses have low risk of post-fire sediment delivery due to their locations in areas with low relative burn probabilities and shallow slopes. Communication towers on Quarry Mountain and Bald Mountain and a handful of sites with petroleum storage tanks or tier 2 chemical inventory facilities could be exposed to damaging post-fire sediment delivery. These sites with hazardous material are primarily maintenance shops with a small number of storage tanks. Less than 10% of the Richardson Superfund site is in watersheds with high risk of post-fire sediment delivery.

Critical infrastructure - Water infrastructure in the area has a high risk of damaging post-fire sediment. The high risk of streams and other water infrastructure to post-fire sediment delivery is particularly concerning given the importance of watersheds in this part of Utah for the delivery of clean drinking water (Figure 2.4.2). Numerous springs, water tanks and water points of distribution are in at-risk areas in and around Round Valley, Iron Canyon, Bald Eagle Mountain, Bald Mountain, Pocatello Gulch and south of Richardson Flat. About 40% of the length of pipelines, 15% of canals and ditches and 54% of streams and rivers are in at-risk areas, including 6.2 miles of McLeod Creek, 3.0 miles of the perennial stream in Thaynes Canyon, 2.7 miles of Kimball Creek, 2.0 miles of the ephemeral stream in Bloods Lake Drainage and 1.9 miles of the ephemeral stream in Walker and Webster Gulch. These at-risk streams were analyzed as part of the rapid stream assessment for this broader project (see chapter 2.3 Stream Condition).

One ephemeral stream and two perennial streams with high-risk flow out of the analysis area and into Jordanelle Reservoir, which is an important water supply for Jordan Valley Water Conservancy District. Several smaller lakes are also directly at risk of post-fire sediment or of receiving post-fire sediment from at-risk streams, including Silver Lake, Lake Mary, Dog Lake, Bloods Lake in the southwestern part of the analysis area and White Pine Lake in the central-western part. Although not included in this analysis, Rockport Reservoir, an important source of culinary water for Park City, could also be exposed to sediment delivery due to topography and potential fire behavior in the surrounding watersheds.

About 15% of overhead distribution lines and 28% of overhead transmission lines are in areas with high risk of post-fire sediment. At-risk transmission lines occur in and around White Pine Canyon, Iron Canyon, Walker and Webster Gulch, Guardsman Pass and south of Jupiter Hill. All electrical substations are predicted for low risk of post-fire sediment.

Transportation infrastructure - About 30% of the length of roads in the study area have a high risk of post-fire sediment, including over 4 miles of Highway 40 and 1 mile of Highway 224. The bridge on State Route 224 over Deer Valley ski run and on Deer Valley Drive over Silver Creek could be exposed to post-fire sediment. Sedimentation and debris flows over major roads and bridges can cause significant damage and road closures, such as occurred following the 2018 Pole Creek and Bald Mountain Fires, 2014 Levan Fire and 2012 Seeley Fire (Table 2-6). The bus stop at Snow Parks Lodge could also experience damage from post-fire sedimentation.

Recreation infrastructure - There is a significant risk of post-fire sediment delivery to recreation infrastructure in the Park City area. Almost all the Brighton Ski Resort in the study area could experience post-fire sediment delivery, as could over 50% of Deer Valley Resort and Park City Mountain Resort and almost 70% of the length of ski lifts. Over 45% of the length of trails in the study area and 11 trailheads have a high risk of post-fire sediment due to their location on steep slopes with high burn probabilities. This includes almost 10 miles of Mid Mountain Trail and 4 miles of Rambler and Pinecone Trails.

Heritage resources - Most historic buildings and homes in downtown Park City have low risk of post-fire sediment delivery. Glenwood Cemetery has a high risk of post-fire sediment delivery from McLeod Creek at the base of Crescent Ridge, and McPolin Farmstead could receive high sediment delivery from Iron Canyon. Historic structures at Thaynes Mine, California-Comstock Mine, Jupiter Mine, Alliance Mine and Silver King Mine are at risk of post-fire sediment delivery from watersheds around Jupiter Hill, Treasure Hill, Crescent Ridge, Thaynes Canyon and Webster and Walker Gulch.

Medical care, education, and other community services and resources - A majority of health and medical facilities, schools, churches, grocery stores and other community services and resources have low risk of post-fire sediment delivery. Most of these community assets are in watersheds with low relative burn probabilities and shallow slopes in downtown Park City and Snyderville. Exceptions include Park City Mountain Medical Clinic near McLeod Creek at the base of Crescent Ridge, St. Mary's Catholic Church and Holy Cross Ministries Preschool near the mouth of White Pine Canyon and Westgate Marketplace near the mouth of Willow Draw and Red Pine Canyon.

We did not model landslides, channel erosion or debris flows, so an even greater number of community assets might be at risk of damaging sediment and flooding than those described here. Much of downtown Park City could potentially be exposed to flooding and debris flow from Thaynes Canyon, McLeod Creek, Walker and Webster Gulch and Ontario Canyon, as could much of Snyderville due to flooding and debris flow from Willow Draw and Red Pine Canyon.

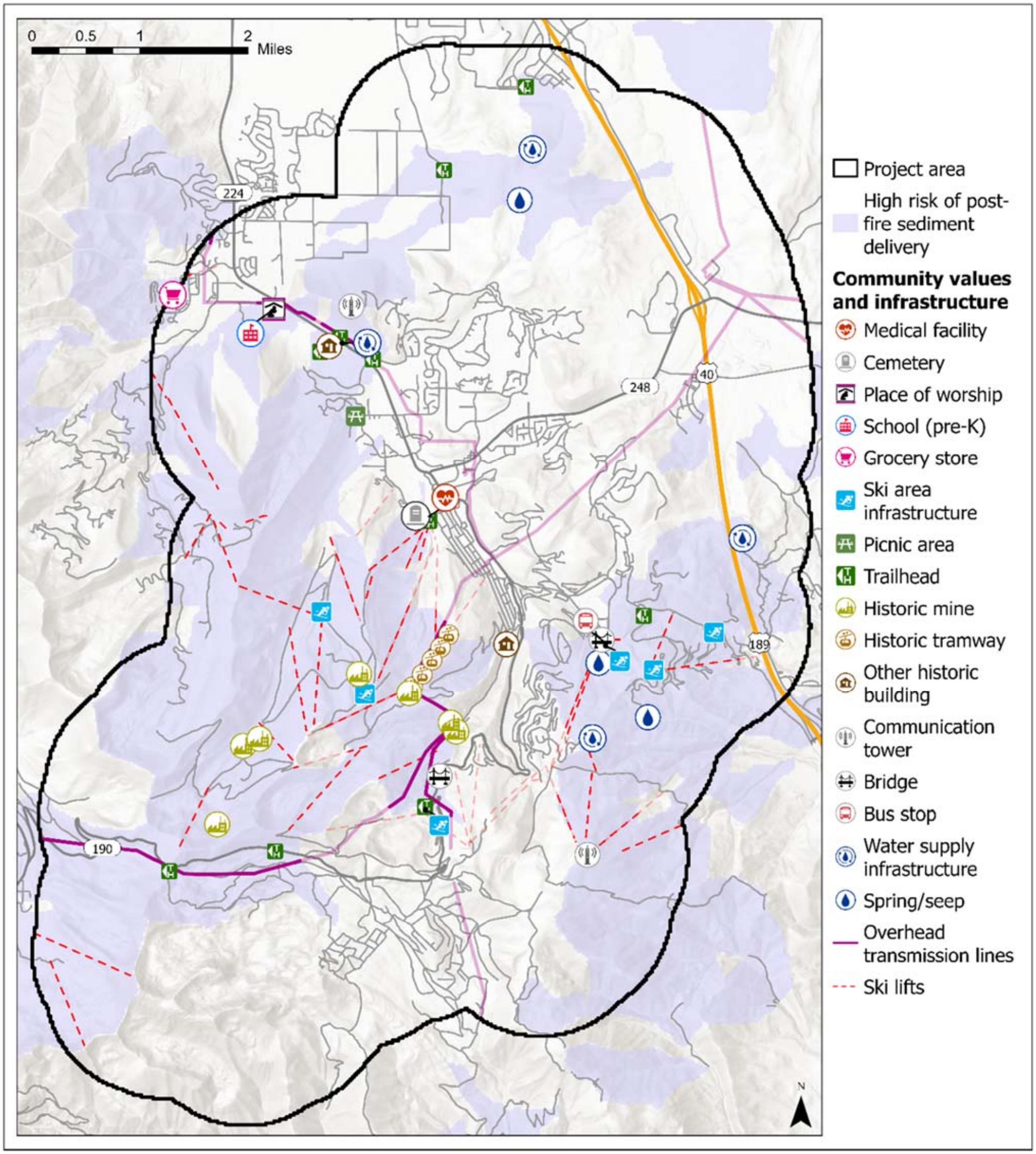

Figure 2-0-17. Community values and infrastructure in watersheds with high risk of post-fire sediment delivery. Ski lifts and overhead transmission lines in lighter shades are segments not at high risk. Zoomed-in maps of values at risk in each project zone are available in Figures 2-25 – 2-28.

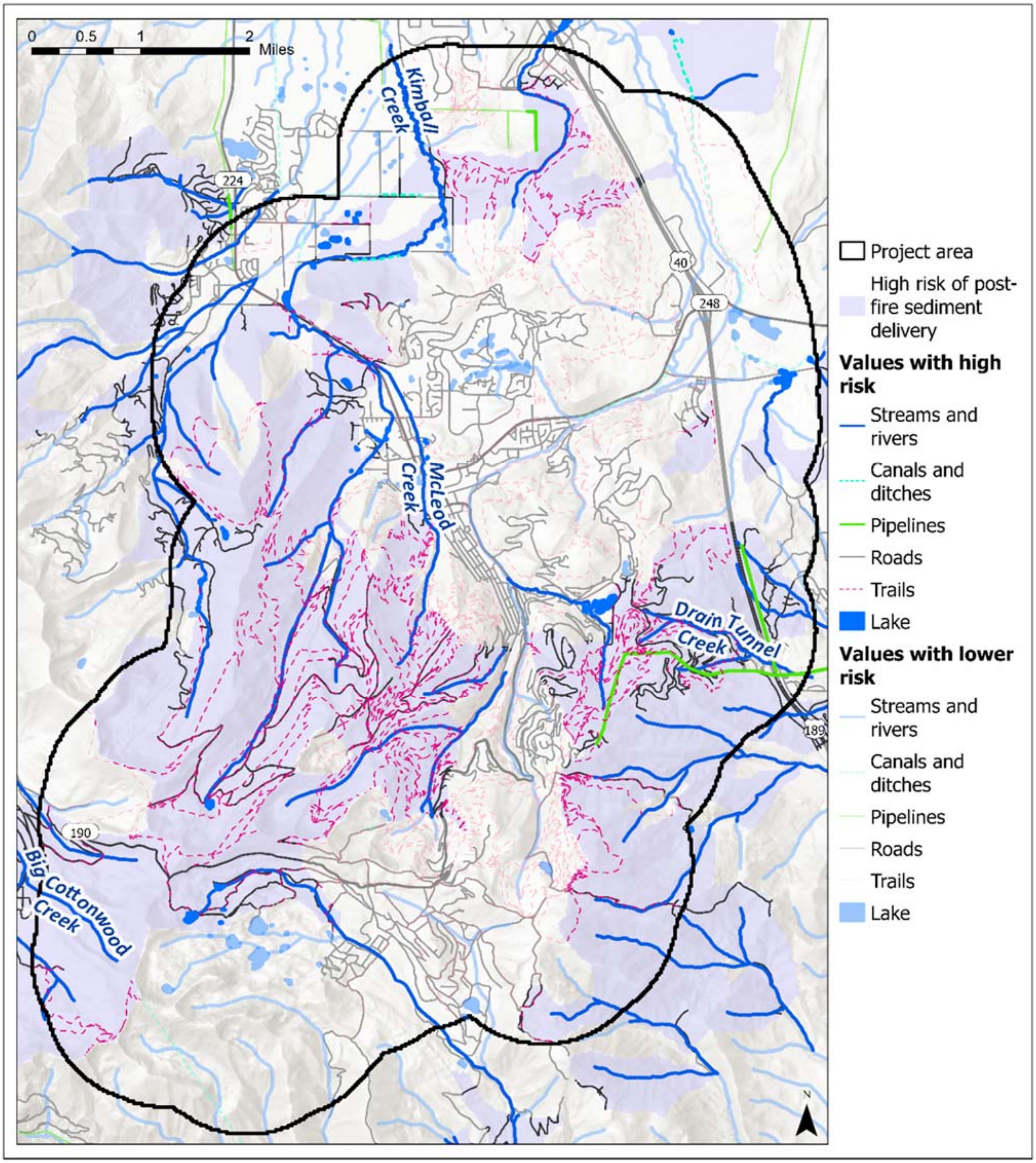

Figure 2-0-18. Roads, trails, streams, canals, ditches, pipelines and lakes in watersheds with high risk of post-fire sediment delivery. Segments of streams/rivers and lakes downstream of watersheds with high potential post-fire sediment delivery were also identified as high risk because they could receive sediment from upper reaches. Features in lighter shades are those not at high risk. Zoomed-in maps of values at risk in each project zone are available in Figures 2-25 – 2-28.

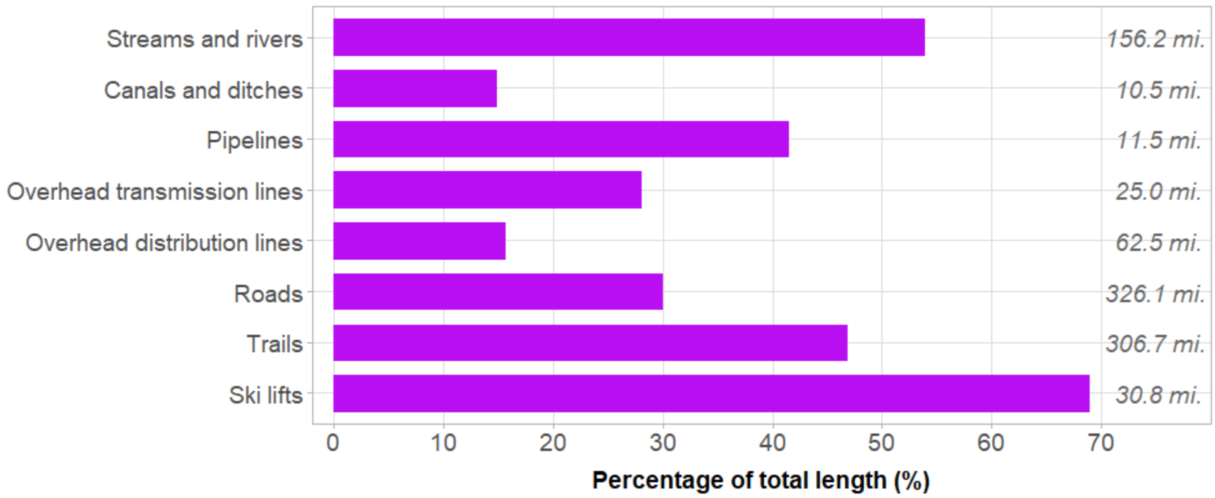

Figure 2-0-20. Percentage of the length of community assets and infrastructure in the watershed analysis area with high risk of post-fire sediment delivery. Annotations to the right indicate the total length of each feature in the analysis area in miles.

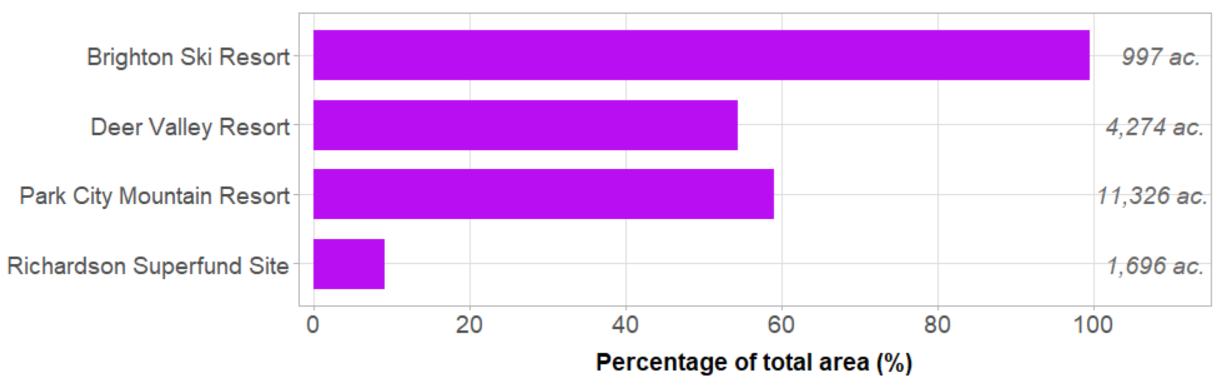

Figure 2-0-19. Percentage of the area of ski resorts and the Richardson Superfund Site in the watershed analysis area with high risk of post-fire sediment delivery. Annotations to the right indicate the total area of each feature in the analysis area in acres.

Recommendations and Conclusion

Pre-Fire Mitigation Measures

The potential for post-fire sediment delivery and damage to values at risk can be mitigated through activities to improve stream health and resilience, strategic fuel treatments to reduce fire hazards and pre-planning for emergency response. This assessment of post-fire sediment delivery fed into recommendations for priority actions to improve the resilience of streams to wildfires (see chapter 2.3. Post-Fire Sediment

Delivery) and the location of proactive fuel treatments to mitigate wildfire and post-fire impacts (see chapter 5.0 Wildfire Risk Assessment).

Rivers and stream channels that can dissipate flood waters and store sediment are those that have high floodplain connectivity, contain features that can slow the velocity of water and sediment (e.g., boulders, beaver dams, and large pieces of wood) and are lined with abundant riparian vegetation (Fairfax and Whittle, 2020; Wheaton et al., 2019a). See chapter 2.3 Stream Condition for a description of the current condition of streams in the Park City area and recommended management actions to improve stream health and resilience. These activities are particularly important for streams in areas with a high potential for sediment delivery, including Kimball Creek, East Canyon Creek, McLeod Creek, Silver Creek, the perennial stream in Thaynes Canyon and ephemeral streams in Bloods Lake Drainage and Webster and Walker Canyon.

Fuels treatments can help avoid costly post-fire damage to infrastructure by reducing fire intensity and extent, and therefore reducing the likelihood of post-fire debris flows and sedimentation (Gannon et al., 2019; K. W. Jones et al., 2017). Several projects to mitigate wildfire risk and reduce the likelihood of post-fire sediment have already been completed in the vicinity of Park City, including a $1.24 million project funded by the Utah Division of Wildlife Resources/Utah Watershed Restoration Initiative to mitigate fire risk and restore ecosystem conditions in Parleys Canyon. Fuel treatments recently completed on Treasure Hill could reduce fire severity and potentially reduce the likelihood and magnitude of post-fire sediment delivery into the downtown area of Park City. Watersheds in Iron Canyon, Thaynes Canyon, Walker and Webster Gulch, along Crest Ridge, and around Bald Mountain and Bald Eagle Mountain could especially benefit from fuel treatments given their high potential to deliver sediment to homes and community assets after wildfire.

We recommend that emergency managers in the Park City area continually revise and strengthen plans for developing and maintaining water drainage infrastructure, conducting proactive fuel treatments and coordinating post-fire emergency response in coordination with federal and state agencies, utility companies, ski resorts and other affected parties. It is vital to educate residents and business owners about potential risks of post-fire sediment and encourage them to develop plans to protect their families, homes and businesses prior to an emergency ever arising. Table 2-8 describes valuable resources to assist with city-level and individual-level planning around post-fire flooding.

Post-Fire Mitigation Measures

After a wildfire, a variety of mitigation options can stabilize hillslopes, reduce post-fire erosion and protect lives and property. Robichaud & Ashmun (2013) review the relative effectiveness of different post-fire mitigation measures, and Robichaud et al. (2000) provide cost estimates for different measures. The Summit County Sediment and Erosion Control BMP Manual outlines the intended uses, benefits and ideal design for different mitigation measures (Summit County Engineering Department, 2004).

Common stabilization treatments include the application of straw mulch or a seed mix (usually annual grasses) to burned hillsides. Water barriers, such as contour-felled logs or straw wattles, can slow the movement of water and sediment downslope. Particularly effective measures are straw or wood mulches and log or rock check dams. Contour-felling can reduce sediment delivery under low-intensity rainfall, but this approach is less effective under high-intensity rainfall conditions (Robichaud & Ashmun 2013).

Creative, low-cost and effective approaches to post-fire mitigation can include building artificial beaver dams to decrease the velocity of downstream flows and trap sediment. This type of project was undertaken by the

Utah Division of Wildlife Resources, U.S. Fish & Wildlife Service, Trout Unlimited, Sageland Collaborative and private landowners in 2016 in Miller Creek following the 2012 Seeley Fire (Utah Division of Wildlife Resources, 2021).

Actions undertaken by Burned Area Emergency Response teams and Utah's Watershed Restoration Initiative following past wildfires along the Wasatch Range have included the following (Table 2-17):

- Aerial seeding and mulching to increase ground cover and decrease the potential for erosion.
- Assessment, treatment and monitoring of invasive species.
- Maintenance, repair and installation of drainage features such as check dams, water bars and sediment basins.
- Streambank stabilization and reshaping to decrease the potential for future flooding events.
- Closures and warning signs to protect public safety.
- Storm patrols to assess damages after large rainfall events.

The appropriateness and effectiveness of different post-fire mitigation methods depend on burn severity, soil texture, topography, years-since-fire, storm conditions, accessibility of the site, values at risk, and tradeoffs between mitigation actions and natural resource conditions. BAER teams can help assess potential sediment delivery for a specific event, values at risk and effective mitigation methods after a wildfire occurs on federal lands. They do not conduct assessments on local-, state- or privately owned land, but findings from BAER reports can be useful for informing mitigation on surrounding lands, and federal agencies have coordinated with Utah's Watershed Restoration Initiative to support post-fire mitigation on non-federal land.

There are important planning steps that municipalities, land managers, emergency managers, water providers and utilities can undertake to prepare for post-fire mitigation before an event even happens. The Colorado Post-Fire Recovery Playbook is an excellent example of developing a process with checklists, contact information and potential funding sources for mitigation actions (see link in Table 2-8). A Post-Fire Recovery Playbook for this part of Utah could include information about providers of weed-free seeds and information about funding sources such as Utah's Watershed Restoration Initiative.

Proactive planning and activities to mitigate impacts of wildfires and post-fire sediment are key components of becoming a fire-adapted community. Immediate and long-term action to address potential post-fire sediment are important for protecting values at risk across the Park City area. Climate change makes immediate action even more imperative as the future is likely to include more frequent large, high-intensity wildfires and extreme rainfall events (Sankey et al., 2017; Touma et al., 2022).

Table 2-8. Resources for homeowners, business owners, water providers, utility companies, municipalities and counties to mitigate impacts of post-fire flooding, sediment delivery and debris flows. Website links were active as of January 2023.

TITLE AND SOURCE	TARGET AUDIENCE	EXAMPLE OF ACTIONS TO MITIGATE AND/OR RESPOND TO POST-FIRE SEDIMENT DELIVERY
Flood and landslide sections in Part 3 and 5 of the 2022 Pre-Disaster Mitigation Plan for Summit, Utah, and Wasatch Counties (Mountainland Association of Governments, 2022)	Local governments	Require hazardous materials to be located outside flood areas. Retain thick vegetation on public lands flanking rivers.
Colorado Post-Fire Recovery Playbook (Dunlap et al., 2021)	Counties, tribes, municipalities and water providers. The document is specific to Colorado but provides a good framework for local governments in other states.	Obtain geospatial data on critical infrastructure and drinking water supplies. Coordinate with local entities to establish a local recovery group.
Wildfire incident action checklist for water utilities (U.S. Environmental Protection Agency, 2022)	Water utility companies and municipalities	Identify potential failure points within service areas. Install a rain gauge upstream of raw water intakes for early warning of heavy precipitation.
Flood hazard information for property owners (Utah Division of Emergency Management, 2023; includes links to ready.gov, FEMA, and the National Flood Insurance Program)	Homeowners and business owners	Purchase flood insurance. Elevate and anchor critical utilities, including electrical panels, propane tanks, sockets, wiring, appliances and heating systems.
Post-wildfire hazards (Utah State University Extension, 2023)	Homeowners and business owners	Secure important documents in a waterproof deposit box. Ensure sump pumps are working and have a battery-operated backup power source.
Homeowner's Guide for Flood, Debris, and Erosion Control (Los Angeles County Public Works, 2018). Homeowners and business owners.	Although not specific to Utah, this resource has incredible infographics and clear action steps that apply to all post-fire emergencies.	Install more permanent measures to protect your home, such as terraces and slope drains. Avoid altering drainage patterns that could worsen conditions for your neighbor.

Methods Details

We modeled erosion using the Water Erosion Prediction Project (WEPP) version 2.0 following the approaches of Elliot et al. (2016) and Miller et al. (2011). WEPP is a process-based model that predicts runoff and sediment yields from hillslopes and small, unchannelized watersheds (Elliot & Hall, 2010). WEPP models sheet and rill erosion and hydrological processes such as snow accumulation and melt, deep percolation of soil water and subsurface lateral flow under different land uses, climate and hydrologic conditions. WEPP does not model landslides, channel erosion or debris flows. The WEPP model was developed by the U.S. Department of Agriculture Forest Service, Agricultural Research Service and numerous universities.

We delineated hillslopes through ArcPro version 3.0.3 using a modified version of the WEPP Hillslope Toolbox, which is based on TOPAZ (Topographic Parameterization Software) from the USDA Agricultural Research Service. Small watersheds can be subdivided into at least three hillslopes—one on each side of a stream or river and one above the headwaters of the watershed (Figure 2-0-21). We modified the original toolbox to be compatible with ArcPro 3.0.3 and to improve model performance. We used a 30-meter resolution digital elevation model from the U.S. Geological Service.

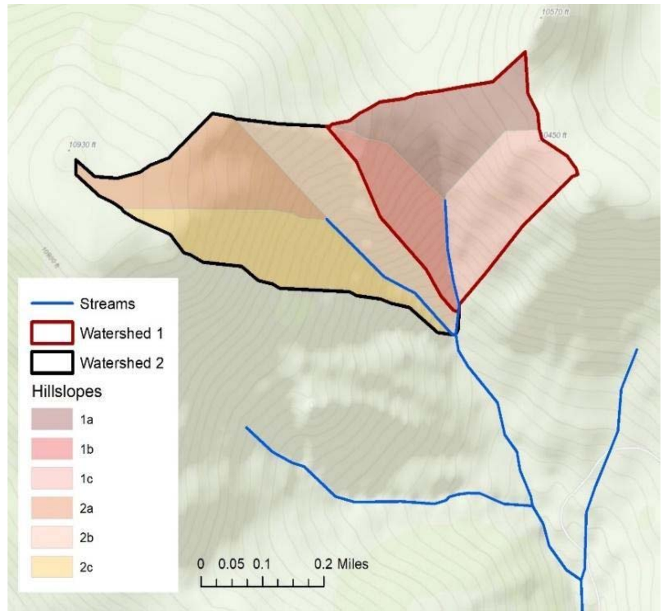

Figure 2-0-21. Example of small watersheds and hillslopes.

Hillslopes were delineated with a critical source area (CSA) of 25 acres and a minimum source channel length (MSCL) of 330 feet. Watersheds were delineated with a CSA of 75 acres and a MSCL of 330 feet. We delineated 1,729 hillslopes within the analysis area with an average size of 68 acres (range of 3 to 3,000 acres), and we aggregated results within 320 larger watersheds with an average size of 370 acres (range of 5 to 4,620 acres). Watersheds contained an average of 5 hillslopes (range of 1 to 29 hillslopes). Watershed predictions of sediment delivery in tons/acre/year were weighted averages based on hillslope size, and total sediment delivery was a sum of hillslope predictions in tons/year.

We used the WEPP batch processing spreadsheet available from the U.S. Forest Service to predict erosion from hillslopes within the analysis area. WEPP requires the following inputs: hillslope area, slope profiles for upper and lower portions of hillslopes, soil texture, percentage of soil as rock, vegetation type and/or burn severity, and surface cover (Figure 2-0-22).

Hillslopes were assigned the most prevalent soil texture, burn severity and vegetation types present on flow paths within the upper and lower portion of the hillslopes. Soil textures came from the Soil Survey Geographic Database (SSURGO) produced by the USDA Natural Resources Conservation Service and available from the Utah Geospatial Resource Center's State Geographic Information Database (SGID). We associated soil textures from SSURGO with WEPP soil texture categories and assigned each soil type a percent rock value based on the NRCS Field Book for Describing and Sampling Soils (Schoeneberger et al., 2013) (Table 2-9).

Vegetation data came from associating 2016 LANDFIRE existing vegetation type (EVT) physiognomic subclasses with WEPP vegetation categories. Percent ground cover estimates for WEPP vegetation categories were based on default values from the online WEPPcloud Post-Fire Erosion Prediction tool (Table 2-10).

We associated predicted flame length from IFTDSS under extreme (97th percentile) fire weather conditions with burn severity classes and percent cover values following Elliot et al. (2016) and default values from the online WEPPcloud Post-Fire Erosion Prediction tool (Table 2-11). The post-fire scenario assumed that fires burned every portion of a watershed—a reasonable assumption given that the sizes of watersheds delineated for this analysis (5 to 4,620 acres) are within the size range of wildfires along the Wasatch Range that resulted in post-fire sediment (160-103,500 acres) (Table 2-6). See chapter 5.0 Wildfire Risk Assessment for a description of fire behavior methodology and output.

We ran the WEPP model under 50 years of different weather conditions generated by the Rocky Mountain Research Station Climate Generator (Rock:Clime) (Elliot et al., 1999). Weather scenarios were based on historical observations from 45 years at the Silver Lake Brighton Station (NWS cooperative station 427846), which is 0.3 miles west of the study area, and from 65 years at the Snake Creek Powerhouse Station (NWS cooperative station 427909), which is 2.5 miles south of the study area (Figure 2-0-23). The two weather stations within the study area—Park City Fire Station 31 (NWS cooperative station 426644) and Snyderville (NWS cooperative station 427942) were not incorporated into the Rock:Clime program because they have less than 30 years of historical observations (Table 2-12).

We ran the WEPP model under 50 years of different weather conditions generated by the Rocky Mountain Research Station Climate Generator (Rock:Clime) (Elliot et al., 1999). Weather scenarios were based on historical observations from 45 years at the Silver Lake Brighton Station (NWS cooperative station 427846), which is 0.3 miles west of the study area, and from 65 years at the Snake Creek Powerhouse Station (NWS cooperative station 427909), which is 2.5 miles south of the study area (Figure 2-0-23). The two weather stations within the study area—Park City Fire Station 31 (NWS cooperative station 426644) and Snyderville (NWS cooperative station 427942) were not incorporated into the Rock:Clime program because they have less than 30 years of historical observations (Table 2-12).

Historical weather conditions were substantially cooler and wetter at the Silver Lake Brighton Station (elevation of 8,740 feet) and the Snake Creek Powerhouse Station (elevation of 6,010 feet) (Table 2-13). Historical observations from the weather stations at Park City Fire Station 31 and Snyderville were comparable to those from the Snake Creek Powerhouse Station (Table 2-14). We used conditions from the Silver Lake Brighton Station to model potential erosion for areas ≥8,000 feet and those from the Snake Creek Powerhouse Station for areas <8,000 feet.

We classified post-fire sediment delivery into five categories (low, moderate, high, very high and extreme) based on the distribution of predictions (Table 2-15). For our values at risk analysis, we compiled and validated the locations of community assets from various sources and utilized a similar categorization as that for the Qualitative Wildfire Risk Analysis as part of the broader project for Park City Municipal Corporation (Table 2-16). We considered all community assets within a watershed to share the same risk regardless of their specific topographic position within a watershed. Due to the scale of analysis, we could not model different exposure levels for infrastructure located at the top of a watershed versus at the bottom of a watershed, but it is likely that infrastructure near the bottom of watersheds have a greater exposure to cumulative sedimentation.

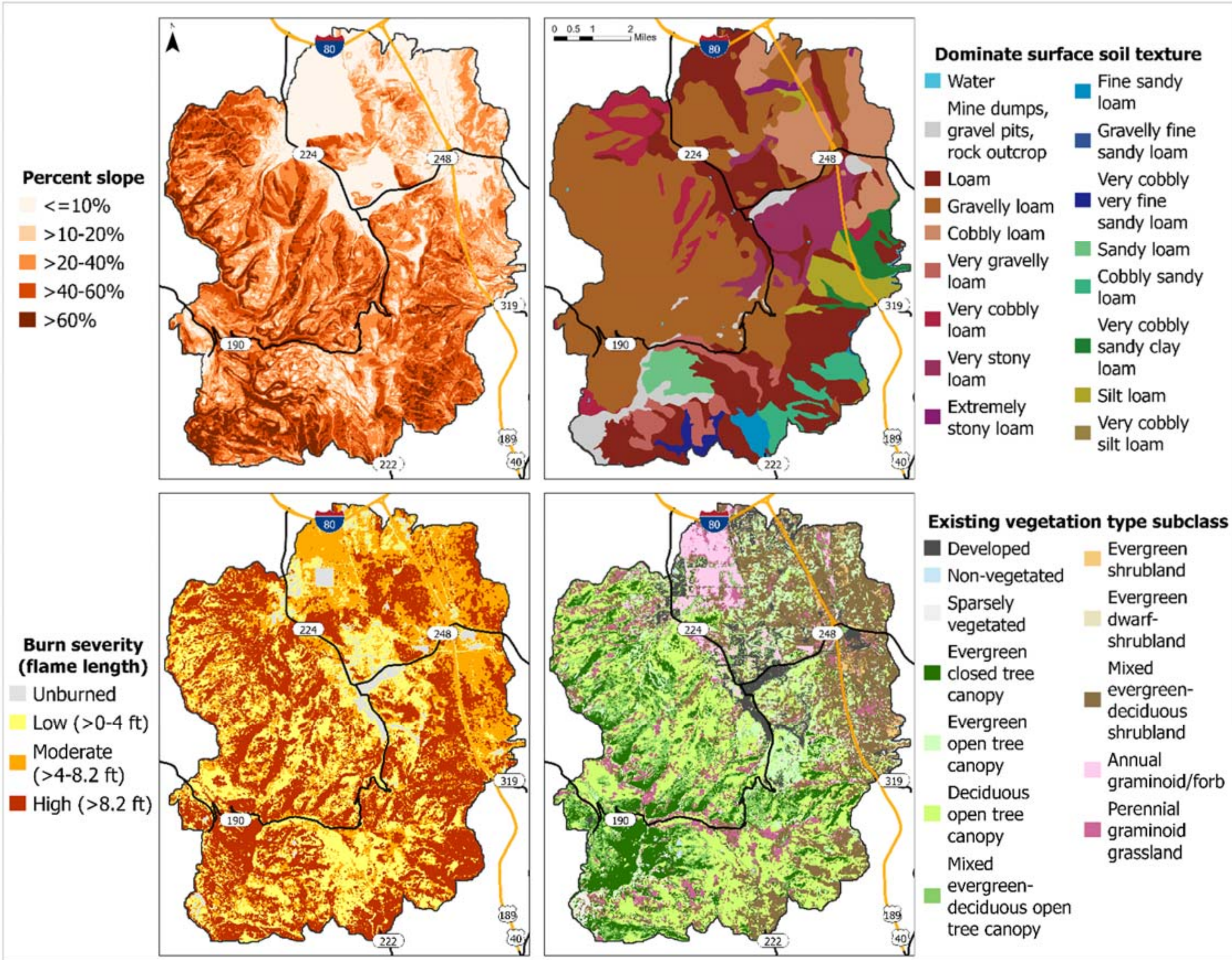

Figure 2-0-22. Inputs used for predicting sediment delivery with WEPP. Sources: Slope from LANDFIRE 2016, soil texture from the Soil Survey Geographic Database, burn severity derived from flame length predictions from IFTDSS (see chapter 5.0 for fire behavior methodology), existing vegetation type subclass from LANDFIRE 2016.

Table 2-9. Relationships between soil textures from SSURGO and WEPP soil textures and percent rock content, and the percent of the study area represented by each SSURGO soil texture.

SSURGO soil texture	WEPP soil texture	Percent rock (%)[1]	Percent of erosion analysis area
Loam	Loam	7	22
Cobbly loam Gravelly loam	Loam	25	50
Very cobbly loam Very gravelly loam Very stony loam	Loam	48	13
Extremely stony loam	Loam	75	<1
Sandy loam Fine sandy loam	Sandy loam	7	3
Cobbly sandy loam Gravelly fine sandy loam	Sandy loam	25	2
Very cobbly very fine sandy loam Very cobbly sandy clay loam	Sandy loam	48	3
Silt loam	Silt loam	7	3
Very cobbly silt loam	Silt loam	48	<1
Gravel pit Mine dump Rock outcrop	Sandy loam	75	3
Water	N/A	N/A	<1

[1] Percent rock values are the midpoint of the percent rock associated with soil texture modifiers "gravelly" and "very gravelly" according to (Schoeneberger et al., 2013).

Table 2-10. Relationship between LANDFIRE existing vegetation type (EVT) physiognomic subclasses and associated WEPP vegetation categories and percent cover values.

LANDFIRE EVT physiognomic subclasses	WEPP vegetation type	Percent ground cover (%)	Percent of erosion analysis area (%)
Evergreen closed tree canopy	20-year-old forest	90	14
Deciduous open tree canopy Evergreen open tree canopy Mixed evergreen-deciduous open tree canopy	Shrub-dominated[1]	90	44
Evergreen dwarf-shrubland Evergreen shrubland Mixed evergreen-deciduous shrubland	Shrub-dominated	85	24
Perennial graminoid grassland	Tall grass	80	4
Annual graminoid/forb (croplands)	Tall grass	90	6
Sparsely vegetated	Short grass	50	1
Developed and non-vegetated	Short grass[2]	50	7

[1] Shrub-dominated was used for open tree canopy types because, according to WEPP, this vegetation can produce reasonable estimates for harvested forests 3 years after harvest, which might more closely represent overstory and understory conditions than the 20-year-old forest conditions.
[2] WEPP does not have a category for barren, so short grass was used instead.

Table 2-11. Relationship between predicted flame length, burn severity and percent cover following Elliot and others (2016) and default values from the online WEPPcloud Post-Fire Erosion Prediction tool.

BURN SEVERITY CATEGORY	PREDICTED FLAME LENGTH (FT)	PERCENT GROUND COVER (%)	PERCENT OF EROSION ANALYSIS AREA (%)
Unburned	0	See Table A.2.4.2	4
Low	>0 to 4	60	27
Moderate[1]	>4 to 8.2	45	28
High	>8.2	15	41
[1] WEPP does not have a cover category for moderate severity fire, so low-severity fire was used with the ground cover value indicated above.			

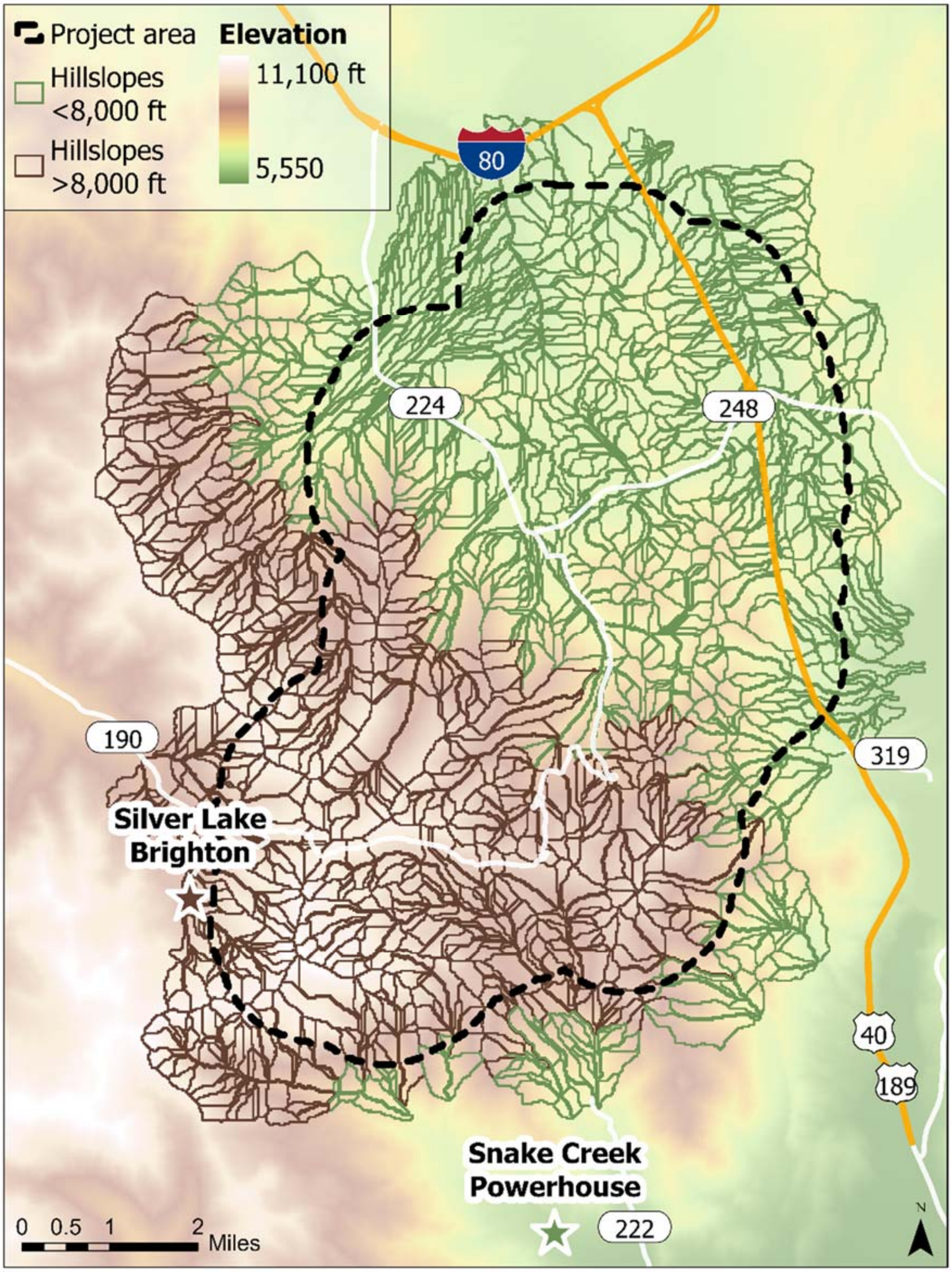

Figure 2-0-23. Location of the Silver Lake Brighton Station (NWS cooperative station 427846), which was used to model weather conditions for areas ≥8,000 feet in elevation, and the Snake Creek Powerhouse Station (NWS cooperative station 427909), which was used for areas <8,000 feet.

Table 2-12. Location and characteristics of National Weather Service (NWS) cooperative stations in the Park City area. Data from the Western Regional Climate Center (2023).

Station name (NWS COOP ID)	Years of records	Latitude	Longitude	Elevation (ft)
Silver Lake Brighton (427846)	1948-2016 (45 years of record used by Rock:Clime)	40°N 36' 00"	111°W 35' 00"	8,740
Snake Creek Powerhouse (427909)	1928-2016 (65 years of record used by Rock:Clime)	40°N 32' 43"	111°W 30' 15"	6,010
Park City Fire Station 31 (426644)	1992-2016 (not included in Rock:Clime)	40°N 40' 00"	111°W 30' 00"	6,910
Snyderville (427942)	1991-2016 (not included in Rock:Clime)	40°N 42' 00"	111°W 32' 00"	6,460

Table 2-13. Annual climate conditions under average and 50-year conditions (i.e., those likely to occur only once in 50 years) based on simulated climate scenarios from the Rock:Clime model (Elliot et al., 1999) and historical observations at the Snake Creek and Silver Lake Brighton weather stations.

	Snake Creek Powerhouse Station (watersheds < 8,000 ft)		Silver Lake Brighton Station (watersheds >= 8,000 ft)	
Weather characteristic	Average conditions	1-in-50-year conditions	Average conditions	1-in-50-year conditions
Precipitation (rain + snow; inch/year)	23.1	34.6	42.9	58.0
Precipitation events/year	95	105	119	129
Maximum monthly average temperature (F)	84.5	84.3	72.1	73.9
Minimum monthly average temperature (F)	13.0	13.8	11.7	10.0

Table 2-14. Average weather conditions for NWS cooperative stations in the Park City area. Data for Silver Lake Brighton and Snake Creek Powerhouse from Rock:Clime (Elliot et al., 1999) and Park City Fire Station 31 and Snyderville from the Western Regional Climate Center (2023).

Weather characteristic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average maximum temperature													
Silver Lake Brighton	30.8	33.4	36.7	44.5	53.2	63.8	72.1	70.3	62.3	51.4	38.1	32.0	49.1
Snake Creek Powerhouse	33.5	38.1	45.7	57.0	67.0	76.5	84.5	82.3	73.8	62.4	45.7	36.2	58.6
Park City Fire Station 31	34.6	37.0	45.8	54.2	65.6	74.9	83.3	81.0	70.9	59.1	43.6	35.0	57.1
Snyderville	33.4	34.9	44.6	50.9	62.4	71.7	78.6	79.8	72.1	57.0	42.8	35.2	55.3
Average minimum temperature													
Silver Lake Brighton	11.7	11.8	14.1	20.3	28.5	36.4	43.9	42.4	35.1	26.4	16.3	11.7	24.9
Snake Creek Powerhouse	13.0	15.0	20.5	27.7	34.2	39.9	46.3	45.2	37.5	29.3	20.1	14.4	28.6
Park City Fire Station 31	12.8	13.9	21.6	28.1	34.9	41.0	48.3	47.4	38.8	29.6	19.8	14.1	29.2
Snyderville	9.4	8.6	19.0	25.7	33.5	37.9	41.6	43.2	35.2	25.3	16.3	10.9	25.6
Average precipitation (inches)													
Silver Lake Brighton	5.0	4.5	5.3	3.9	3.0	1.6	1.5	1.8	2.1	3.2	4.7	4.9	41.6
Snake Creek Powerhouse	2.9	2.7	2.3	1.8	1.5	1.0	0.9	1.2	1.2	1.8	2.2	2.7	22.1
Park City Fire Station 31	2.0	1.9	1.9	1.8	2.1	1.4	1.0	1.3	1.4	2.2	2.0	1.7	20.6
Snyderville	2.8	2.1	2.2	2.3	1.9	1.6	1.0	1.3	1.2	2.0	1.9	2.3	22.6

Table 2-15. Categories for potential sediment delivery the first year following wildfire and under 1-in-50-year storm conditions.

Sediment category	Total sediment (tons/year)	Per-acre sediment (tons/acre/year)	Reason for upper cutoff value
Low	0 - 90	0 - 0.5	90th percentile value for unburned conditions at the watershed scale.
Moderate	>90 - 315	>0.5 - 2.0	Median value for post-fire conditions at the watershed scale.
High	>315 - 870	>2.0 - 5.0	75th percentile value for post-fire conditions at the watershed scale.
Very high	>870 - 1,680	>5.0 - 9.5	90th percentile value for post-fire conditions at the watershed scale.
Extreme	>1,680 - 9,955	>9.5 - 30	Maximum value for post-fire conditions at the watershed scale.

Table 2-16. Categorization scheme for community values and infrastructure and data sources used for this analysis. Acronym descriptions appear as a footnote below the table. A subset of these values were included in the QWRA process, described in chapter 5.0 Wildfire Risk Assessment. The QWRA process limits the number of values at risk and categories that can be used, but the suite of values at risk was not limited for our post-fire sediment assessment.

Category	Source(s)	Included in QWRA?
Critical infrastructure		
Overhead transmission lines	Rocky Mountain Power	Yes
Overhead distribution lines	Rocky Mountain Power	Yes
Electrical substations	Rocky Mountain Power	Yes
Water point of distribution	Bureau of Reclamation	Yes
Water treatment plants	Bureau of Reclamation	Yes
Water tanks	Bureau of Reclamation	Yes
Water pump stations	Bureau of Reclamation	Yes
Springs/seeps	UGRC and USGS NHD	Yes
Tunnels, culverts, and pipelines	UGRC and USGS NHD	Yes
Resort infrastructure		
Snow-making infrastructure	Deer Creek Resort	Yes
Resort day lodges	Digitized by Alpine Forestry from resort websites and aerial imagery	Yes
Ski lifts	Digitized by Alpine Forestry from resort websites and aerial imagery	Yes
Other recreation infrastructure		
Sports center	UGRC, OpenSourcePlaces, Google Maps	No
Recreation area	UGRC, OpenSourcePlaces, Google Maps	No
Campground	UGRC, OpenSourcePlaces, Google Maps	No
Picnic area	UGRC, OpenSourcePlaces, Google Maps	No
Trailhead	UGRC, OpenSourcePlaces, Google Maps	Yes
Trails	UGRC plus additions from Alpine Forestry	Yes
Heritage resources		
Museum	UGRC and OpenSourcePlaces	No
Historic mines	Park City Historic Site Inventory	Yes
Other historic buildings	Park City Historic Site Inventory	Yes
Human habitation		
Residential and commercial structures	UGRC, Microsoft Building Footprints, Google aerial imagery	Yes
Education and childcare (included under human habitation for QWRA)		
Public library	UCRC, USBE, WFRC	No
Childcare center	UGRC, HIFLD, OpenSourcePlaces, Google Maps	Yes
Schools (pre-K to 12)	UCRC, USBE, WFRC, HIFLD	Yes
Other community services and resources		
Cemeteries	UGRC, OpenSourcePlaces	No
Place of worship	UGRC, Google Maps	No
Senior center	Google Maps	Yes
Grocery store	UGRC, WFRC, UDAF, Google Maps	No
Post office	UGRC, U.S. Postal Service	No

City government	UGRC, HIFLD, OpenSourcePlaces	No
PUBLIC SAFETY		
Fire station	UGRC	Yes
Law enforcement	UGRC	No
Court houses	HIFLD	No
FM radio towers	HIFLD	Yes
Cell towers	HIFLD	Yes
Land mobile commercial towers	HIFLD	Yes
Superfund site	EPA	Yes
Contaminated sites	EPA	Yes
Solid waste facility	UGRC, UWMRC	No
Toxic release inventory	UGRC, UDEQ	No
Petroleum fuel tanks	UGRC, UDEQ	No
Tier 2 Chemical Inventory Facility	UGRC, UDEQ	No
HEALTH AND MEDICAL (INCLUDED UNDER PUBLIC SAFETY FOR QWRA)		
Hospitals	UGRC, Utah DHHS, Utah DEM, Google Maps	Yes
Clinics	UGRC, Utah DHHS, Utah DEM, Google Maps	Yes
Mental health facilities	UGRC, Utah DHHS, Utah DEM, Google Maps	Yes
Urgent care	UGRC, Utah DHHS, Utah DEM, Google Maps	Yes
Surgery center	UGRC, Utah DHHS, Utah DEM, Google Maps	Yes
Health departments	HIFLD	No
Nursing homes	None in analysis area	N/A
TRANSPORTATION		
Bus stop	UGRC, UTA, OpenSourcePlaces, Google Maps	No
Gas station	UGRC, Utah DEQ	No
Bridge	FTA NTD	No
EPA = U.S. Environmental Protection Agency FTA NTD = Federal Transit Authority, The National Transit Database HIFLD = Homeland Infrastructure Foundation-Level Data UDAT = Utah Department of Agriculture and Food UDDHS = Utah Department of Health and Human Services UDEM = Utah Division of Emergency Management UDEQ = Utah Department of Environmental Quality UGRC = Utah Geospatial Resource Center USBE = Utah State Board of Education USGS NHD = U.S. Geological Survey National Hydrography Dataset UTA = Utah Transit Authority UWMRC = Utah Division of Waste Management and Radiation Control WFRC = Wasatch Front Regional Council		

Additional Tables and Figures

Table 2-17. Suppression costs, potential losses from post-fire debris flows and sedimentation, funding for post-fire mitigation and specific mitigation actions. Funding sources are federal funding from Burned Area Emergency Response teams (BAER), state funding from the Utah's Watershed Restoration Initiative (UWRI) and other funding sources (specified in footnotes). Costs are not adjusted for inflation.

		Funding for mitigation			
Fire	Suppression cost	BAER	UWRI	Other	Mitigation actions
Parleys Canyon Fire (2021)	$2.6 million	$0	$68,537	Aerial seeding.	Aerial seeding. Source: (Edgel, 2022; Waterman, 2021)
Pole Creek & Bald Mountain Fires (2018)	$40.3 million	$372,605	$1.4 million	$9.6 million[1]	Aerial seeding. Weed inventory, control and monitoring. Debris and hazard tree removal. Drainage feature repair and installation. Road and streambank stabilization. Warning signs, closures and storm patrol. Source: (Edgel, 2019; Hardy, 2018; Hardy & Waterman, 2018b)
Coal Hollow Fire (2018)	Not reported	$477,297	None		Aerial seeding. Weed inventory, control and monitoring. Drainage feature repair and installation. Warning signs, closures and storm patrol. Source: (Natharius & Meccariello, 2018)
Dollar Ridge Fire (2018)	$18.2 million	$13,430	$1.4 million	$28.5 million[2]	Water treatment plant improvements. Aerial seeding. Weed inventory, control and monitoring. Trail stabilization and repair. Warning signs. Source: (Central Utah Water Conservancy District, 2021; Hardy, 2018; Mathis, 2019)
Levan Fire (2014)	$3.5 million	$508,475	$178,561		Aerial mulching and seeding. Drainage feature repair. Debris basin construction. Warning signs and storm patrol. Source: (Davidson, 2014; Whittaker, 2015)

		Funding for mitigation			
Fire	Suppression cost	BAER	UWRI	Other	Mitigation actions
Quail Fire (2012)	$1.1 million	$12,690	$41,570	$1.8 million[3]	Aerial seeding. Debris basin construction. Weed inventory, control and monitoring. Source: (Allred, 2014; Condrat, 2012; Sorenson, 2013)
Seeley Fire (2012)	$8.5 million	$1.87 million	None		Aerial mulching. Weed inventory, control and monitoring. Hazard tree removal. Drainage feature repair and installation. Streambank stabilization. Warning signs, closures and storm patrol. Source: (Chatel, 2012)
Dump Fire (2012)	$1.5 million	None	$225,232	$3.5 million[4]	Aerial seeding. Streambank stabilization. Drainage feature installation. Source: (Bullock, 2013; C. Jones, 2013)
Salt Creek Fire (2007	$4.2 million	$988,346	$89,900		Aerial seeding and mulching. Weed inventory, control and monitoring. Hazard tree removal. Drainage feature repair and installation. Warning signs and storm patrol. Source: (Pope & Higginson, 2007)
Cascade II Fire (2003)	$2.5 million	$1.08 million	N/A[5]		Aerial and ground mulching and seeding. Drainage feature repair and installation. Road reshaping and stabilization. Source: (Pope, 2004)
East Vivian Fire (2000)	$5 million[6]	$125,006	N/A[5]		Seeding (method not specified). Drainage feature installation. Road reshaping. Source: (Pope, 2002)
Affleck Park Fire (1988)	Not reported	Not reported	N/A[5]		Seeding (method not specified). Drainage feature installation. Canyon mouth reshaping. Source: (DuMont, 1990; Nelson & Rasely, 1988)

[1] Pole Creek & Bald Mountain Fires (2018): The Supplemental Appropriations for Disaster Relief Act of 2019 provided over $9.6 million through the USDA Natural Resources Conservation Service's Emergency Watershed Protection Program to help Utah County with post-fire mitigation, including debris removal and stream bank protection (Curtis, 2019).
[2] Dollar Ridge Fire (2018): The Federal Emergency Management Agency (FEMA), Utah Drinking Water Board, Utah Permanent Community Impact Fund Board and Central Utah Water Conservancy District spent $28.5 million to update the Duchesne Valley Water Treatment Plant to remove post-fire sediment and debris (Central Utah Water Conservancy District, 2021).
[3] Quail Fire (2012): Alpine City and the USDA Natural Resources Conservation Service spent $1.8 million to alter and expand sediment basins in response to post-fire debris flows in 2013 (Allred, 2014).
[4] Dump Fire (2012): The City of Saratoga Springs and CRS Engineers obtained a $3.5 million grant from the USDA Natural Resources Conservation Service to restore and strengthen over a mile of open channels to reduce future flooding and debris flows.
[5] UWRI was incepted in 2005.
[6] Suppression cost for the entire Wasatch Complex.

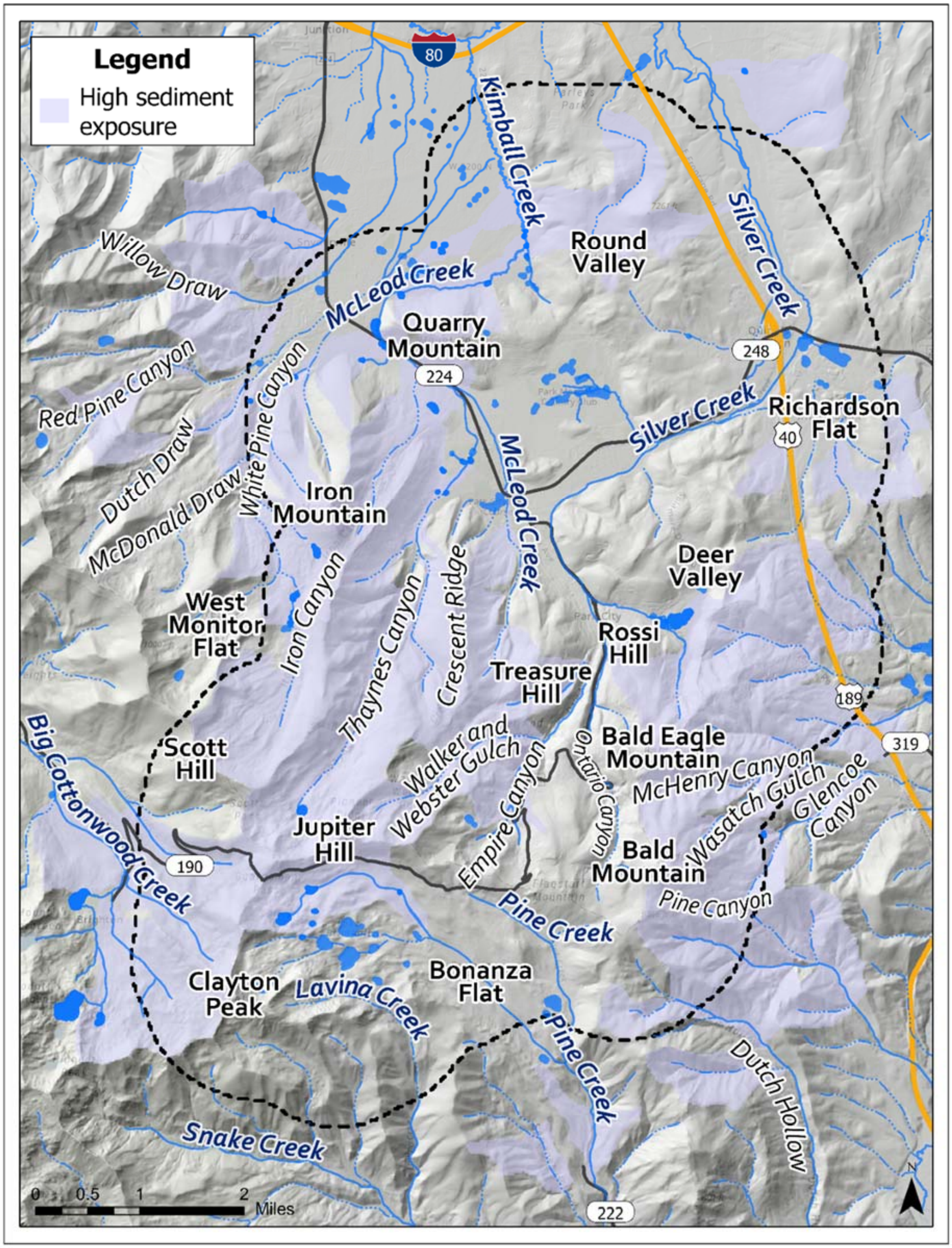

Figure 0-24. Topographic landmarks referenced throughout the summary of the sediment analysis.

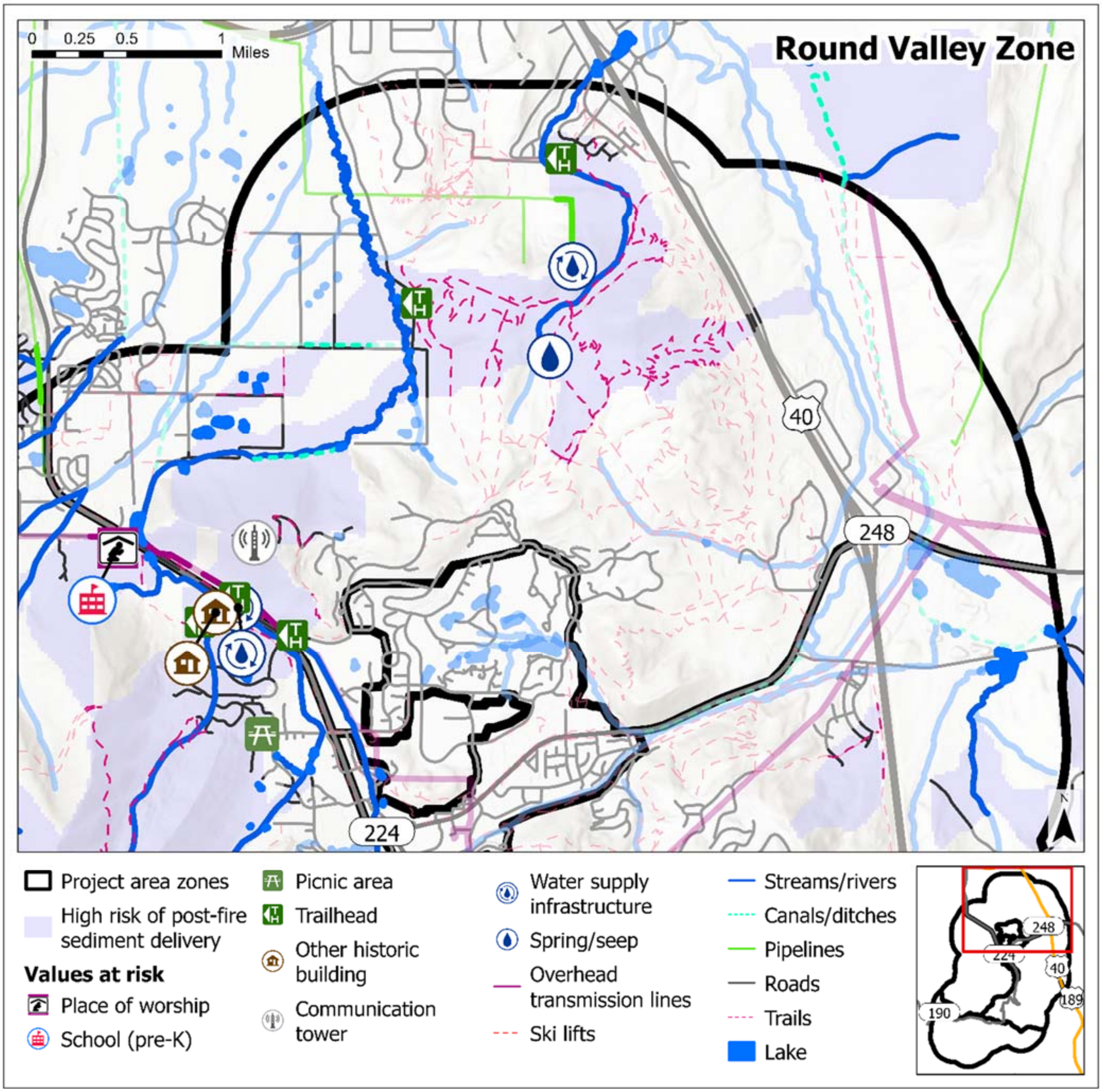

Figure 2-0-25. Values at risk to high sediment delivery in the Round Valley Zone of the project area. Labels included for streams, roads, trails and ski lifts with >1.0 miles at high risk of sediment delivery

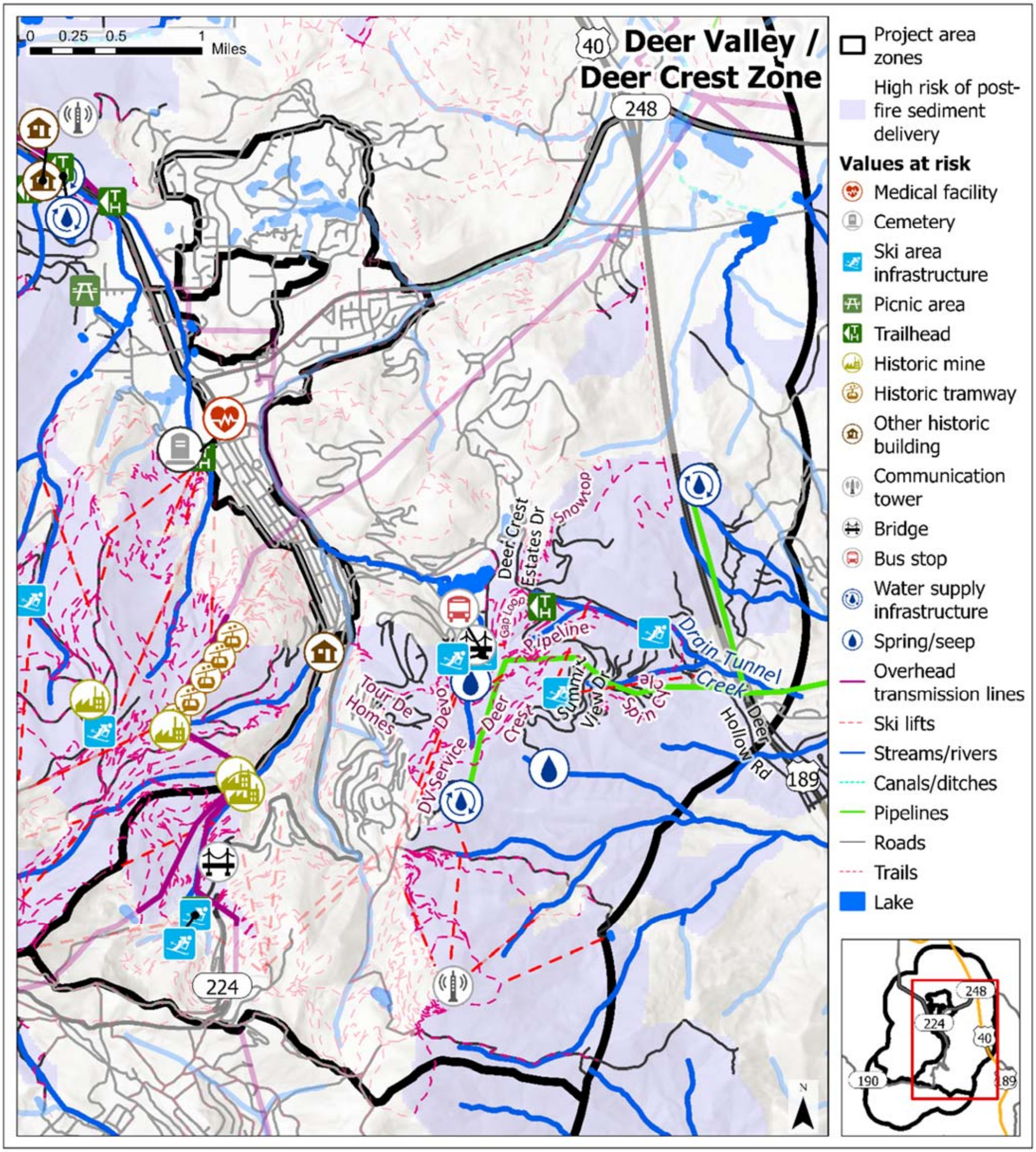

Figure 2-0-26. Values at risk to high sediment delivery in the Deer Valley/Deer Crest Zone of the project area. Labels included for streams, roads, trails and ski lifts with >1.0 miles at high risk of sediment delivery.

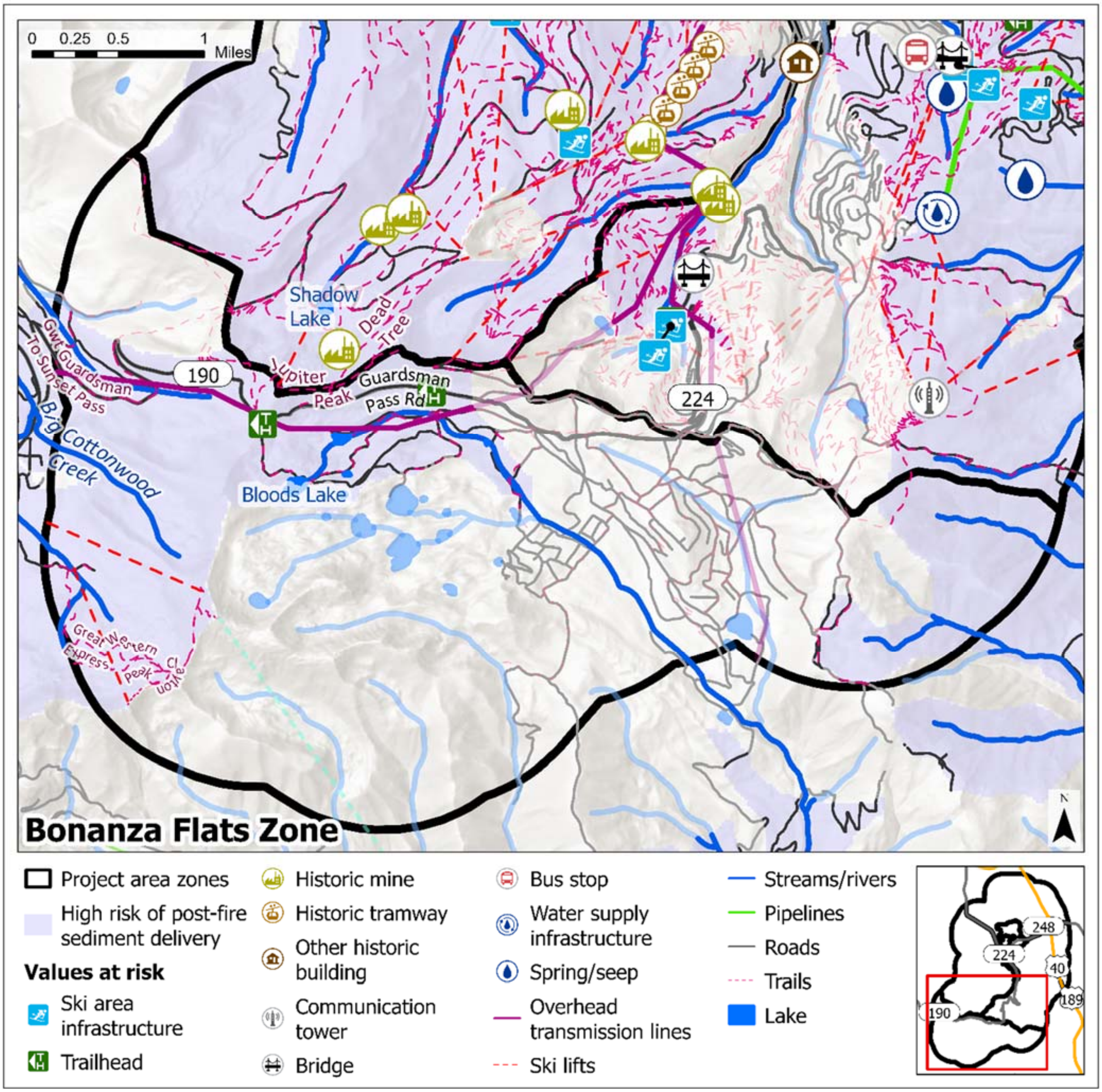

Figure 2-0-27. Values at risk to high sediment delivery in the Bonanza Flats Zone of the project area. Labels included for streams, roads, trails and ski lifts with >1.0 miles at high risk of sediment delivery.

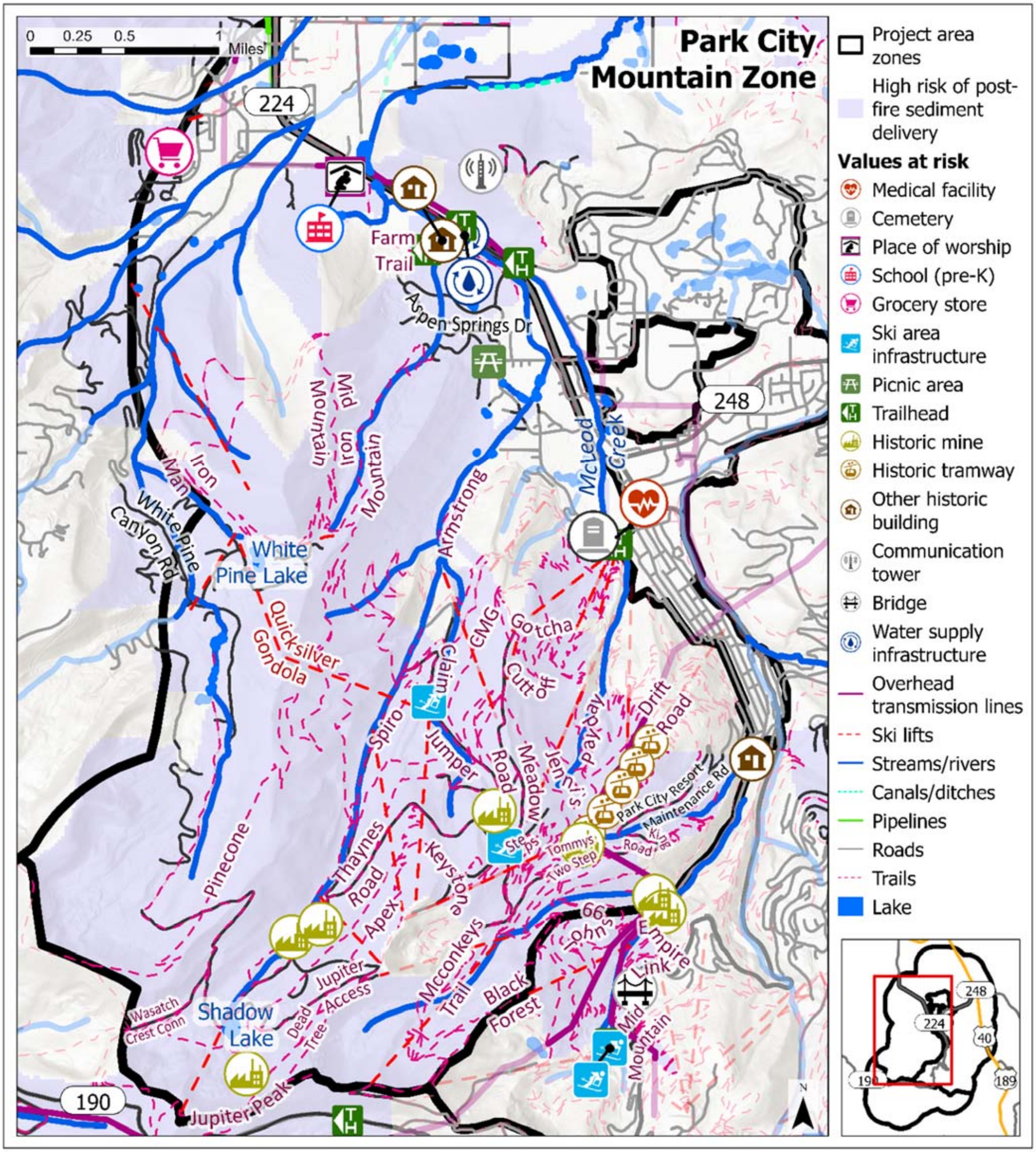

Figure 2-0-28. Values at risk to high sediment delivery in the Park City Mountain Zone of the project area. Labels included for streams, roads, trails and ski lifts with >1.0 miles at high risk of sediment delivery.

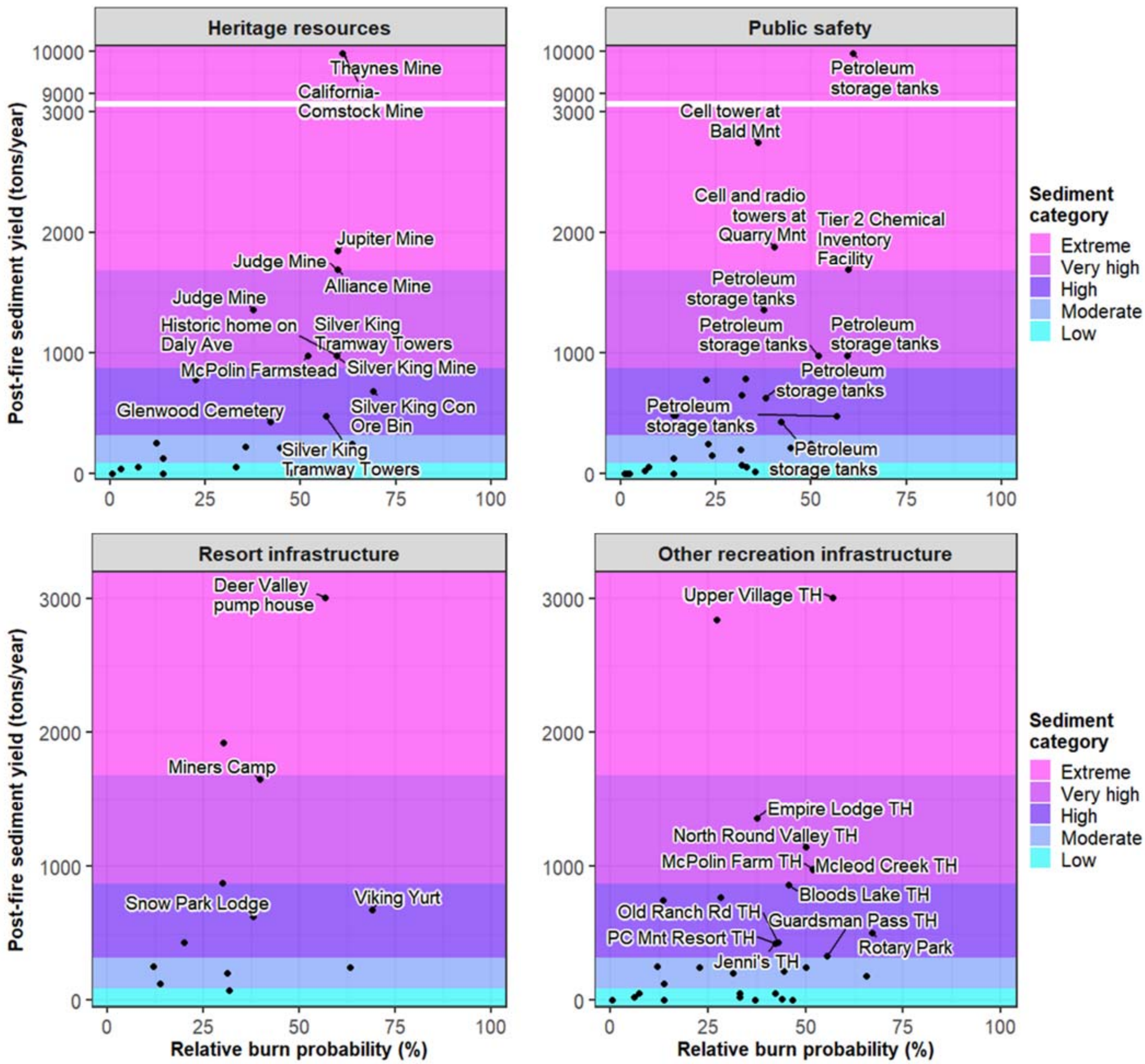

Figure 2-0-29. Risk of post-fire sediment to community values and infrastructure based on predicted watershed-scale sediment yield and relative burn probability. Labels are displayed for values occurring in watersheds with high to extreme post-fire sediment yield (>315 tons/year) and high relative burn probability (≥33%). See Table A.2.4.8. for a list of values included in each category.

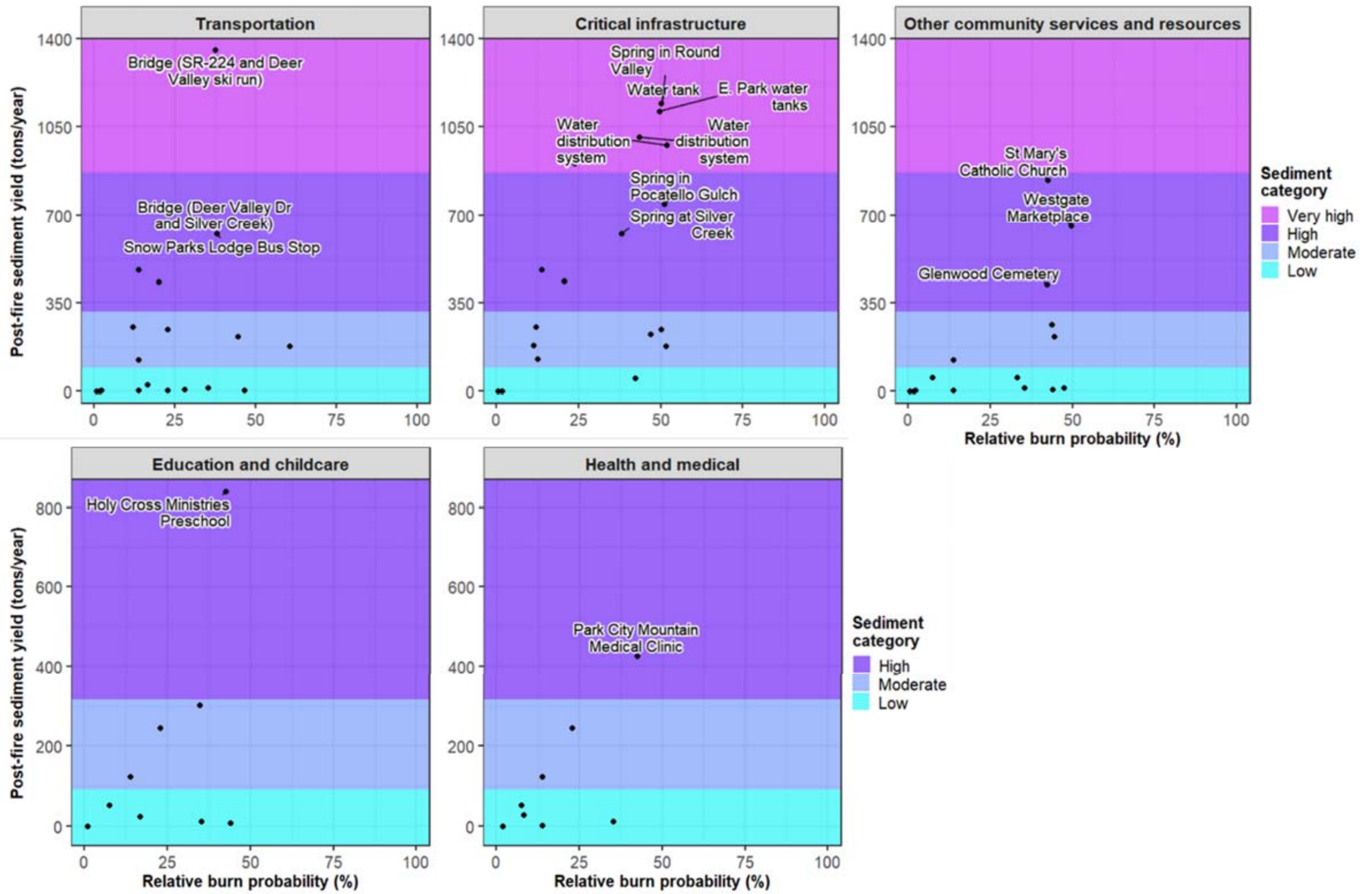

Figure 2-0-30. (continued) Risk of post-fire sediment to community values and infrastructure based on predicted watershed-scale sediment yield and relative burn probability. Labels are displayed for values occurring in watersheds with high to extreme post-fire sediment yield (>315 tons/year) and high relative burn probability (≥33%). See Table 2-16 for a list of values included in each category.

Table 2-18. River, roads, trails and ski lifts with over 1.0 miles in watersheds with high risk of post-fire sediment delivery. Features are sorted by type and descending miles at risk.

TYPE	NAME	LENGTH WITH HIGH RISK (MILES)
River	McLeod Creek	6.2
River	Perennial stream in Thaynes Canyon	3.0
River	Kimball Creek	2.7
River	Big Cottonwood Creek	2.3
River	Ephemeral stream in Bloods Lake Drainage	2.0
River	Ephemeral stream in Walker and Webster Gulch	1.9
River	Drain Tunnel Creek	1.8
River	Pine Creek	1.5
River	White Pine Canyon Road	10.9
River	Guardsman Pass Rd	4.3
River	Highway 40	4.3
River	Deer Crest Estates Dr	2.4
River	Deer Hollow Rd	2.1
River	Bear Hollow Dr	1.9
River	Summit View Dr	1.7
River	Highway 224	1.2
River	Park City Resort Maintenance Rd	1.2
River	Aspen Springs Dr	1.1
River	Big Cottonwood Canyon Rd	1.1
River	Quarry Mountain Rd	>1.0
Trail	Mid Mountain	10.0
Trail	Rambler	4.3
Trail	Pinecone	3.9
Trail	Jenni’s	3.7
Trail	DV Service	3.2
Trail	CMG	2.7
Trail	Spiro	2.4
Trail	Iron Man	2.4
Trail	Armstrong	2.1
Trail	Thaynes Road	2.1
Trail	Spin Cycle	2.0
Trail	Keystone	2.0
Trail	Gap Loop	1.9
Trail	Mcconkeys Trail	1.8
Trail	Deer Crest	1.8
Trail	McLeod Creek	1.7
Trail	Pipeline	1.7
Trail	Apex	1.7
Trail	Johns 99	1.6
Trail	Great Western Express	1.6
Trail	Empire Link	1.6

Type	Name	Length with high risk (miles)
Trail	Rusty Shovel	1.6
Trail	Snowtop	1.5
Trail	Tommys Two Step	1.5
Trail	Claim Jumper	1.4
Trail	Gotcha Cuttoff	1.3
Trail	Iron Mountain	1.3
Trail	Black Forest	1.2
Trail	Jupiter Peak	1.2
Trail	Round Valley Express	1.2
Trail	Gwt Guardsman To Sunset Pass	1.1
Trail	Devo	1.1
Trail	King Road	1.1
Trail	Payday	1.1
Trail	Dead Tree	1.1
Trail	Drift Road	1.1
Trail	Jupiter Acc	>1.0
Trail	Tour De Homes	>1.0
Trail	Farm Trail	>1.0
Trail	Wasatch Crest Conn	>1.0
Trail	Meadow Road	>1.0
Trail	Steps	>1.0
Trail	Clayton Peak	>1.0
Ski lift	Quicksilver Gondola	1.4

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2.3 Stream Condition

Executive Summary

The area of the Park City Municipal Corporation Community Wildfire Risk Assessment Project is part of several watersheds that feed into the Provo, Jordan, and Weber rivers. The streams and rivers in our watersheds are some of the highest value natural assets because they supply water for drinking, recreation, wildlife, and ecosystem services like floodwater retention. High intensity and large wildfires can negatively impact these resources. The purpose of this report is to use the Rapid Stream Riparian Assessment to assess the condition or health of eight streams in and near the Project area and how resilient they may be to wildfires. The health of the streams surveyed generally scored average or higher than average. This means these streams have characteristics that make them more resilient to the negative impacts of a wildfire, should one occur. Measures to maintain or improve stream health are recommended.

Background

The purpose of the Park City Municipal Corporation Community Wildfire Risk Assessment (the Project) is to assess and mitigate wildfire risk to the community and its resources. This information can inform decision makers, stakeholders, and the community when deciding how to protect resources.

Watersheds are areas of land that channel rain and snow into streams and rivers that feed into reservoirs, oceans, or basins. The Park City region is part of four major watersheds that feed into the Provo River, the Jordan River, the Lower Weber River, and the Upper Weber River. All of Park City's watersheds feed into the Great Salt Lake, a terminal basin. The condition of Park City's watersheds are related to the quality of water resources that humans and wildlife rely on. Rivers, streams, and their associated wetlands are High Value Resources and Assets to the Park City community (see Quantitative Wildfire Risk Assessment Report for detail). These features provide clean water for drinking, places for wildlife and fish to live, recreation, and ecosystem services like floodwater retention.

Rivers and streams are shaped by erosion and sedimentation processes, but extreme post-fire sediment and debris flows can be damaging. Burned land is prone to increased soil erosion and debris flows (see Post-Fire Sediment Delivery Report for full detail). Sediments laden with carbon and nutrients are then transported into streams, rivers, and wetlands which reduces water quality and degrades wildlife habitat (Leonard et al. 2017, Ball et al. 2021). Healthy streams and watersheds can be more resilient to the negative impacts of wildfires (Wohl et al. 2022, Fairfax and Whittle 2020). Healthy rivers and streams share a number of physical characteristics that relate to ecological processes. For example, healthy river and stream channels are "connected" with their floodplain so that during floods, water and sediment can be dissipated and absorbed, instead of intensified. Healthy rivers and streams naturally contain boulders, beaver dams, and large pieces of wood that help slow the velocity of water and sediment during floods (Wheaton et al. 2019a). Healthy rivers and streams are bordered by wetlands with lush shrubs and trees. These plants keep soils from eroding away in floods, but also serve as fire breaks and stop or slow wildfires (Fairfax and Whittle 2020).

Unfortunately, many rivers and streams in the west no longer have these characteristics and are not healthy. Therefore, when floods or debris flows from wildfires occur, rivers and streams become further degraded and resources like water quality are impaired. The purpose of this report is to investigate the condition of streams within and immediately downstream of the Project area in order to understand how they may respond to sediment and debris flows after a wildfire.

Methods

The condition of eight representative streams was assessed within the Park City Municipal Corporation Community Wildfire Risk Assessment Project area (Figure 2-0-24). Stream were selected if they were 1) downstream of potential high intensity wildfires as mapped by the Fire Behavior Analysis, 2) predicted to have high post-fire sediment delivery, and 3) if Project staff had permission to enter the sites from landowners. Sageland Collaborative has an existing stream restoration program in the region with partners like the Swaner Preserve and EcoCenter. Former stream surveys that were outside of the Project area, but within an area of impact should a wildfire occur, were also included.

The condition of streams was determined using the Rapid Stream Riparian Assessment ([RSRA], Stacey et al. 2006, Figure 2-0-24, Table 2-19). The RSRA protocol was developed to efficiently assess the overall condition of a stream. RSRA utilizes qualitative and quantitative data to generate a score for five categories that relate to stream health:

1. Water Quality. The potential for pollutants or solar exposure to degrade water quality.
2. Hydrogeomorphology. The ability of the system to limit erosion and withstand flooding without damage.
3. Fish and Aquatic Habitat. The presence of habitat for native fish and other aquatic species.
4. Riparian Vegetation. The structure and composition or vegetation near the stream, including the occurrence of non-native species.
5. Terrestrial Habitat. The suitability of habitat for terrestrial wildlife.

Data is then converted to a score that ranges from 1 to 5. Mean scores of 1 to 2 indicates a stream is in poor condition and not providing ecosystem services such as water purification, sediment retention, habitat for fish and wildlife, and flood control. Scores of 2 to 4 indicate some stream components may be healthy while others are not. A stream scoring 4 to 5 equates to a healthy stream providing ecosystem services.

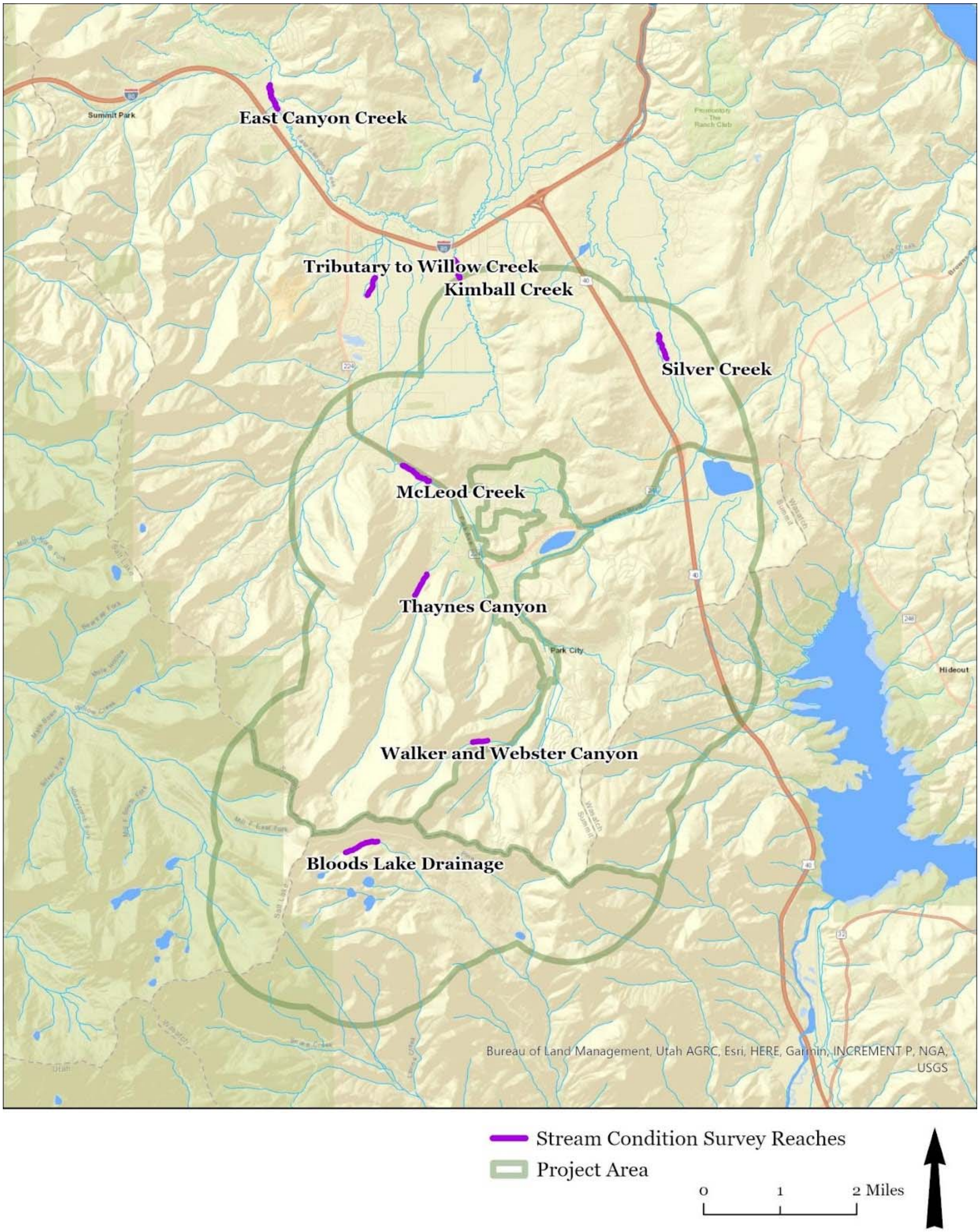

Figure 2-0-31. Locations of stream condition surveys in and around the Park City Wildfire Risk Assessment Project Area.

While these scores are relative and general, the RSRA method provides a useful snapshot for managers and planners to understand stream conditions, prioritize restoration or management activities, or pinpoint areas for further study. The RSRA protocol can be used on streams that flow year round or intermittently (i.e., seasonal flow). However, if flowing water is not present in a stream during the time of data collection, some metrics cannot be collected (e.g., diversity of aquatic insects). For those metrics, they are denoted as “NA” for Not Applicable and not included in the average scores. Some streams did not historically support an upper tree canopy like cottonwoods and instead only contained willows and other shrubby vegetation. In these streams, the metrics regarding the presence of tree species may be denoted as “NA” and are not included in the average scores.

Key Findings

The condition of the streams surveyed for the Project varied (Table 2-19). Streams generally had average or higher than average scores in each of five categories that relate to stream health. Higher scores, especially the indicators for floodplain connection (#3), hydraulic habitat diversity (#5), beaver activity (#7), large woody debris (#12), and riparian density (indicators #21 – 23) are highly correlated to streams that are more resilient to wildfire. Results of each stream are detailed in Table 1 and in sections 3.1 through 3.8.

Of the streams surveyed, those in the poorest condition were Silver Creek, East Canyon Creek, and Bloods Lake Drainage, which scored 2.5, 2.6, and 2.8, respectively. Factors contributing to low scores in these creeks included poor floodplain connection, water quality issues, and lack of riparian vegetation. Thaynes Canyon and McLeod Creek were in better condition, each scoring 3.6.

Table 2-19. Stream condition scores.

Stream Reach	Bloods Lake Drainage	East Canyon Creek	Kimball Creek	McLeod Creek	Silver Creek	Thaynes Canyon	Tributary to Willow Creek	Walker & Webster Canyon
Stream condition indicators and scores								
1 – Algal growth[a]	NA	2	5	5	NA	5	1	NA
2 – Channel shading	3	1	2	3	2	5	3	5
Water quality score	**3.0**	**1.5**	**3.5**	**4.0**	**2.0**	**5.0**	**2.0**	**5.0**
3 – Floodplain connection	1	3	5	1	5	1	2	1
4 – Vertical bank stability	5	4	5	5	4	4	5	4
5 – Hydraulic habitat diversity[a]	NA	3	5	5	NA	3	5	NA
6 – Riparian area soil integrity	5	4	5	3	4	5	5	1
7 – Beaver activity	1	3	3	4	1	1	2	1
Hydrogeomorphology score	**3.0**	**3.4**	**4.6**	**3.6**	**3.5**	**2.8**	**3.8**	**1.8**
8 – Riffle-pool distribution[a]	NA	2	2	3	NA	2	3	NA
9 – Underbank cover	1	3	4	4	2	3	5	1
10 – Cobble embeddedness[a]	NA	3	3	3	NA	2	1	NA
11 – Diversity aquatic invertebrates[a]	NA	5	5	5	NA	5	5	NA
12 – Large woody debris	4	1	2	1	1	5	5	5
13 – Overbank cover	5	2	3	4	5	5	5	5
Fish/Aquatic Habitat Score	**3.3**	**2.7**	**3.2**	**3.3**	**2.6**	**3.7**	**4.0**	**3.7**
14 – Plant cover diversity	3	2	3	3	2	4	3	4
15 – Dominant shrub demography	3	3	3	3	3	2	3	3
16 – Dominant tree demography[b]	3	1	NA	1	NA	4	NA	4
17 – Non-native herb. plant cover	3	2	1	5	2	3	1	5
18 – Non-native woody plant cover	5	5	5	5	5	5	5	5
19 – Mammalian herbivory	1	5	5	5	4	5	4	5
20 – Mammalian browsing	1	4	5	5	1	1	1	2
Riparian Vegetation Score	**2.7**	**3.1**	**3.7**	**3.9**	**2.8**	**3.4**	**2.8**	**4.0**
21 – Riparian shrub density	2	2	2	3	2	3	2	3
22 – Riparian mid-canopy density	2	2	1	3	1	3	2	4
23 – Riparian upper canopy density[b]	2	1	NA	2	NA	4	NA	4
24 – Fluvial habitat diversity	1	4	3	5	2	2	3	1
Terrestrial Habitat Score	**1.8**	**2.3**	**2.0**	**3.3**	**1.6**	**3.0**	**2.3**	**3.0**
Average score	2.8	2.6	3.4	3.6	2.5	3.6	3.0	3.5

[a] NA if stream was dry at time of survey and variable could not be collected.
[b] NA if upper tree canopy would not naturally occur on stream (e.g., shrub or willow dominated community).

Bloods Lake Drainage

The Bloods Lake Drainage is a relatively small ephemeral stream located at 9,100 feet in elevation. The drainage is within the Provo River watershed and flows into Pine Creek and Snake Creek. The stream reach is owned by Park City Municipal Corporation and managed as the Bonanza Flat Conservation Area. The area is highly valued by the community for open space, recreation, wildlife habitat, and watershed protection.

Figure 2-0-32. Bloods Lake Drainage.

Bloods Lake Drainage's overall mean RSRA score was 2.8 as a result of average scores across each category. The drainage scored low for floodplain connectivity meaning this stream channel is incised. Several variables could not be measured because of lack of water in the stream during the time of the survey. Riparian vegetation showed signs of extensive browsing and grazing in the riparian area from moose and deer; cattle and sheep are not currently grazed in this site. However, the riparian area was heavily vegetated and had high soil integrity, which improved scores.

Table 2-20. Overall mean Rapid Stream Riparian Assessment score for Bloods Lake Drainage.

Variable	Score
Water quality	3.0
Hydrogeomorphology	3.0
Fish & aquatic habitat	3.3
Riparian habitat	2.7
Terrestrial wildlife habitat	1.8
Mean Score	2.8

Bloods Lake Drainage is in the headwaters of the Provo River watershed and could convey sediment from a wildfire downstream to the Provo River. The stream reach that was surveyed is also mapped as an area at high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). In the event of a wildfire, this drainage would likely be severely degraded and impact downstream infrastructure and streams. To improve the resiliency of Blood's Lake Drainage, efforts to improve connection with the floodplain by adding structure may help trap sediment and re-charge wetlands (Table 2). In turn, this may help improve the density of riparian plants and reduce the intensity of sediment delivery through the stream channel.

East Canyon Creek

East Canyon Creek is a perennial stream located at 6,320 feet in elevation and the main tributary in the Weber River watershed. It is managed by Snyderville Basin Special Recreation District and Summit County as open space. East Canyon and its adjacent floodplain wetlands were historically used to graze cattle and sheep but are now surrounded by residential and commercial development in many areas.

Figure 2-0-33. East Canyon Creek.

East Canyon Creek provides designated beneficial uses for domestic water, primary and secondary contact recreation, agricultural water supply, and cold-water game fish (SWCA Environmental Consultants 2010). It is impaired for cold water species of game fish, cold water aquatic life and aquatic organisms in their food chain. This stream was once a high-quality trout fishery. Degraded water quality (i.e., low dissolved oxygen) from polluted stormwater, increased erosion, and higher water temperature has limited fish habitat. Bonneville cutthroat trout, a Utah Species of Conservation Concern, historically occurred in East Canyon Creek but is now limited to isolated locations and low numbers (Marshall Wolf, Utah State University, personal communication). East Canyon Creek is impaired due to low dissolved oxygen and excess phosphorus level.

Table 2-21. Overall mean Rapid Stream Riparian Assessment score for East Canyon Creek.

Variable	Score
Water quality	1.5
Hydrogeomorphology	3.4
Fish & aquatic habitat	2.7
Riparian habitat	3.1
Terrestrial wildlife habitat	2.3
Mean Score	**2.6**

The overall mean RSRA score was 2.6 due to poor water quality (abundant filamentous algae) and lack of vegetation to shade the stream channel. More tree cover would be expected, but these species have not recovered from historic grazing activity and wetland loss. Numerous tributaries (including McLeod Creek and Thaynes Canyon) are mapped as high risk for post-fire sediment delivery according to the Post-Fire Sediment Delivery Report. Consequently, East Canyon Creek could receive significant quantities of sediment from upstream sources should a wildfire occur. Prized by the community and stakeholders, the East Canyon Creek Watershed Committee has initiatives underway to improve the stream condition and wildfire resilience. These include promoting riparian vegetation, managing beaver, adding structure to streams, and restoring floodplains (Table 2). Education and policy programs are also underway. See https://www.eastcanyoncreek.org/ for more information.

Kimball Creek

Kimball Creek is a perennial stream located at 6,400 feet in elevation. Kimball Creek is a major tributary to East Canyon Creek in the Weber River watershed. The stream reach is managed by Utah State University's Swaner Preserve and EcoCenter as open space. The stream and its adjacent floodplain wetlands have a history of use as agricultural land.

Figure 2-0-34. Kimball Creek.

Kimball Creek has high phosphorus levels and low dissolved oxygen, creating degraded conditions for aquatic life (SWCA Environmental Consultants 2010). Much of the water supply is diverted for irrigation purposes which creates low flow conditions that also degrade the stream. Kimball Creek's overall mean RSRA score was 3.4. This reach scored high for hydrogeomorphology due to stable banks and connection with the floodplain. This reach scores low for terrestrial wildlife habitat as willow canopy is still regenerating after a century of former land practices.

Table 2-22. Overall mean Rapid Stream Riparian Assessment score for Kimball Creek.

Variable	Score
Water quality	3.5
Hydrogeomorphology	4.6
Fish & aquatic habitat	3.2
Riparian habitat	3.7
Terrestrial wildlife habitat	2.0
Mean Score	**3.4**

While the area of Kimball Creek that was surveyed is outside of the Project area, it is downstream of drainages that are in the Project area. McLeod Creek and upper portions of Kimball Creek are mapped as high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). Kimball Creek has been the focus of restoration efforts at the Swaner Preserve and EcoCenter. These efforts include promoting riparian vegetation, adding structure, and restoring the floodplain (Table 2, Wheaton et al. 2019a). These tools are collecting sediment and allowing the floodwaters to dissipate over the adjacent floodplain wetlands, which are on lands protected as open space. To the extent that Kimball Creek is able to dissipate debris flows and sediment, it will buffer East Canyon Creek from negative impacts. With these improvements, Kimball Creek will continue to improve its wildfire resiliency.

McLeod Creek

McLeod Creek is a perennial stream located at 6,640 feet in elevation. McLeod Creek is a major tributary to Kimball Creek and East Canyon Creek. The stream reach is managed by the Utah Division of Wildlife Resources as wildlife habitat. The adjacent floodplain has a history of use as agricultural land and the nearby uplands are still used for cattle grazing.

Like Kimball Creek, much of McLeod Creek's water supply is diverted for irrigation purposes which creates low flow conditions (SWCA Environmental Consultants 2010). McLeod Creek's overall mean RSRA score was 3.6. This reach scored high for water quality due to the lack of filamentous algae and a shaded stream channel. Compared to other stream reaches in the region, McLeod Creek has higher canopy cover of high-value riparian species like willow. Bonneville cutthroat trout are known to occur near this stream reach (Marshall Wolf, Utah State University, personal communication).

McLeod Creek and nearly all of its tributaries are in areas mapped as high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). Of all the streams in the Project area, McLeod Creek has some of the highest potential to be negatively impacted by post-fire sediment and debris flows.

Figure 2-0-35. McLeod Creek.

Table 2-23. Overall mean Rapid Stream Riparian Assessment score for McLeod Creek.

Variable	Score
Water quality	4.0
Hydrogeomorphology	3.6
Fish & aquatic habitat	3.3
Riparian habitat	3.9
Terrestrial wildlife habitat	3.3
Mean Score	3.6

Beaver occur in sections of McLeod Creek, and their activity creates ponding and sediment capture that can help mitigate these impacts (Fairfax and Whittle 2020). McLeod Creek's largely vegetated riparian corridor could serve as a fire break for active wildfires.

This reach has been the focus of restoration efforts (i.e., adding structure, restoring floodplains, managing beaver) by stakeholders in the region (Table 2). Efforts to promote riparian vegetation by managing cattle grazing along McLeod Creek will continue to improve stream health. With continued implementation of measures, McLeod Creek may be more resilient to the impacts of a wildfire, which can also protect downstream resources in Kimball and East Canyon Creek.

Silver Creek

Silver Creek is an intermittent stream located within a freshwater emergent wetland at 6,560 feet in elevation. Located within the Weber River watershed, it flows north and connects with the Weber River between Rockport and Echo reservoirs. This reach is owned and managed by Snyderville Basin Special Recreation District and is currently used for grazing, open space, and recreation. Private landowners use property above and below the reach for grazing. Historically, this site was altered for mining, agriculture, and grazing. An irrigation canal runs to the east of the stream and de-waters Silver Creek. Silver Creek is listed by the Utah Department of Environmental Quality as an Impaired Water for protected cold-water species of game fish and other cold-water aquatic life due to dissolved cadmium and zinc (Baker and Psomas 2004). It is downstream from the Richardson Flat Tailings site which contains contaminated mine tailings from operations between 1953 and 1981. It is understood the tailings site is the major contributor of pollutants into Silver Creek.

Figure 2-0-36. Silver Creek.

Table 2-24. Overall mean Rapid Stream Riparian Assessment score for Silver Creek.

Variable	Score
Water quality	2.0
Hydrogeomorphology	3.5
Fish & aquatic habitat	2.6
Riparian habitat	2.8
Terrestrial wildlife habitat	1.6
Mean Score	**2.5**

Silver Creek's overall mean RSRA score was 2.5 as a result of a lack of aquatic and riparian habitat features like willows. Silver Creek scored highest for hydrogeomorphology and the stream is largely connected with its floodplain. This means if there are high flows, the adjacent wetlands can dissipate floodwaters. Despite Silver Creek's impairment, the site contains important wetland habitat for wildlife. A northern leopard frog was observed and this reach is potential habitat for Ute ladies'-tresses orchid, a federally threatened species.

This reach of Silver Creek is in an area mapped as high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). While the Richardson Flat Tailings site was not mapped as high risk for post-fire sediment delivery, this may still be a concern because of the potential to spread any amount of cadmium and zinc into Silver Creek and the Weber River (Baker and Psomas 2004). Preserving and restoring floodplains, adding structure to the stream, and promoting riparian vegetation (i.e., grazing management) will help moderate erosion and movement of contaminated sediment (Table 2). Silver Creek can also be improved by establishing native willows and actions to ensure the stream and its adjacent wetlands have water supply year-round.

Thaynes Canyon

Thaynes Canyon is a shallow, perennial stream located within a relatively narrow drainage at 7,250 feet in elevation. Thaynes Canyon is within the Weber River watershed and, together with McLeod Creek, is the headwaters of East Canyon Creek. The stream reach is owned and managed by Park City Municipal Corporation and is currently used for open space and recreation. Historically, this site was used for mining activities and grazing but currently shows little signs of disturbance (SWCA Environmental Consultants 2010).

Figure 2-0-37. Thaynes Canyon

Thaynes Canyon overall mean RSRA score was 3.6 as a result of a well-vegetated riparian area and diversity of aquatic and in-stream habitat. Thaynes Canyon scored highest for water quality because of the shaded stream and absence of filamentous algae.

The entire length of Thaynes Canyon is in an area mapped as high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). Based on Thaynes Canyon's scores, this stream

may be relatively more resilient to the impacts of a wildfire because it is has structure from vegetation and woody structure (e.g., fallen logs). However, Thaynes Canyon is steep which can equate to higher intensity post-fire sediment delivery. There are residences below this steep canyon which may be impacted.

Table 2-25. Overall mean Rapid Stream Riparian Assessment score for Thaynes Canyon.

Variable	Score
Water quality	5.0
Hydrogeomorphology	2.8
Fish & aquatic habitat	3.7
Riparian habitat	3.4
Terrestrial wildlife habitat	3.0
Mean Score	**3.6**

This stream may benefit from measures that help restore the floodplain, such as beaver dam analogues (Table 2). Maintenance of the existing riparian vegetation is also a priority. This area may also be a candidate for prioritizing upland wildfire treatments to reduce the risk of intensive post-fire sediment delivery.

Tributary to Willow Creek

The Tributary to Willow Creek is a perennial stream located within a freshwater emergent wetland at 6,640 feet in elevation. This tributary flows into Willow Creek, Kimball Creek, and East Canyon Creek. The stream reach is managed by Utah State University's Swaner Preserve and EcoCenter as open space. Similar to Kimball Creek, this tributary stream and its adjacent floodplain wetlands have a history of use as agricultural land. This stream was likely modified from its natural form to convey irrigation water. The source of the Tributary to Willow Creek is likely from groundwater and has been highly altered by upstream residential development.

Figure 2-0-38. Tributary to Willow Creek.

The Tributary to Willow Creek and its adjacent wetlands are part of one of the largest wetland complexes in the Project area that is protected by the Swaner Preserve and EcoCenter. These wetlands sequester carbon and function to provide clean water. This reach's overall mean RSRA score was 3.0. This reach scored low for water quality and terrestrial habitat because of the presence of algae and lack of vegetation cover. This reach is part of Swaner Preserve and EcoCenter's restoration efforts that include promoting riparian vegetation through plantings and adding structure (e.g., beaver dam analogues) to restore the floodplain and wetlands (Table 2). These tools are collecting sediment and allowing the floodwaters to dissipate over the adjacent floodplain wetlands.

Table 2-26. Overall mean Rapid Stream Riparian Assessment score for Tributary to Willow Creek.

Variable	Score
Water quality	2.0
Hydrogeomorphology	3.8
Fish & aquatic habitat	4.0
Riparian habitat	2.8
Terrestrial wildlife habitat	2.3
Mean Score	3.0

The Tributary to Willow Creek is not mapped as high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). In terms of implementing wildfire resiliency measures, streams like Willow Creek may be less of a priority for the community

Walker and Webster Canyon

Walker and Webster Canyon is an ephemeral stream located at 7,750 feet in elevation. Walker and Webster Canyon is within the Weber River watershed and flows north into Silver Creek. The stream reach is owned and managed by Park City Municipal Corporation and is currently used for open space and recreation. Historically, this site was used for mining activities with infrastructure still in place nearby. The stream in Walker and Webster Canyon was dewatered in the late 1880s from a drain tunnel used for mining activities. Currently, the stream flows seasonally (i.e., intermittently) with snow melt.

Figure 2-0-39. Walker and Webster Canyon.

Walker and Webster Canyon's overall mean RSRA score was 3.5 as a result of a well-vegetated riparian area and diversity of riparian habitat. While Walker and Webster Canyon scored highest for water quality, this was based all on the extensively shaded stream area and that the presence of filamentous algae could not be measured because of lack of water.

Table 2-27. Overall mean Rapid Stream Riparian Assessment score for Walker and Webster Canyon.

Variable	Score
Water quality	5.0
Hydrogeomorphology	1.8
Fish & aquatic habitat	3.7
Riparian habitat	4.0
Terrestrial wildlife habitat	3.0
Mean Score	**3.5**

The entire length of Walker and Webster Canyon is in an area mapped as high risk for post-fire sediment delivery, should a wildfire occur (see Post-Fire Sediment Delivery Report). Based on Walker and Webster

scores, this stream could be relatively more resilient to the impacts of a wildfire because it contains structure from existing vegetation and woody debris that can mitigate sediment and debris flows.

However, Walker and Webster Canyon has a relatively narrow and steep gradient. This naturally steep gradient means there is not a large floodplain for post-wildfire debris flows to dissipate on to. This drainage could convey significant sediment into downstream waters, should a high-intensity wildfire occur in the uplands. Walker and Webster feeds into urban portions of Park City via Silver Creek and there is increased risk of human infrastructure (e.g., culverts, roads) being negatively impacted.

In steep and heavily forested streams like Walker and Webster Canyon, adding structure to the stream could support debris capture should a post-fire debris flow occur (Table 2). Similar to Thaynes Canyon, the maintenance of the riparian vegetation is a priority on Walker and Webster Canyon. This area may also be a candidate for prioritizing upland wildfire treatments to reduce the risk of intensive post-fire sediment delivery.

Recommendations and Conclusion

Streams are some of the highest value natural assets in the Project area as they supply water for drinking, wildlife habitat, recreation, and ecosystem services like floodwater retention. This report provides an overview of representative streams and their conditions within the Project area. This report is not an exhaustive analysis of all streams in the Project area; rather a sample of representative streams that were in areas downstream of potential high intensity wildfires, predicted to have high post-fire sediment delivery, and were accessible to the Project surveyors.

The streams surveyed show many characteristics of functioning, healthy systems that make them more resilient to the negative impacts of wildfire and subsequent sediment and debris flows. Opportunities where streams can be managed to maintain and improve their health and make them more resilient to the negative impacts of wildfires are recommended for each stream with additional details summarized in Table 2-28. Management activities in streams can be prioritized by further evaluating the outputs of the Quantitative Wildfire Risk Assessment Report and Post-Fire Sediment Delivery Report.

Funding measures to improve stream condition and health are priorities for both the local community and the region. As such, there are a variety of funding sources that can be utilized (Clavet et al. 2021, see also Shared Stewardship, Utah's Watershed Restoration Initiative, and Clean Water Act Section 319(h) funds). Community partnerships are also key to funding and implementing measures to create wildfire resilient streams. There are many stakeholders and groups in the Project area that are active in stream and watershed restoration and accepting new projects. These include Utah Forestry, Fire, and State Lands; Utah Division of Wildlife Resources; U.S. Forest Service, Summit County; Snyderville Basin Special Recreation District; Trout Unlimited, Swaner Preserve and EcoCenter; Sageland Collaborative; the East Canyon Creek Watershed Committee; and many others.

Table 2-28. Potential measures that can be used to maintain and create streams that are more resilient to wildfires.

STREAM RESILIENCY MEASURES	EXAMPLES	RATIONALE	SOURCE
1. Stream, wetland and floodplain protection policies	Enforcing existing or new policies that protect ecological integrity of streams, wetlands, and floodplains.	Preservation of floodplains and wetlands in the watershed can mitigate negative impacts of floods and debris flows.	Endeter-Wada et al. 2020
2. Prioritize land conservation	Easements, land purchases	Preserving open space in and adjacent to floodplains can mitigate negative impacts to infrastructure.	
3. Promote and protect stream-side (riparian) vegetation	Livestock grazing management (strategic fencing, rotation). Restoration plantings.	Conservation and restoration of riparian vegetation like willows and cottonwoods reduces soil erosion, moderates floods, and can create firebreaks.	Kauffman et al. 2022, Fitch et al. 2003, Hoag 2007
4. Beaver management	Managing existing beaver populations. Beaver re-introduction where appropriate.	Beaver create features in streams that make them wildfire resilient. Additional measures need to be taken to properly manage their activity and any potential nuisance.	Whipple 2019, Wohl et al. 2022, Pollock et al. 2015 (see Chapter 9)
5. Adding structure to rivers and stream	Low-tech process-based restoration tools such as beaver dam analogues, log structures, log jams.	Woody structure provides sediment capture, flow moderation, promotes connection with the floodplain, and conditions for riparian vegetation to thrive.	Wohl et al. 2022, Livers and Wohl 2021, Wheaton et al. 2019ab, Rathburn et al. 2017
6. Preserve and restore floodplains	Low-tech process-based restoration tools such as beaver dam analogues, log structures, log jams. Also see beaver management.	Maintain or re-connect streams to their natural floodplains to for flow moderation and support wetlands.	Rathburn et al. 2017, Wheaton et al. 2019ab
7. Prioritize upland wildfire reduction treatments	Forest thinning, prescribed burning.	In zones with potential for high sediment delivery and overlap with High Value Resources and Assets, prioritize upland wildfire mitigation treatments to protect stream resources.	Robichaud et al. 2019

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3.0 Fire-Adapted Communities

In This Chapter

3.1. Community Survey

Executive Summary

The Park City Community Wildfire Preparedness Survey was conducted using multiple choice questions and opportunities for comment. The project team's goal was to gather perspectives from individual community members regarding their values, needs and concerns related to wildfire risk and community preparedness. The survey provided feedback to assist the Park City Municipal Corporation (PCMC) in understanding residents' point of view on a variety of wildfire issues. Engagement will be a key result of the Community Wildfire Risk Assessment (CWRA). Only by understanding the many points of view of residents, business owners and stakeholders will significant engagement and actions be possible. The survey assessed knowledge and awareness of residents and business owners on a variety of wildfire-related topics. These included: About Us, Wildfire Knowledge, Reducing Wildfire Hazards, Evacuation Preparedness, and Resources and Education. A total of 409 responses were received over 40 days. An additional 300 comments were collected during the survey and provided insights into some of the most pressing concerns among respondents. Overall, results highlight opportunities for engagement with residents, as well as obstacles to effective wildfire mitigation. Lack of information showed up as a predominant theme throughout the survey.

Background

The landscape around Park City has been influenced by both anthropogenic and natural disturbances. Park City is within the traditional and ancestral homelands of the Shoshone, Paiute, and Ute Tribes, who were the original stewards of the land. Fire was a part of this stewardship and was used for a variety of purposes that included, among other things, vegetation clearing and forage enhancement. These same forested areas around Park City were intensely logged by European settlers while heavy grazing also reduced grasses and woody vegetation. This combination of disturbances substantially changed the historic forest regime around Park City.

The forests around Park City have suffered recent and significant forest health decline since 2016 when landscape-scale geo-spatial maps were created (updates to these maps are described in the Park City Municipal Corporation – Community Wildfire Risk Assessment Fuels and Fire Behavior Report (Washa, Young, Tobler). Both the non-native fir engraver beetle and non-native balsam woolly adeligid have impacted and caused mortality or tree damage in the stands of mixed conifer forest. Short- and long-term aspen decline is also occurring. The resulting increase in standing dead and down fuels in mixed conifer and aspen vegetation has changed the fuel profile in forests around Park City. Invasive and noxious weeds, such as cheatgrass, are also creating a highly flammable fuel bed of light flashy fuels which contributes to greater rates of fire spread when there is an ignition.

Parallel to declines in forest health, Park City has experienced changes as well. Park City is built on a rugged landscape where roads can be narrow and difficult to navigate, a problem which is made worse during the increasingly busy tourist seasons. Its population has also grown, with residential and commercial building increasingly encroaching on forested areas surrounding Park City. This combination of greater density and declining forest health has raised concerns about wildfire preparedness and evacuations.

To better understand these concerns, we sought responses to a survey about wildfire awareness, wildfire mitigation, and evacuation preparedness. Specifically, we wanted to understand what residents in Park City knew about wildfire, about its prevention, what support there is for different types of mitigation actions, and what wildfire mitigation steps homeowners have undertaken on their own property. Lastly, we sought to understand whether and how residents have developed evacuation plans.

Methods

Both quantitative and qualitative responses were collected using a 20-question online survey that assessed knowledge about wildfire, emergency preparedness, hazard reduction activities and available resources related to wildfire in and around Park City, Utah. Rating scales were used to collect the extent to which a respondent agreed or disagreed while open-ended questions allowed respondents to provide their thoughts on particular topics. Respondents were also asked to endorse answers that described what mitigation or preparedness actions they have undertaken. Subject matter experts reviewed each question for viability and relevance. Initial testing indicated that the survey could be completed within seven minutes. Outreach was conducted via email marketing, advertising on social media and local media channels.

The survey area encompassed Park City, Utah, zip code 84060 and included Home Owner Association (HOA) Board Members, residents, workers, water utility users identified through the Park City WaterSmart program, business owners and other stakeholders. Respondents accessed the survey by following a link either emailed directly to them or posted on Park City's Facebook page. Local advertising also directed interested respondents to a website where they could access the survey. Outreach was conducted between mid-September and late October 2022.

Key Findings

We collected 409 responses using an online survey. Of these 409, 73 percent (n = 299) were full-time residents, 22 percent (n = 99) were seasonal or part-time residents and 5 percent (n = 45) were either business, residential property or land owners.

Perception of Wildfire Risk & Impacts

Our survey was designed to first assess whether, among this sample of residents, there was a perceived risk from wildfire, what the impacts would be if there was a wildfire, how much they knew about how to reduce wildfire impacts on their property and what are acceptable wildfire mitigation actions. Overall, residents expressed high levels of agreement that wildfires posed a risk to their communities and that there would be a multitude of social, economic and ecological impacts on the community should there be a wildfire. Specifically, 96 percent (n = 393) of our sample believed their community was at risk from wildfire and that the impacts would be economically significant on the region as a whole (Figure 3-0-1). However, when viewed personally, just over half (51 percent, n = 209) of residents expressed slight to no concern about the economic impacts on themselves.

There was broad awareness in our sample about the environmental and social impacts of wildfire. For example, 89 percent (n = 364) of our sample expressed a high level of concern about the impacts of wildfire smoke on air quality (Figure 3-0-2 and Figure 3-0-3). Residents also expressed moderate to high levels of concern about the impacts of a wildfire on wildlife (87 percent, n = 355), water quality (85 percent, n = 347) and post-wildfire erosion and flooding (84 percent, n = 344). Impacts on recreation opportunities as well as on historic aspects in their communities were also of concern to many (>70 percent) in our sample.

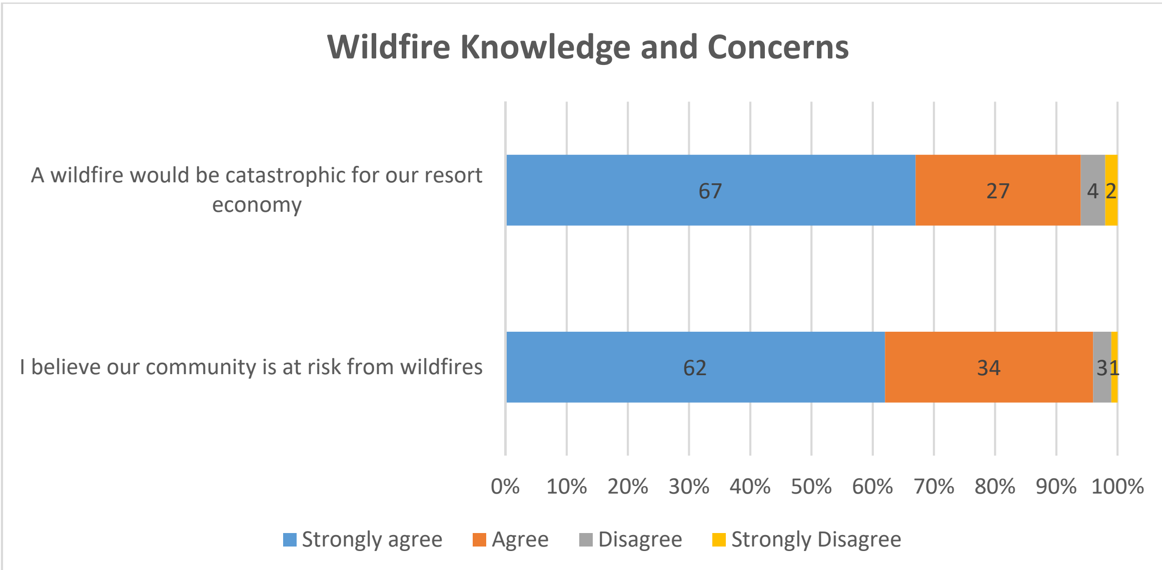

Figure 3-0-1. Residents' expressed levels of agreement regarding risk to their communities and social, economic, and ecological impacts from wildfire.

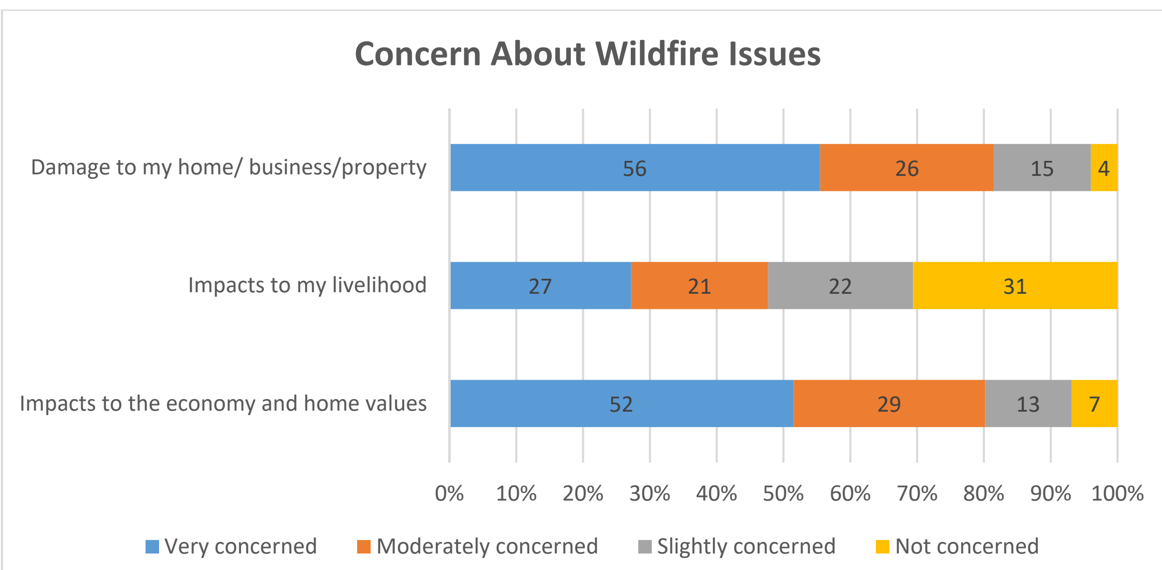

Figure 3-0-2. Resident views regarding economic impacts on themselves and risks to their communities from wildfire.

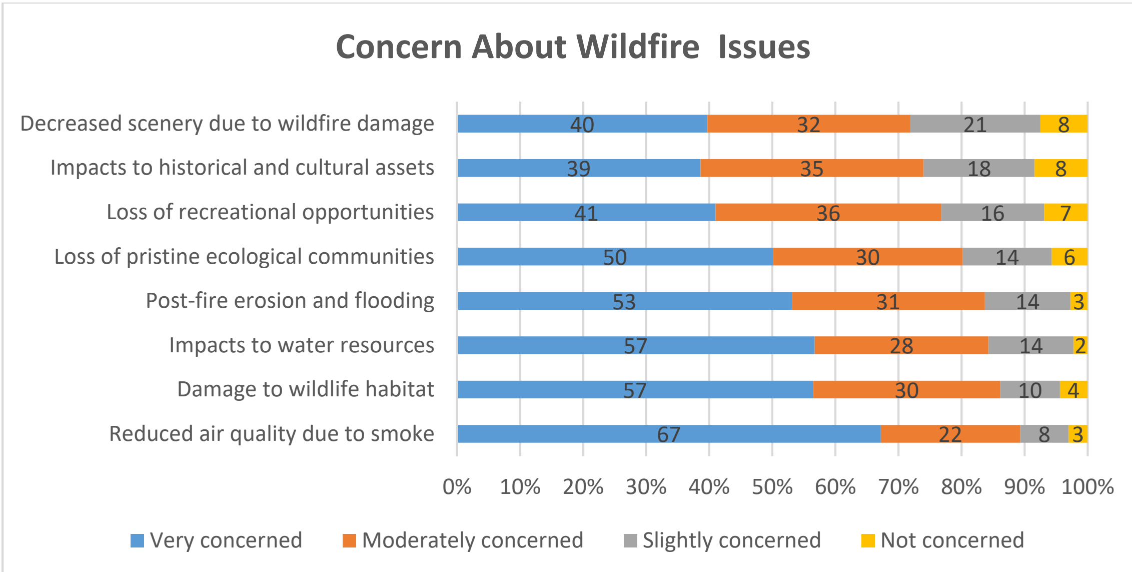

Figure 3-0-3. Resident awareness of the environmental and social impacts of wildfire.

How to Address Wildfire Risk

Addressing the risks from wildfire entails multifaceted actions by both homeowners and those in the wider community. This perspective was reflected in the pattern of responses we obtained (Figure 3-0-4). First, residents strongly supported the idea that each landowner was responsible for mitigation efforts and that local government was in a position to enforce (>90 percent) and support (84 percent, n = 346) mitigation efforts. Second, burning slash piles and the use of prescribed fire in forested areas (> 84 percent) were also widely supported mitigation actions. Finally, cutting trees in general wasn't as strongly endorsed by residents in our sample.

Figure 3-0-5 and Figure 3-0-6 present resident mitigation actions completed on their own property. As shown, basic actions such as removing lower limbs from trees and removing flashy fuels such as pine needles were the most commonly undertaken mitigation actions by residents in our sample. Fewer residents reported moving firewood or modifying combustible vegetation within five feet of their home. Home hardening actions, such as installing screens or an ignition-resistant roof which are often effective in resisting the impacts on a house during ember storms, were not endorsed by 60 percent or more of our sample. Over 80 percent (n = 327), though, endorsed that they knew how to reduce wildfire hazards on their property. Additionally, almost 60 percent of residents indicated that they would only spend $1,000 - $2,000 on mitigation annually, while 26 percent would spend $2,000 - $10,000.

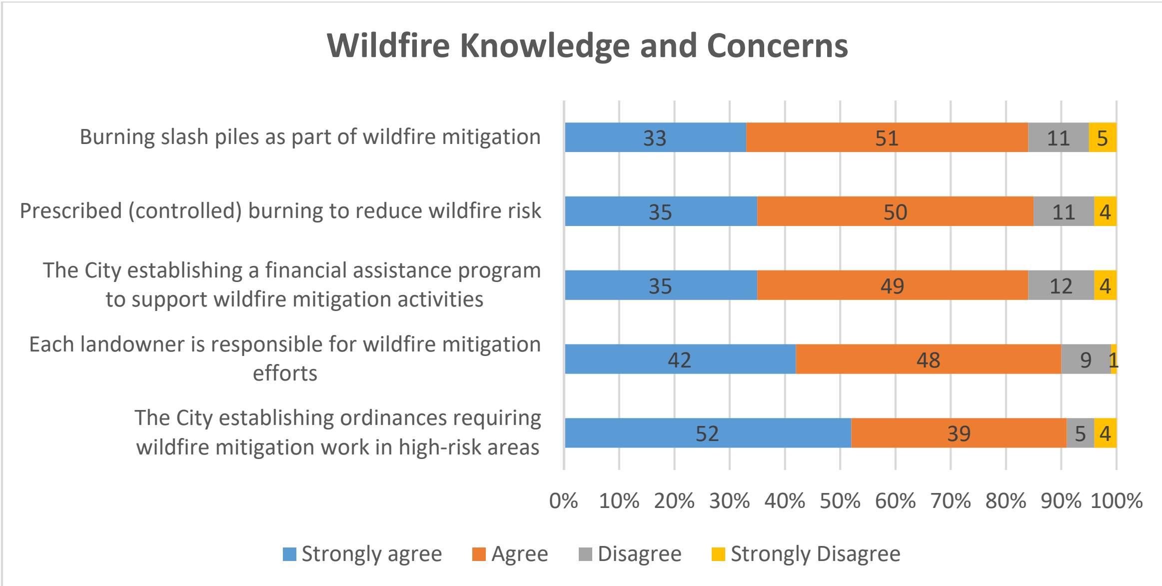

Figure 3-0-4. Resident views on addressing the risks from wildfire.

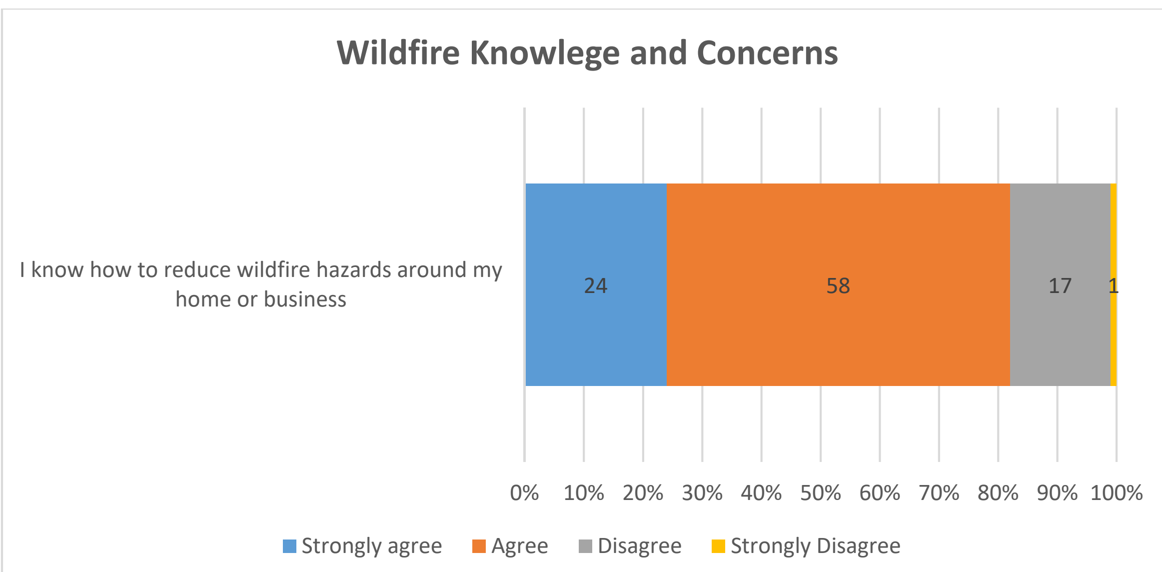

Figure 3-0-5. Residents' expressed views on whether they knew how to reduce wildfire hazards on their property.

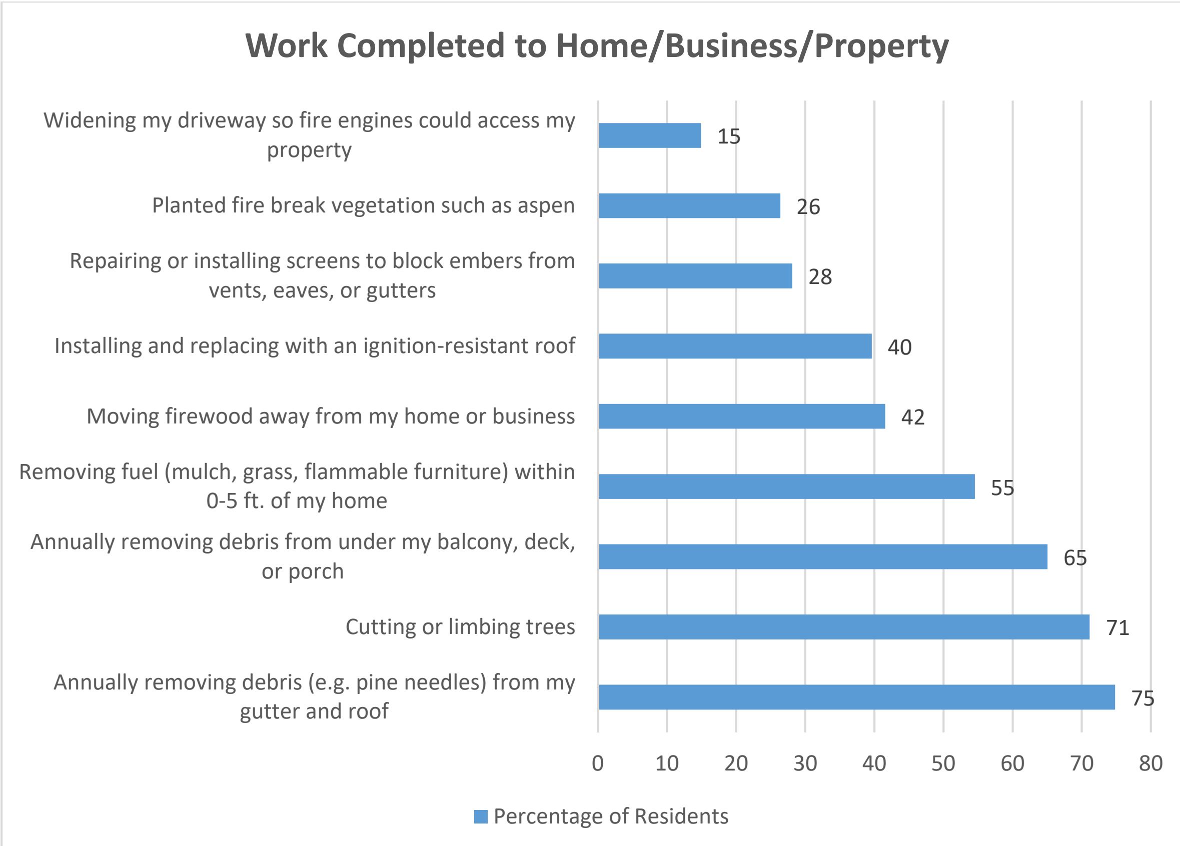

Figure 3-0-6. Resident mitigation actions completed on their own property. Each respondent was allowed to choose multiple answers

Education about Addressing Wildfire Risk

Outreach and education are important to increase community awareness, engage residents to take action and increase planning regarding wildfires (Figure 3-0-7). Responses to multiple questions indicated a strong preference for an in-person review of their own wildfire risks and what to do about them (62 percent, n = 254). Other education opportunities that were of interest included neighborhood programs about wildfire risk (58 percent, n = 229), availability of electronic resources concerning wildfire preparedness (48 percent, n = 196), and further information about local programs such as PCFD's Ready, Set, Go program (47 percent, n = 193). Residents also indicated that their preferred methods for receiving information are email (86 percent), text messages (51 percent) and local media outlets such as KPCW (35 percent).

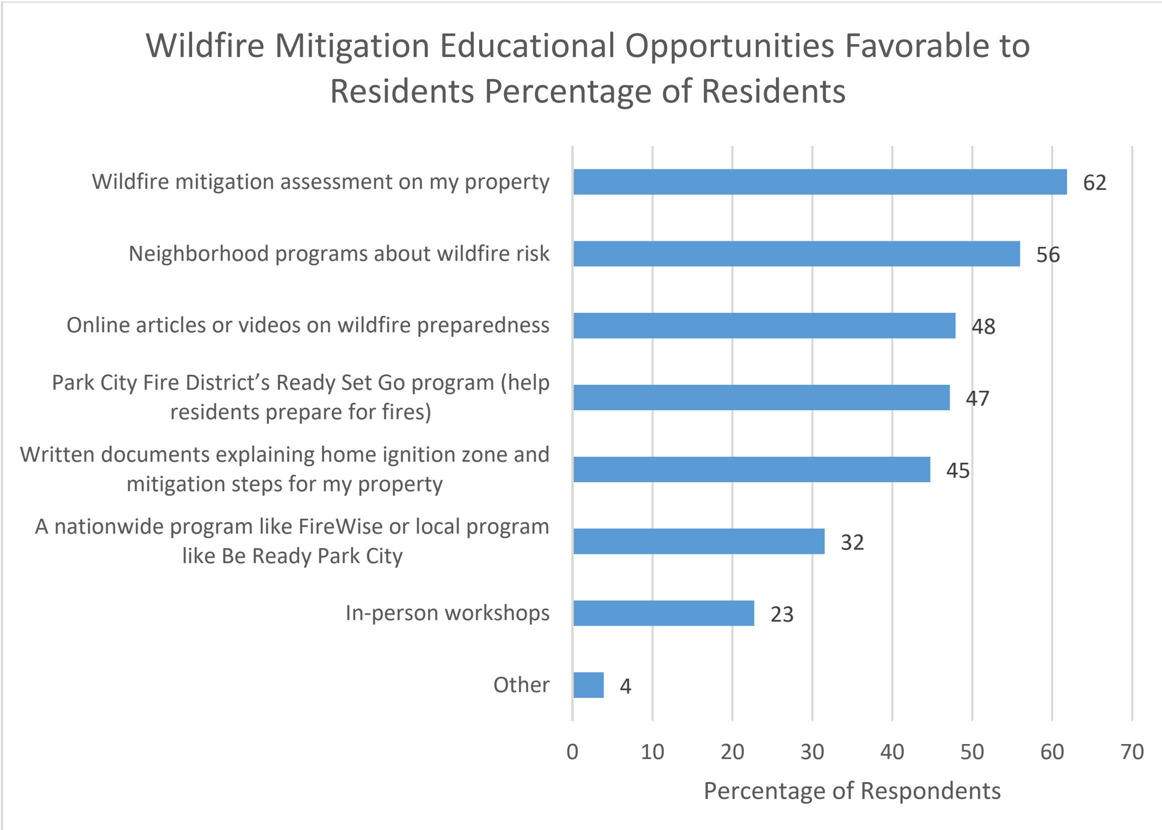

Figure 3-0-7. Wildfire mitigation educational opportunities favorable to residents.

Evacuations

Evacuation planning is an essential part of wildfire preparedness. Among our sample, 56 percent (n = 229) of residents reported having a plan either at their house or business (Figure 3-0-8), but the vast majority of them had not practiced evacuating within 15 minutes of being notified (Figure 3-0-9). Top concerns in the event of an evacuation (Figure 3-0-10) included an inability of the roads to handle evacuation traffic (60 percent) and not receiving timely information about an evacuation (59 percent).

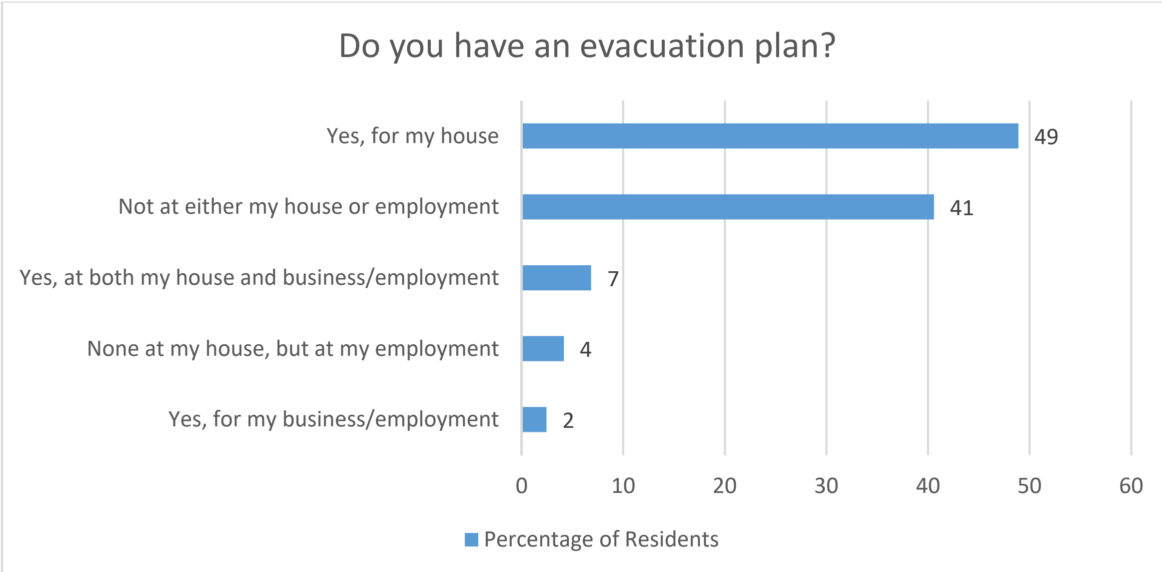

Figure 3-0-8. Resident reports on whether or not they have an evacuation plan for their home or business.

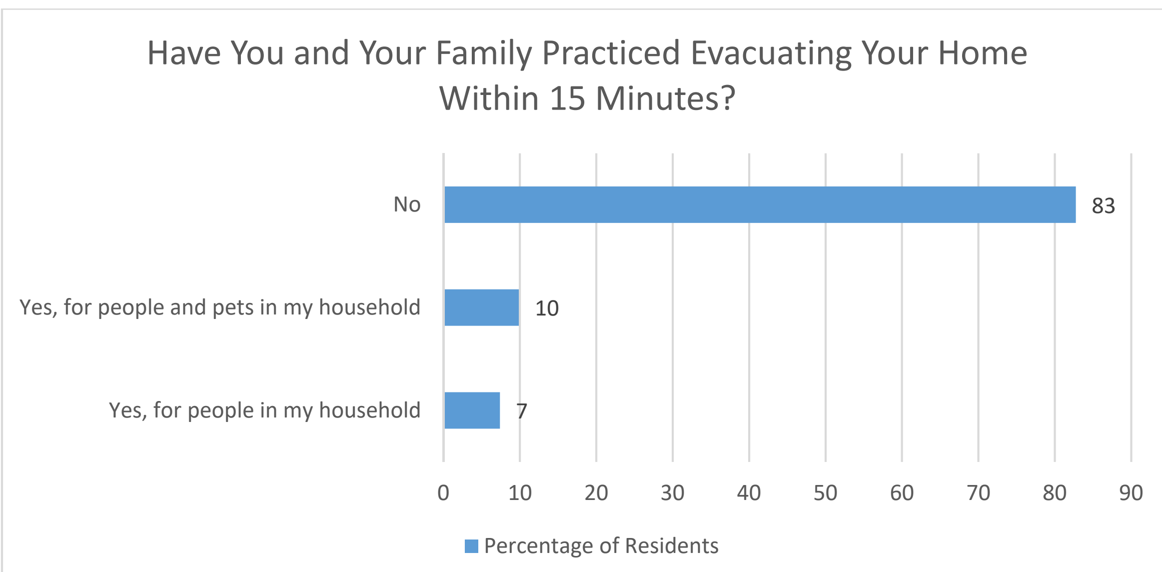

Figure 3-0-9. Most residents have not practiced evacuating their home.

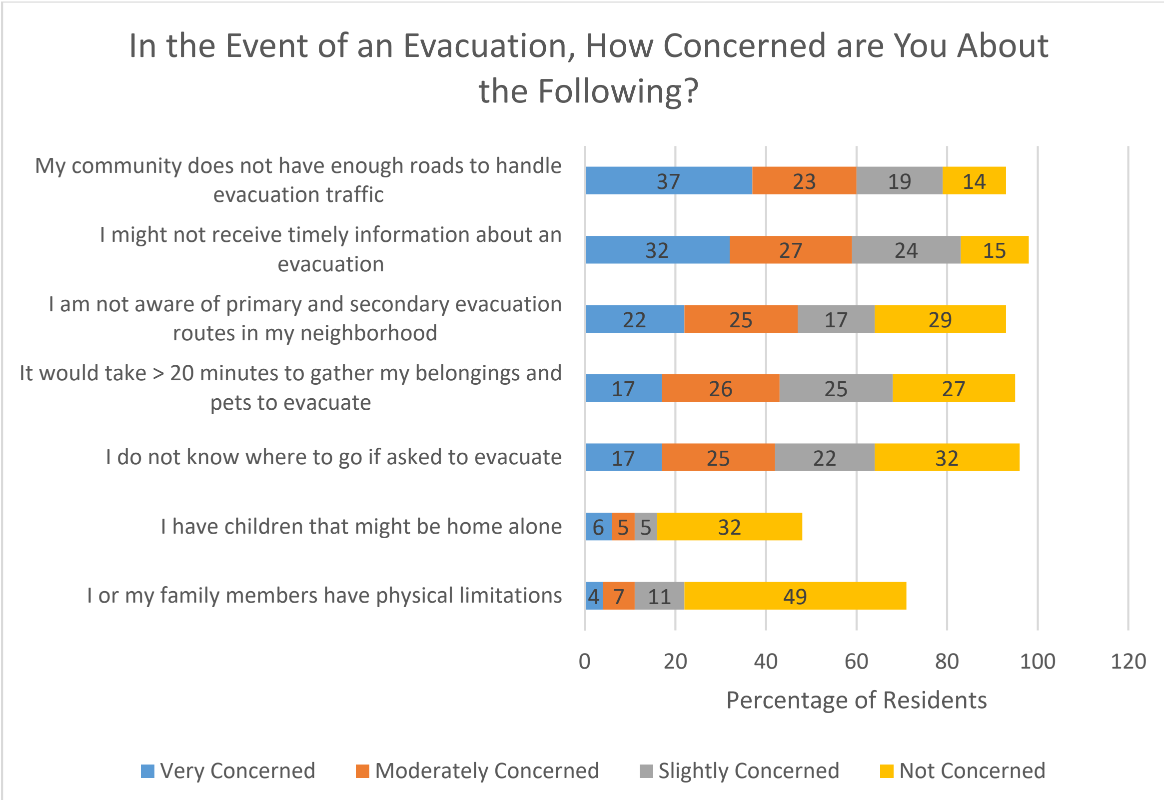

Figure 3-0-10. Resident concerns in the event of an evacuation.

Resident Comments

During the survey, residents were given the option to add comments for each section. Nearly 300 comments were submitted throughout the survey and are provided in the Additional Tables and Figures section of this document. The comments revealed perspectives on wildfire that didn't always show through responses to multiple-choice questions. Multiple points of view were represented throughout the comments ranging from strong support for the project to questioning any type of risk of wildfire in the area.

"It is inevitable that park city will burn."

"We are not a high-risk community at all. Park City has a lot of natural water pathways and reservoirs. Over focus on this is nonsensical and a waste of taxpayer dollars."

<u>Evacuation Issues</u> - Residents/workers don't know what to do or where to get information about evacuating. Significant concerns were noted regarding issues for day workers using public transit, and short-term renters who wouldn't know routes for evacuation or receive notification of an evacuation.

"Would buses be deployed to evacuate neighborhoods?"

Lack of Knowledge/Inaccurate Information - Many comments indicated a lack of knowledge about ignition of wildfires or the risk they pose. Other comments reflected inaccurate information or theories. Numerous comments indicated inaccurate information regarding defensible space and forest health, as well as a lack of knowledge on home hardening. Some respondents felt the lack of wildfires in the past indicated low risk for the future.

“Destroying the trees and vegetation is increasing wildfire risk.”

“I do not know what slash piles are. There should be a “don’t know” option!”

Clear and Concise Information/Guidance from PCMC - While several comments noted support for PCMC ordinances and guidance, many noted the lack of clarity and understandability. Many comments noted challenges with navigating the parkcity.org website – where to find information, user friendliness.

“I would love a clear ordinance to provide clear, concise guidance to park city residents about what they need to do to protect their homes from wildfires.”

Old Town Issues - Several respondents indicated concern with both evacuation and mitigation for those living in Old Town. These included concerns over housing density, small lots and lack of egress for residents and visitors.

“I live in Old Town and I am very concerned about access of fire, medical and police resources and egress of residents and visitors during a fire in and around Old Town.”

“It's totally not clear to me what old town residents can do for wildlife mitigation when we have no land/ trees and live within arms-reach of neighbors.”

Education Resources - Respondents indicated that they want to improve their knowledge so they can take meaningful action. Several noted the actions (or inaction) of stakeholders such as Deer Valley, PCMC Resorts as well as HOAs. This suggests that publicizing the actions and accountability of stakeholders and community organizations could encourage residents to pursue their own planning and action.

“Park City Fire Department needs to make an official response whether the new Alterra project at Snow Park will or will not create issues with fire truck response times during emergencies, fires or evacuations.”

“After this study, I would like to know if the City will publish something for residents/visitors as a guide to what residents/visitors need to know in the event of a wildfire and what actions they need to take to evacuate or otherwise seek safety.”

Recommendations and Conclusion

Risk for a major wildfire is increasing in the Western United States due to a variety of climate-driven factors and historical management decisions. When wildfires occur, they are burning more intensely and having greater impacts on ecosystems and communities alike. Because of this, there is a wider interest in wildfire risk reduction activities and for greater preparedness. Along these lines, we assessed levels of knowledge, areas of concern, and actions undertaken by a sample of residents in the Park City area. An overall observation from this assessment is that there is a lack of information about mitigating wildfire risk and evacuating in the face of and during a wildfire.

In our sample, their appears to be greater acceptance or a belief that mitigation for wildfires involves actions taken in areas where there are few to no homes but not necessarily on or around one's own property. This is suggested by the high endorsement rates of pile burning and prescribed fire and low or moderate endorsement rates for more effective mitigations on and around the home. This is interesting in light of the national headlines from the 2022 Calves Peak and Hermit Peak fires in New Mexico which started as a prescribed fire but spread beyond control lines and burned 342,471 acres. Prescribed fire is a useful tool in reducing fire intensity and improving forest health, but embers from wildfires in general can travel up to a mile or more and ignite similar fuels within neighborhoods and around homes. Mitigation in one area without similar mitigations in others is not as effective as doing both.

This apparent discrepancy provides a number of important opportunities. First, if endorsement rates in this sample can be taken as broad support for prescribed fire programs, then efforts to coordinate such programs with additional stakeholders could provide important steps to reduce fuel loading within the surrounding forests and improve the health of highly valued landscapes. Second, belief that mitigation is a homeowner's responsibility could support messaging around different types of mitigation homeowners can do on their property. Communications that include home hardening information as well as firewise vegetation and landscaping principles could prove effective outreaches. Lastly and importantly, helping residents understand fire dynamics, fire's place in the ecosystem, and what impacts certain mitigation actions can have and why these are important can be motivating and empowering given the belief that their community faces very high wildfire risks.

Preparedness is an important part of mitigating the risks associated with wildfire. Lessons from the 2018 Camp Fire, which burned through the town of Paradise, CA, underscores the importance of evacuations and having a plan that is known and practiced. In our sample, nearly half of the respondents did not have a plan for how to leave safely from their home and communities. Further, nearly all the respondents to our survey indicated they had not practiced an evacuation. The feedback and concerns identified in our survey strongly encourage that more outreach with specific types of communications be done ahead of wildfire season. Outreach that specifies primary and secondary evacuation routes and where to get information about evacuations are critically important given that over half of respondents indicated they were concerned about these topics.

Our survey is not without its limitations. First, our sample size is small and thus may not represent the range of viewpoints in the wider community. Second, because the survey was intended to be brief and not impose too much burden on respondents, some demographic information was not collected. Such information could have provided additional insights into the data collected.

In conclusion, similar to many other areas in the Western United States, there appears to be an interest in better understanding the wildfire risk facing Park City and what can be done to mitigate those risks. As such, outreach and education to these ends should be a priority. Essential to this is developing a cohesive outreach plan among the Park City Municipal Corporation, Park City Fire Department and local homeowner's associations. Our data also strongly encourages strengthening emergency preparedness in terms of incentivizing residents to perform wildfire mitigation as well as evacuation planning.

Recommendations

Build Wildfire Awareness through Outreach and Education

- Update PCMC website to be clear, concise and understandable for residents.
- Heavily advertise the Summit County/Park City Emergency Alerts program. Employ the local radio, newspaper, social media and HOA newsletters.
- Encourage stakeholders (Park City and Deer Valley Resorts, utilities, and public transit) to prioritize wildfire mitigation actions and publicize this to the local community.
- Coordinate educational programs that cover defensible space, home hardening and emergency planning. These programs could be coordinated with the PCFD's Ready, Set, Go Program.
    - Set up a monthly newsletter or blog to highlight wildfire awareness. HOA, STR licensees and water utility user records could be used to distribute the newsletter.
- Organize a coordinated outreach plan with cohesive messaging from PCMC, PCFD and HOAs.
- Create a robust smoke management plan to communicate information to residents on prescribed fire smoke management (techniques, air quality regulations and FAQs).
- Promote the PCFD Wood Chipping Program if/when it becomes available.
- Support a Neighborhood Ambassador Program to help property owners better understand wildfire risks and spark coordinated action that affects positive change. Utilize property owners and community groups to work with PCMC, Park City Fire District and other partners to address shared risk.

Bolster Emergency Preparedness

- Use Wildfire Awareness Month in May to encourage residents to set up emergency preparedness plans. This could include registering their cell phones and email addresses through Summit County/Park City Emergency Alerts—the official emergency notification system for residents, businesses, second home owners and visitors within the limits of Summit County, Utah.
- Promote preparation of a go-bag and a family emergency plan before the threat of wildfire is in your area. Encourage HOAs to publicize awareness in their neighborhoods of coordinated plans with family and neighbors.
- Address issues with egress routes (where no one knew who had a key) through HOAs. Use newsletters, emails, annual meetings to disseminate information.
- Encourage residents to visit the Rotary Wildfire Ready website to learn about go-bags and evacuation planning.

Incentivize Wildfire Mitigation

- Establish a program that provides wildfire mitigation home assessments and/or a list of certified wildfire mitigation specialists in the area. If not, think of other ways to get information out about assessments.
    - Consider grant funding to build a voucher or discount program to remove financial barriers.
- Adopt ordinances to enforce adequate home hardening.
- Review existing regulations. Anticipate and address challenges. Involve the public. Use examples from other cities, counties or programs that have successfully implemented code updates.

  - Require short-term rentals to have a wildfire assessment done as part of the licensing requirements. Include emergency preparedness as part of this assessment (how to notify renters of evacuation, egress routes).
- Develop a homeowner cost-planning tool for wildfire mitigation work and make it available to the public.

<u>Government, PCFD, Stakeholders Must Lead the Way</u>

- PCMC, PCFD and HOAs represent credible and respected sources for information. By building a cohesive approach, residents and business owners will take guidance leading to meaningful action.
- Major stakeholders such as Deer Valley and PCMC Resorts, Park City Transit and utility companies have an opportunity to be good examples for the community. These organizations taking actions regarding emergency preparedness and wildfire mitigation and publicizing it will go a long way towards encouraging residents to do the same.

Additional Tables and Figures

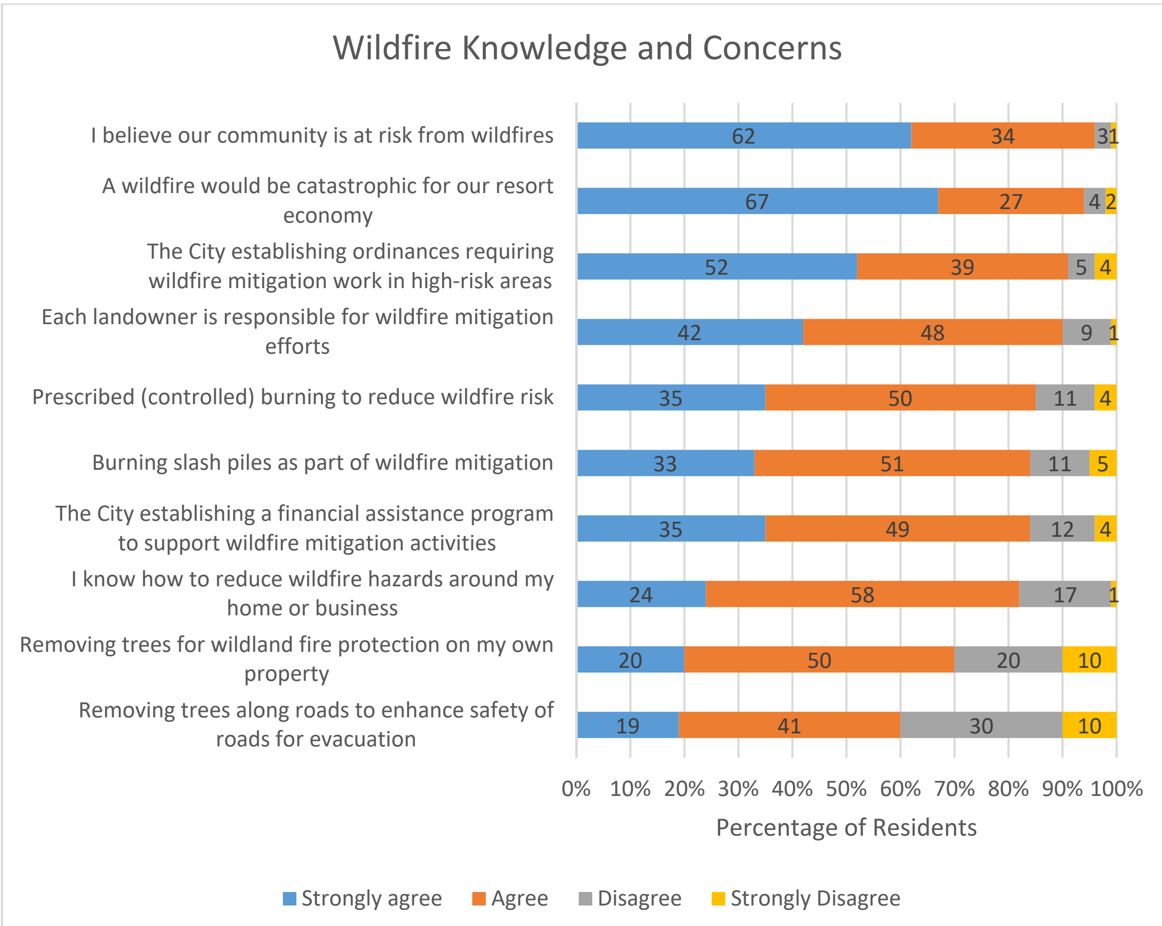

Figure 3-0-11. Residents' level of concern regarding wildfires. Includes data from Figure 4 plus additional responses.

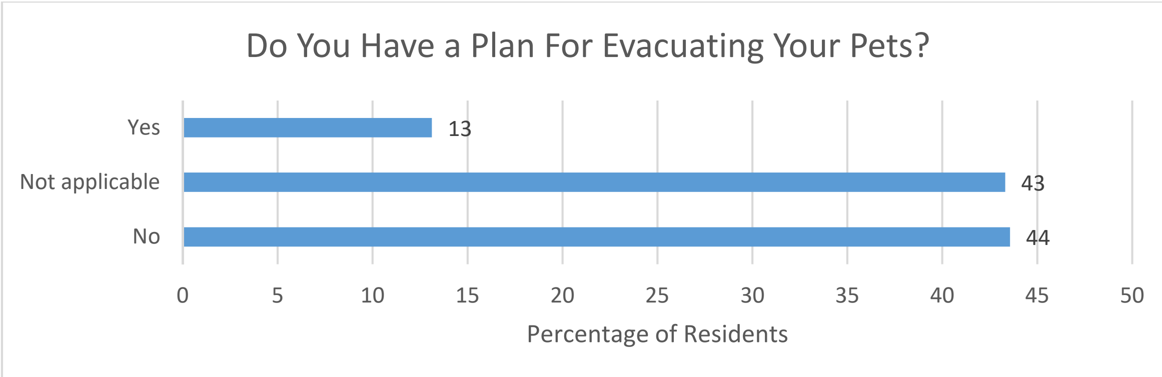

Figure 3-0-12. Residents with plans for evacuating pets.

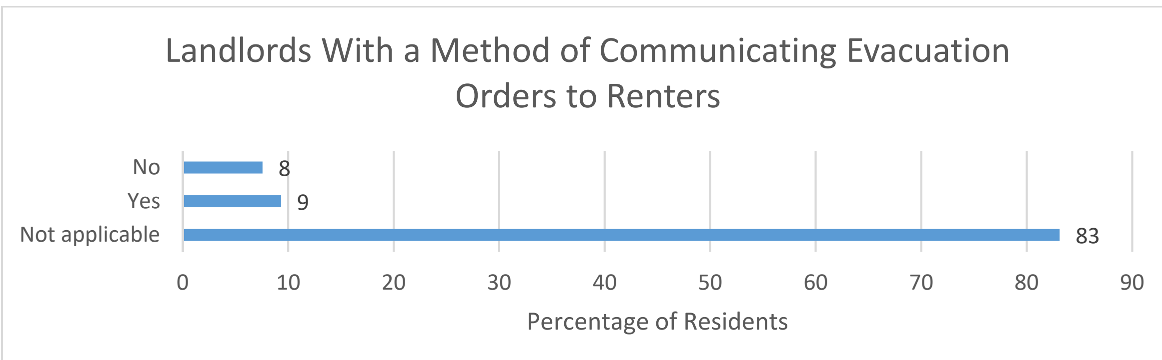

Figure 3-0-13. Short-term rental owner's notification of renters.

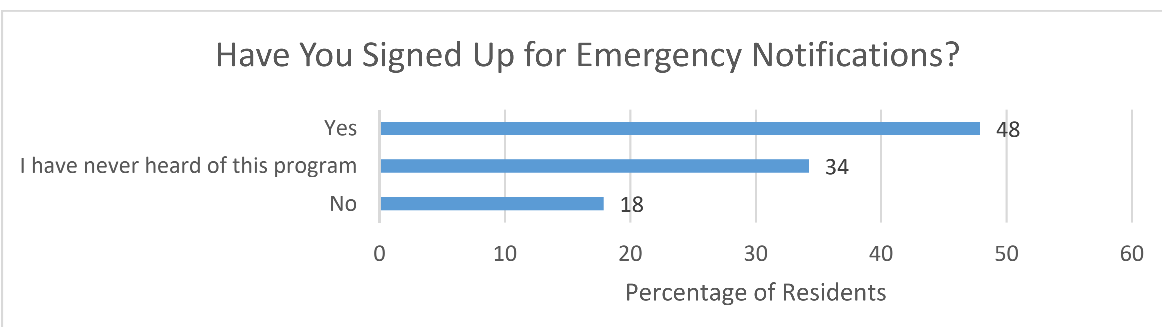

Figure 3-0-14. Residents registered for Summit County/Park City emergency alert system.

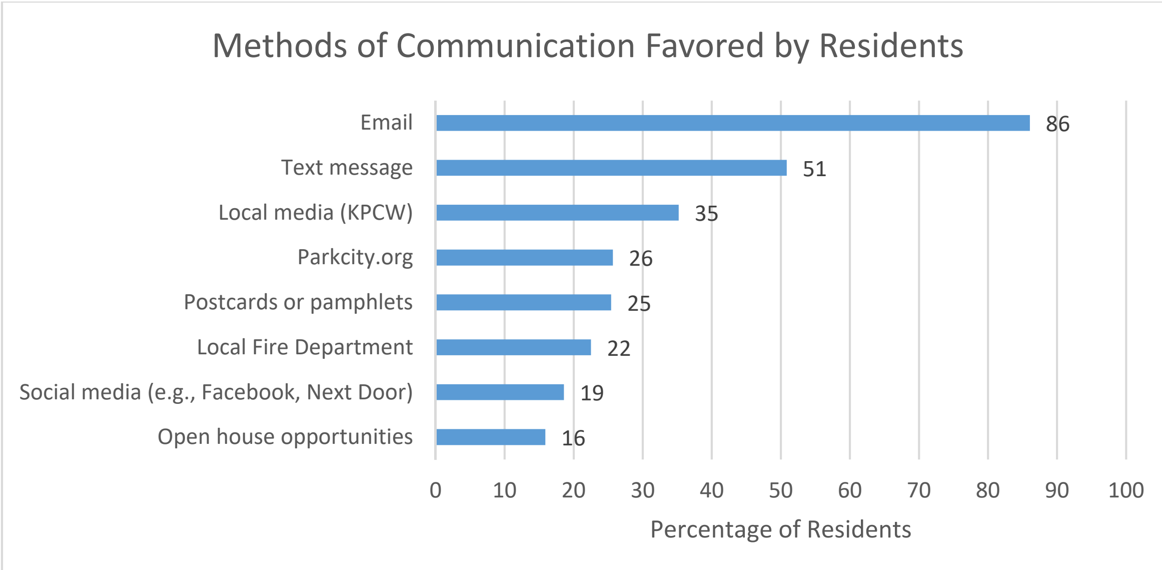

Figure 3-0-15. Preferred methods to communicate wildfire emergency to residents.

Table 1. Residency status of survey respondents. Each respondent was allowed to choose multiple answers.

Residency Status	Residents (%)
Full-time resident	73
Seasonal resident	22
Owner of rental property	5
Other	3
Business owner	2
Owner of undeveloped lots	1

References

Utah Department of Natural Resources. Division of Forestry, Fire, and State Lands. Utah Firewise Living. 2022, https://ffsl.utah.gov/wp-content/uploads/FINAL-DRAFTMarch2608-LowRes.pdf.

Wildfire Adapted Partnership. Fire Adapted Communities Neighborhood Ambassador Approach - Increasing Preparedness through Volunteers. Apr. 2018, https://static1.squarespace.com/static/5b28059d266c074ffe39b9b9/t/5bd7648315fcc0d2d293febc/1540842637107/AmbassadorGuide_v2018-09-24.pdf.

4.0 Suppression Response

In This Chapter

4.1 Suppression Response

Executive Summary

Safe, effective and risk-based wildfire response is one of the three goals of the National Wildland Fire Management Cohesive Strategy (Cohesive Strategy)—the key strategic framework for addressing wildland fire challenges across the nation. As part of the PCMC Community Wildfire Risk Assessment project, we organized a suppression working group with extensive experience in wildland and structural fire to assess and summarize the wildfire response capacity of the Park City Fire District (PCFD). We developed general recommendations for PCFD based on our team's wildfire suppression experience, industry norms, lessons learned from other small- to medium-sized fire districts in the western U.S. and recommendations and tasks in local, regional, national strategic plans (Cohesive Strategy, 2013 Western Regional Action Plan, 2013 Utah Catastrophic Wildfire Reduction Strategy, 2021 PCMC CWPP and 2013 PCFD CWPP) and best practices from NFPA's Fire Department Wildfire Preparedness and Readiness Capabilities report (Haynes & Madsen, 2017).

Within the PCMC Community Wildfire Risk Assessment Area, several entities have jurisdictional responsibility for wildland fire including Park City Fire District, Summit and Wasatch counties, Utah Forestry, Fire and State Lands, the US Forest Service and the Bureau of Land Management. The largest response duties of these entities fall on the Park City Fire District (PCFD), and such is the focus of this suppression review. PCFD has positioned itself to respond to local wildfires. Additional adjustments could further enhance PCFD's ability to fulfill the third goal of the Cohesive Strategy—safe, effective and risk-based wildfire response--and PCFD's mission to "enhance the quality of life for those we serve, safeguard the environmental and economic base of our community, make a positive difference and provide excellence in service."

Key reasons for PCFD to invest in wildfire response capacity now are: (1) elevated wildfire risk in the Park City area, with risk likely to increase in the coming years due to climate change and increasing development in the wildland/urban Interface; (2) exposure of values at risk to damage from wildfire and post-fire sediment delivery; (3) benefits of proactive measures within the community to reduce the severity and impacts of future wildfires; and (4) current availability of grant funding to support fire department capacity and preparedness. This assessment can fulfill the tasks assigned PCFD in the 2021 PCMC CWPP (Goal B.4. Evaluate response personnel, facilities, and equipment).

Top recommendations for PCFD are:

- Formalize the internal wildland fire program with dedicated and consistent oversight and restructuring.
- Provide additional opportunities for staff to gain wildland fire experience and qualifications.
- Increase resources and availability to support area residents in wildfire risk mitigation, education and activities.
- Update and expand formal fire management plans.
- Reevaluate the potential to support a seasonal wildfire and fuels mitigation crew.

Background

National Wildland Fire Management Cohesive Strategy and the Role of Local Fire Departments

Safe, effective and risk-based wildfire response is one of the central goals of the National Wildland Fire Management Cohesive Strategy (2023; Cohesive Strategy). The Cohesive Strategy is the key strategic framework for addressing wildland fire challenges across the nation. The Cohesive Strategy emerged from the Federal Land Assistance, Management, and Enhancement Act of 2009 (FLAME Act) and was finalized in 2014 after rigorous planning, analyses and stakeholder engagement. A re-evaluation and amendment to the Cohesive Strategy was released in 2023 to address emerging issues, such as climate change, workforce capacity, community resilience, diversity, equity and inclusion. The 2013 Utah Catastrophic Wildfire Reduction Strategy is centered around the same three goals as the Cohesive Strategy.

Local fire departments have a central role to play in implementing the Cohesive Strategy and Utah Catastrophic Wildfire Reduction Strategy. The U.S. Fire Administration under FEMA suggests the following actions for fire departments to support the Cohesive Strategy:

- Help your jurisdiction create a Community Wildfire Preparedness Plan.
- Provide guidance to resident leaders to develop fire-adapted communities.
- Ensure that fire service personnel responding to wildfires have adequate training and equipment.

The Western Regional Strategy Committee proposed a series of goals, actions and tasks in the 2013 Western Regional Action Plan to fulfill the third goal of the Cohesive Strategy. Local fire departments are identified as important implementers for many of the tasks in the action plan, including:

- Develop a local unified vision pre-season through annual operating plans and involve affected agencies and stakeholders (Goal 3.2, Action 3.2.a, Task 8)
- Map areas where aggressive suppression is the expected initial response (Goal 3.2, Action 3.2.a, Task 10).
- Discuss plans for areas and situations (weather, time of year, vegetation types, etc.) in which aggressive suppression is not the desired response (Goal 3.2, Action 3.2.a, Task 11).

GOALS OF THE COHESIVE STRATEGY (UPDATED IN 2023)

RESILIENT LANDSCAPES

Landscapes, regardless of jurisdictional boundaries are resilient to fire, insect, disease, invasive species and climate change disturbances, in accordance with management objectives.

FIRE-ADAPTED COMMUNITIES

Human populations and infrastructure are as prepared as possible to receive, respond to and recover from wildland fire.

SAFE, EFFECTIVE, RISK-BASED WILDFIRE RESPONSE

All jurisdictions participate in making and implementing safe, effective, efficient risk-based wildfire management decisions.

Roles of Local Fire Departments in Utah for Wildfire Prevention, Response and Proactive Management

Responsibilities for wildfire prevention, response and proactive management in the State of Utah depend on the location where action is occurring. Responsibilities are outlined in the Utah State Code 65A-8-2 (Management of Forest Lands and Fire Control, Fire Control; 2023) and the Utah Division of Forestry, Fire & State Lands Annual Operating Picture. Local fire departments for municipalities have the responsibility to:

1. Reduce the risk of wildfire to incorporated, privately owned and municipality owned forest, range, watershed and wildland-urban-interface land, with private landowner permission, through appropriate wildfire prevention, preparedness and mitigation actions; and
2. Ensure effective wildfire initial attack on forest, range, watershed and wildland-urban-interface land within the municipality's fire protection boundary.

Local fire departments may assign these responsibilities to a fire service provider or an eligible entity through contract, delegation, interlocal agreement or another method (Utah State Code 65A-8-2-200.5; effective 01/01/2017).

The Utah Cooperative Wildfire System (CWS) was established by the Utah legislature in 2017 to create a system wherein the state incurs the costs of large and extended-attack wildland fire ("catastrophic fires") in exchange for local governments agreeing to implement prevention, preparedness and mitigation actions that are proven to reduce the risk and costs of wildland fire in the long run (Utah Division of Forestry, Fire and State Lands, 2023). Eligible entities include counties, cities and certain special districts. All 29 counties in Utah and most cities (including Park City and Summit County) have opted into the CWS. Participating entities must meet the following three criteria to receive the option of authorizing the Delegation of Fire Management Authority and Transfer of Fiscal Responsibility to the State (Utah Division of Forestry, Fire and State Lands, n.d.) when wildfires escape initial attack:

1. **Annual participant commitments:** Commitments are met through prevention, preparedness and mitigation work—direct spending or in-kind efforts—accomplished at the local level. Commitments are calculated based on average historic fire cost within the jurisdictional boundary and a risk assessment evaluation by the Utah Wildfire Risk Assessment Portal (UWRAP). Participant commitments are regularly recalculated with older fires dropped and newer fires added to the estimate of average historic fire cost.
2. **Initial attack:** The participating entity and its associated fire department make the best possible initial attack (IA) to control and contain wildland fires in this early phase. Increasing wildfire preparedness through training, annual firefighting refreshers and purchase of equipment that will enhance their wildland firefighting IA capabilities.
3. **Community Wildfire Preparedness Plan (CWPP):** Participating entities must create CWPPs within two years of opting into CWS and keep their plan updated. CWPPs must identify local values at risk, priority areas and actions to reduce risk. Staff of the Utah Division of Forestry, Fire and State Lands can provide assistance to participating entities when preparing their CWPP.

Importance of PCFD's Wildfire Response Capacity

Park City Fire District (PCFD) is involved in local initial-attack wildfire response and has experience with several local and out-of-area incidents. All firefighters with PCFD are required to have wildland fire qualifications (hold red cards) and the Department holds annual wildland fire refresher trainings and has one Type 3 wildland fire engine available for out-of-district wildfire deployments. PCFD firefighters have gone on 20 deployments across the U.S. in the past 12 years. PCFD played a key role in responding to the 2021 Parleys Canyon Fire north of Park City. Quick action by PCFD responding crews in conjunction with the Summit County Sheriff's Department resulted in organized evacuations of threatened homes, and laid the foundation for the arrival of state and federal resources, including firefighting aircraft over the fire in a very short timeframe, helping to prevent any loss of life and property.

Key reasons for PCFD to invest in wildfire response capacity in the coming years are:

1. Elevated wildfire risk in the Park City area, with risk likely to increase in the coming years due to climate change and with the expansion of the wildland/urban interface (see chapter 5.0).
2. Exposure of values at risk to damage from wildfire and post-fire sediment delivery (see chapters 2.0 and 5.0).
3. Benefits of proactive measures within the community at reducing the severity and impacts of future wildfires (see chapter 5.0).
4. Strategic alignment with the Cohesive Strategy, 2013 Utah Catastrophic Wildfire Reduction Strategy, 2013 Western Regional Action Plan, PCFD's mission to "enhance the quality of life for those we serve, safeguard the environmental and economic base of our community, make a positive difference, and provide excellence in service," and tasks in the 2013 Park City Fire District CWPP (Utah Division of Forestry, Fire and State Lands, 2013) and 2021 PCMC CWPP (Utah Division of Forestry, Fire and State Lands, 2021) (Table 4-1 and 4-2).
5. Current availability of grant funding to support fire department capacity and preparedness (see list of potential funding sources at the end of this chapter).

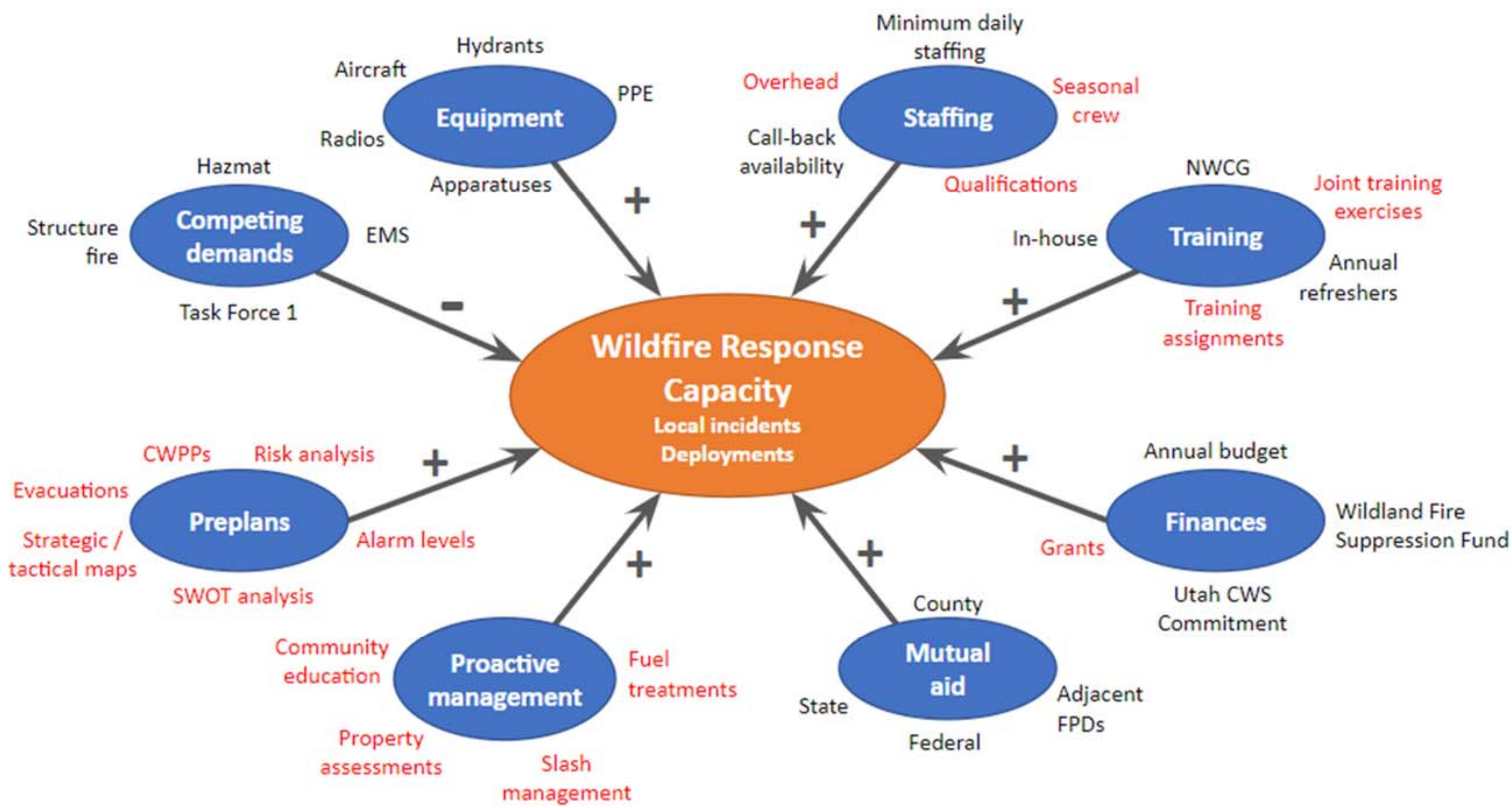

Figure 4 0-1. Figure 1. The capacity for fire departments to respond to local wildfires and participate in out-of-area deployments is influenced by a variety of factors. Increases in these factors increase wildfire response capacity, except for competing demands, which decrease the capacity of fire departments. Items in red are mentioned in general recommendations for PCMC and PCFD.

Methods

We organized a suppression working group with extensive experience in wildland and structural fire to summarize PCFD's wildfire response capacity and provide general recommendations. Wildfire response capacity for local incidents and out-of-area deployments is influenced by a myriad of factors related to competing demands for staffing, equipment, training, finances, mutual aid, preplans and proactive management (Figure 4-0-1). We assessed conditions in each of these areas based on conversations with PCFD leadership and review of relevant documents, such as 2020-2022 PCFD Annual Reports, 2020 Blue Ribbon Committee report, PCFD pre-plans, minute meetings for the PCFD Administrative Control Board, 2021 PCMC CWPP (Utah Division of Forestry, Fire and State Lands, 2021), 2013 Park City Fire District CWPP (Utah Division of Forestry, Fire and State Lands, 2013), Utah Statewide Operating Plan (2013), PCMC's Comprehensive Emergency Management Plan (2020), 2022 Pre-Disaster Mitigation Plan for Summit, Utah, and Wasatch Counties (Mountainland Association of Governments, 2022), and Utah State Code.

We developed general recommendations for PCFD based on our team's wildfire suppression experience, industry norms, lessons learned from other small- to medium-sized fire districts in the western U.S., recommendations and tasks in local, regional and national strategic plans (Cohesive Strategy, 2013 Western Regional Action Plan, 2013 Utah Catastrophic Wildfire Reduction Strategy, 2021 PCMC CWPP, and 2013 PCFD CWPP) and best practices from NFPA's 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report (Haynes & Madsen, 2017).

Key Findings

Competing Demands

PCFD has an important role in wildland fire response and proactive management. However, they face similar challenges as other small- to medium-sized fire departments in the wildland urban interface, including competing demands for staffing, training and funding (Madsen et al., 2018). In addition to wildland fire response and community outreach, PCFD responds to structural fires, engages in fire prevention inspections, community outreach, plan reviews and special events, provides emergency medical services, AEMT ambulance transport, heavy rescue and hazmat response for all of Summit County, and provides community EMS training. PCFD is contractually committed to respond to nation-wide emergencies through Utah Task Force 1, up to several times a year. Understandably, these other responsibilities make it harder for PCFD to commit staff time to wildland fire training and out-of-area deployments.

> *Historically, local fire departments have focused on structural fire protection while wildfire protection has been the domain of the state and federal government. Each type of protection requires different firefighting techniques and equipment: urban protection is a focused effort to protect structures (requiring heavy duty personal protective equipment, including breathing apparatus, that allows for brief exposure to intense heat that can occur within a building), whereas wildland firefighting emphasizes a more extensive effort to prevent perimeter spread (requiring lighter weight protective equipment that allows for long periods of intense physical work). As a result, direct involvement in wildfire management, particularly fire mitigation efforts, has not always been seen by local fire departments as in their purview of responsibilities. (Madsen et al. 2018, page 451)*

Due to an absence of large wildfires near Park City in the past several decades and the abundance of EMS calls they receive, wildland fire response appears to receive a lesser emphasis than other services offered by PCFD. Emergency medical calls are abundant with 32,000 year-round residents in the district and 4 million annual daytime and overnight visitors, mostly in the winter and summer months. According to PCMC annual report, they responded to 6,413 calls for service in 2022—58% of these calls were for EMS, 40% for fire (primarily residential-, commercial-, and automobile-related fires) and 2% for rescue.

Oversight

PCFD's wildland fire program has traditionally been managed as a collateral duty, with responsibilities shared informally at multiple levels from Chief to Captain, Engineer and Firefighter/Paramedic. Duties have typically been assigned to staff that have experience or passion for this area of expertise. Currently, the public-facing aspects of the program to the community are handled by the Fire Marshall (Chief level), while most internal program details are handled by a station Captain and station Engineer.

Staffing

According to PCFD's 2022 Annual Report (Park City Fire District, 2023), they employ 80 paid firefighters, 24 full-time non-firefighter AEMTs and paramedics, 13 part-time EMTs and 17 administrative support personnel. They maintain minimum staff levels of 23 to 26 firefighters and 8 EMTs. On-duty firefighters are distributed among the Department's seven fire stations. All firefighters with PCFD are required to maintain wildland fire qualifications (hold red cards).

PCFD firefighters interested in wildland firefighting can participate in out-of-area deployments as part of the PCFD wildland "division." This voluntary group is not a formal division, and it consists of 20-30 firefighters and one available type 3 engine for off-district wildland fire assignments. Members of the division have gone on 20 deployments across the U.S. in the past 12 years. Firefighters are not allowed to go on deployments during periods of high fire danger, the 4th of July or when local EMS call volumes are high.

PCFD currently has two National Wildfire Coordinating Group-qualified Engine Bosses and three more firefighters that have almost completed their Engine Boss task books. Various firefighters are working on qualifications such as Firefighter Type 1, Firing Boss and Incident Commander Type 5.

Equipment

PCFD is well equipped with wildland fire apparatuses and personal protective equipment. The Department has:

- One Type 1 engine at each of the seven fire stations with 500 feet of 1 ½" forestry hose and three smokey packs for progressive hose lays with 100 feet of 1 ½" and 100 feet of 1" hose.
- Three Type 3 engines, with an additional Type 3 on the way. One of these engines is dedicated for deployments.
- Two side-by-side UTVs for off-trail rescues.
- One OHV Type 7 pumper engine.
- One Type 1 tactical tender and S2 support tender, each with fold-a-tanks.
- Fifteen BKR500 150mHz radios.

- Wildland fire-specific helmets, Nomex, fire packs and deployment shelters for each firefighter.

Fire hydrants are available in the entire developed area that PCFD is responsible for. In general water pressure is adequate throughout the district with the Colony having the highest pressure, but in older areas of the district the system experiences lower pressure, including parts of Quinn's Junction. Park City Water Division is constantly updating their old infrastructure to increase hydrant pressure, but this is a lengthy and expensive process. Bonanza Estate in Wasatch County is outside of the PCFD, does not have hydrants and most homes are on wells. PCFD works with ski resorts to make sure the Department has access to ponds on ski resorts as draft and/or dip sites.

Training

All new firefighters with PCFD receive basic wildland fire training (S-130/190), and all firefighters take annual refresher training (RT-130) and the arduous work capacity test to maintain current red cards. Annual refresher trainings focus on the following topics:

- Communications and radio use, particularly how to communicate with air resources.
- Shelter deployments.
- Progressive hose lays and calculating hydraulic feasibility of hose lays.
- Pump-and-roll tactics.
- Incident command structure.
- Structure triage.
- Evaluating fire weather and fire behavior.

Stated training objectives centered on communication with air resources and progressive hose lays after experiences with recent wildland fires, including the 2021 Parleys Canyon Fire, where it was too steep to engage the fire with engines. Ordering air resources has become more important to the Department after a myth about the financial burden of air resources was dispelled several years ago.

PCFD also offers several NWCG courses to firefighters including firefighter type 1 (S-131), portable pumps and water use (S-211) and wildland fire chainsaws (S-212). Community partners consisting of agencies and the private sector help teach these courses and offer hands-on experience to PCFD firefighters.

PCFD has conducted joint wildfire training with Utah State Air Operations and North Summit Fire District. They occasionally train with the Unified Fire Authority of Salt Lake County, but these joint exercises are focused on heavy rescue and extractions, not wildland fire.

Mutual Aid

Mutual aid agreements are a tool to help organizations prepare for wildfire events that exceed their capacity. As long as PCFD meets the three criteria for participation in the Utah CWS (Cooperative Wildfire System), PCFD can delegate wildfire authority to the State of Utah when wildfires escape initial attack.

Park City is part of a Multi-Jurisdictional Automatic Aid, Mutual Aid, Fire, Training, Emergency Medical, and Other Services Agreement among 11 municipalities, four fire protection districts and the Unified Fire Authority. This agreement specifies that the first fire department or district to arrive on-scene to a wildfire will assume Incident Command and retain such command until relieved by an appropriate officer of the fire department or district within whose jurisdiction the situation is located. PCFD often delegates authority for local wildfire incidents to the Summit County Fire Warden as soon as possible during initial attack.

PCFD does not have formal mutual aid agreements with surrounding agencies that the project team was made aware of. Our team was particularly interested in wildland-urban-interface areas adjacent to the district/county boundaries with Wasatch County Fire to identify the closest resource response to places like Bonanza Flat or areas around Deer Valley. PCFD does have some informal standard operating agreements with Wasatch County and Unified Fire Authority for specific incident response.

MUTUAL AID AGREEMENT

A written or oral agreement between and among agencies, organizations and/or jurisdictions that provides a mechanism to quickly obtain assistance in the form of personnel, equipment, materials, and other associated services. The primary objective is to facilitate the rapid, short-term deployment of support prior to, during, and/or after an incident (NWCG Glossary of Wildland Fire, PMS 205).

Finances

About three-fourths of PCFD's annual revenue in 2022 came from property taxes. The Department received an additional 1% of their revenue from grants and donations. PCFD also receives reimbursement for personnel, equipment, fleet vehicles and supplies when responding to wildland fires outside their jurisdictional area under the Utah Statewide Operating Plan. The policy for reimbursement of interagency fire resources (personnel, equipment, fleet vehicles and supplies) is outlined in Section 5 of the Utah Statewide Operating Plan.

Park City's annual participant contribution to the Utah CWS is currently around $10,000, and Summit County's annual contribution is $80,000. These contributions are likely to decrease in the coming years when two larger, older fires (2018 Tollgate Fire and 2013 Rockport Fire) are dropped from the calculation of average historic fire cost. PCFD meets their CWS participant contribution through their chipping and community education programs (see Proactive Management below).

Preplans

Pre-Attack Plans

Preplanning is an essential activity to prepare local, state and federal agencies for wildland fires, particularly complex wildfires in the wildland urban interface. Preplans can go by various names, including pre-attack plans, pre-planned dispatch, structure protection plans and annual operating pictures. Community Wildfire Preparedness Plans are also a form of preplanning, although their function and content are usually substantially different from pre-attack plans.

In 2008, PCFD prepared Wildland/Urban Interface Quick Access Preplans for eight communities in the district (Bear Hollow, Colony, Daly Canyon, Iron Canyon, Ontario to Empire Canyons, Red Hawk, Swanner, and Upper Deer Valley). Preplans include general descriptions of hazards, tactical objectives, structure fire protection analyses and water systems (Item 1). These preplans include geographic coordinates for features such as dip and draft sites and safety zones, but they do not include maps. Goals and tactics in the preplans are fairly general, for example, a strategic goal in the 2008 pre plan for Daly Canyon is to "contain fire to a specific geographic area or redirect fire away from populated areas."

A representative from PCFD participates in annual hazard mitigation meetings to prepare Pre-Disaster Mitigation Plans for Summit, Utah, and Wasatch counties. The Fire Marshall with PCFD is also a member of the Emergency Management Group that helps prepare PCMC's Comprehensive Emergency Management Plans (CEMPs). However, the 2020 Park City CEMP has very little information on wildfire response.

Evacuation Planning

The Park City Emergency Manager is responsible for planning and coordinating evacuations during wildfires in PCFD per Utah State Code 53-2a-2-205 (effective 05/04/2022), and the Chief of Police or County Sheriff, depending on jurisdiction, is in charge of ordering and enforcing evacuation orders per PCMC's CEMP. PCFD is only peripherally involved in evacuation planning and operations; PCFD is not assigned official roles for evacuations in the Department's Operational Plan or in PCMC's CEMP. Employees of PCFD participated in a mock evacuation scenario in 2022 in Upper Deer Valley, and the Department conducts community outreach events to encourage all residents to have a home evacuation plan and family communication plan for emergency situations.

Item 1. Content from PCFD's 2008 Wildland/Urban Interface Quick Access Preplans

1. General overview:
    - Description of the subdivision.
    - Units / stations available to respond.
    - Description of water supply availability (hydrants, tenders, tanks in engines and draft options).
    - General fire behavior predictions.
    - List of strategies (e.g., offensive attack, defensive attack, stabilization, property conservation).
    - List of anticipated problems (e.g., evacuation, numerous structures involved, inadequate resources).
    - List of hazards to personnel (e.g., overhead power lines, congested escape routes).

2. Command and control:
    - Attack mode (e.g., offensive, defensive, combination).
    - Strategic goals (e.g., ensure life safety, contain fire to specific geographic areas, protect structures).
    - Tactical objectives (e.g., evacuate or shelter residents, manage utilities, place necessary hose lines, establish control lines).
    - Special concerns (e.g., road access issues, community assets).
    - Location of potential geographic divisions.
    - Alarm response levels.

- Location of potential staging locations.
- Location of potential command posts.

3. Structural fire protection analysis:
    - Site assessment, including general description of number of homes in four different response categories (no protection required, little effort required, maximum effort required, and non-defensible structure), and the locations of the most concerning structures.
    - Firefighter safety, including that location of potential safety zones.
    - General description of fuel conditions.
    - Primary routes for evacuations, with the specification that Park City Police Department will handle evacuations.
    - The proper entity to contact to coordinate turning on and off utilities.

4. Water system:
    - Threads, operating pressures, and outlet sizes for hydrants.
    - Capacity and locations of water tanks.
    - Locations of ponds, creeks, and other natural water sources.

Community Wildfire Preparedness Plans

Community Wildfire Preparedness Plans (CWPPs) empower communities to organize, plan and act on wildfire issues that impact community safety. Preparing and updating CWPPs are requirements for participation in the Utah CWS, and participating entities such as PCFD must assist with CWPP creation. The update period for CWPP's are not specified by the State. Using the State of Utah CWPP Template, PCFD helped create the 2013 Park City Fire District CWPP, and PCFD was on the planning committee for the 2021 PCMC CWPP. These CWPPs included priority action items for PCFD (Table 4-1 and 4-2).

Since completing the 2013 PCFD CWPP, the district has encouraged local entities to complete their own CWPPs that are specific to local needs with no stated plans to update the PCFD's CWPP. PCFD has provided guidance to the following HOAs in PCMC and unincorporated communities outside of PCMC as they produce their own CWPPs: The Colony, Jeremy Ranch, Moose Hollow, Silver Springs, Pinebrook, Summit County Special Service District #3, Stagecoach, Promontory, Sun Peak, Glenwild and American Flag. PCFD has limited capacity to be deeply involved in CWPP preparation.

Table 4–1. Tasks assigned to PCFD as part of the 2013 Park City Fire District CWPP to assist with wildfire prevention, preparedness and mitigation.

CWPP GOAL/TASK	COMMUNITY LEAD	TIMELINE	PRIORITY
Goal A. Community will decrease fuels within the community to reduce wildfire impact in and around the community.			
Work with resorts, DR, PCMR nd Canyons to reduce fuels	PCFD, Resorts, FFSL, PCMC, Summit County	Ongoing	High
Increase the number of homes & HOAs with defensible space	PCFD, FFSL, PCMC, Summit County	Ongoing	High
Investigate additional chipping options for the entire CWPP area potentially with state resources	PCFD, Summit County, PCMC, Resorts, FFSL	Ongoing	Medium
Educate the landscaping contractor community in Firewise landscaping & defensible space	PCFD, Summit County, PCMC, FFSL	Ongoing	Medium
Goal C. Community will evaluate, upgrade, and maintain community wildfire preparation and response facilities and equipment			
Firefighting helicopter with bucket	PCFD, Summit County	Spring 2014	Medium
New fire station at Quinn's Junction and at Summit Park	PCFD	Spring 2014	Medium
Two Type 3 fire engines and two 3,500-gallon water tenders	PCFD	Fall 2013	High
Goal D. Community will develop and implement a comprehensive emergency response plan.			
Identify evacuation routes with signage	PCFD, PCMC, HOAs	Fall 2013	High
Communicate fire evacuation plans to residents	PCFD, PCMC	Fall 2013	Medium
Finish community fire plan and pre-attack plans	PCFD, PCMC, Summit County	December 2012	High
Goal E. Community will actively address identified regulatory issues impacting community wildfire prevention and response needs.			
Educate HOA groups to post fire-regulation signs at the entrance of each HOA community	PCFD, HOAs	Summer 2013	Medium
Develop model WUI code for new structures	PCFD, Building Officials, PCMC and Summit County Planning Depts	Spring 2014	Medium
Goal F. Community education about wildfire risk, preparation and response			
Promote awareness that Park City is within the wildland urban interface and at high risk for wildfire	PCFD, PCMC, Summit County	May-October annually	High
Have Firewise Utah booth at community events (e.g., Silly Market, Wednesday concerts at Deer Valley, 4th of July, Miners Day)	PCFD, FFSL	May-October annually	Medium
Encourage additional communities to become Firewise/develop CWPPs and acknowledge those that complete this work	PCFD, FFSL	2013-2015	Medium
Maintain and expand the chipper program as able to reduce fuel load	PCFD, FFSL	2013-2014	High
Model fire hazards throughout PCFD (sandbox exercises)	PCFD, PCMC, Summit County	November 2013	High

Table 4-2. Tasks assigned to PCFD as part of the 2021 PCMC CWPP to assist with wildfire prevention, preparedness, and mitigation.

CWPP Goal/Subgoal/Task	Community Lead	Timeline	Priority
Goal A. Prevention			
Expand chipper program	PCFD	2019-2022	1st
Goal B. Preparedness			
Goal B.1. Evaluate, upgrade and maintain community wildfire preparation			
Increase response agency depth	PCFD, County	Ongoing	1st
Lot assessments – PSA to help homeowners do their own	PCFD	Ongoing	3rd
Goal B.2. Educate community members to prepare for and respond to wildfire			
Preparedness fairs and public meetings	City, PCFD, EM	2019-2025	2nd
Goal B.4. Evaluate response personnel, facilities and equipment			
Personnel, training and qualiifications	PCFD	Ongoing	1st
Equipment requirements and maintenance	PCFD	Ongoing	1st
Facilities evaluations and improvements	PCFD	Ongoing	1st
Local IMT / Response Type – Type III incidents	PCFD	Ongoing	2nd
Goal C. Mitigation			
Goal C.1. Decrease fuels within the community to reduce wildfire impact in and around the community.			
Chipper program (FEMA grant)	PCFD, Summit County	2020-2022	1st

Proactive Management

Fuel mitigation

Fuel treatments are a land management tool for reducing wildfire hazard by decreasing the amount and altering the distribution of wildland fuels. Managing slash produced from fuel treatments and mitigation in the home ignition zone is vital to reducing wildfire risk. PCFD operates a chipping program with a three-person seasonal crew, one chipper and one heavy truck to haul chips between mid-April and mid-August or September. PCFD annual reports show that PCFD processed 1,225 piles in 2022, 887 piles in 2021 and 1,300 piles in 2020. Usage of the program tends to be concentrated in the Summit Park/Pinebrook and Jeremy Ranch area. In 2021 and 2022, PCFD participated in a grant program with FFSL in Summit Park to chip and remove woody material to reduce wildfire fuel load. Currently PCFD disposes of chips by giving them to large local landowners, landscaping companies and private residents. PCFD stated that the limited local options to get rid of woodchips is the biggest threat to maintaining the chipping program.

Beyond the seasonal chipping crew, PCFD does not have the capacity to support fuels mitigation projects on private or city-owned land. PCFD previously scoped establishing a 5-person hand crew to support local wildfire response and out of area deployments. However, the startup cost was deemed too high for their current budget, with the PCFD's priority being local emergency response to their service area.

Community engagement and outreach

Local fire departments can play a particularly effective and central role in engaging citizens and facilitating community risk reduction efforts. PCFD engages in community outreach around wildfire and home fire prevention, emergency medical response and general wildfire awareness. In 2020, PCFD reported engaging in eight presentations on wildfire awareness, six group home assessments with an average of 10 residents per group and 14 meetings to work on CWPPs and FireWise status with HOAs. One of PCFD's fire inspectors developed a video series to educate homeowners on home hardening and defensible space. There are six FireWise communities in the PCFD response area: Pinebrook, Sun Peak, The Colony, Summit Park, Stagecoach Estates and Promontory.

PCFD also operates a voluntary wildland structure inspection program. Formerly a full-time seasonal employee visited homes to evaluate the property and home construction using Firewise standards and recommend improvements to homeowners so they could better protect their home in the event of a wildfire. This program was only in existence in 2020 when PCFD conducted 124 inspections. The reason for terminating the program was stated to be that PCFD felt it wasn't utilized by the community; however, the COVID-19 pandemic may have played a role in the lack of participation. PCFD will continue to do home inspections on an as-available basis but does not have additional staffing to meet the potential demand. PCFD has expressed plans for hosting a NFPA-equivalent Structure Assessment training in 2023 for district employees and interested public to assist with local-level structure inspections as they relate to wildfire risk.

Recommendations and Conclusion

PCFD has laid the foundation for an effective wildfire response capacity, and additional adjustments could enhance the district's ability to keep the community safe from wildfire. The 2021 Parleys Canyon Fire demonstrated the important role of PCFD in rapid initial attack, and the Utah CWS requires participating entities and associated fire departments to make the best possible initial attack (IA) to control and contain wildland fires in this early phase. This assessment can help support PCFD's fulfillment of tasks assigned to the Department in the 2021 PCMC CWPP (Goal B.4. Evaluate response personnel, facilities, and equipment).

We developed general recommendations for PCFD based on our team's wildfire suppression experience, industry norms, lessons learned from other small- to medium-sized fire districts in the western U.S., recommendations and tasks in local, regional and national strategic plans (Cohesive Strategy, 2013 Western Regional Action Plan, 2013 Utah Catastrophic Wildfire Reduction Strategy, 2021 PCMC CWPP, and 2013 PCFD CWPP) and best practices from NFPA's 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report (Haynes & Madsen, 2017; Table 4-3). We recognize that many of these tasks require time, resources and leadership commitment to enact, and PCFD would need to assess the relative importance for feasibility of these tasks. Fortunately, there are several funding sources available to fire departments to enhance their ability to provide fire protection and wildfire response (Item 2).

Out of a broader list of recommendations (Table 4-3), our team chose five items to highlight and prioritize for consideration. Some of these actions are relatively bite sized and efforts could be started internally without big changes to budgeting or other constraints.

Top recommendations for PCFD:

- Formalize the internal wildland fire program with dedicated and consistent oversight and restructuring.
- Provide additional opportunities for staff to gain wildland fire experience and qualifications.
- Increase resources and availability to support area residents in wildfire risk mitigation, education and activities.
- Update and expand formal fire management plans.

- Reevaluate the potential to support a seasonal wildfire and fuels mitigation crew.

According to the NWCG, "In a perfect situation, all [wildland-urban] interface areas should be pre-planned to provide an overview of the possible actions, hazards, resources, etc., that are beneficial during an incident. These plans should be jointly prepared by all agencies potentially involved" (National Wildfire Coordinating Group, 2013). The 2nd Edition of the Wildland Urban Interface Chief's Guide states, "Similar to pre-planning for high-occupancy or high-hazard structures in your jurisdiction, response agencies should pre-plan wildland and wildland–urban interface areas as well" (Wildland Fire Policy Committee, 2021). The 2013 Western Regional Action Plan emphasized the importance of developing local unified visions pre-season through annual operating plans that involve all affected agencies and stakeholders (Goal 3.2, Action 3.2.a, Task 8).

The goal of safe, effective and risk-based wildfire response is paramount and critical along with the goals of creating Fire Adapted Communities and managing for resilient landscapes when considering this section of the PCMC Community Wildfire Risk Assessment. All three of these goals must come together to achieve success in managing future wildfires in the Park City area. The 2021 Parleys Canyon Fire and its potential adverse impacts to the greater Park City area is a testament to why suppression response is important if we desire to live in fire-dependent ecosystems.

Before the next large-scale wildfire, it is important to increase experience and enhance qualifications, while looking at potential voids in critical resources and conducting pre-fire planning to create successful outcomes. Such efforts depend upon not just the PCFD but all involved interagency cooperators to enable Park City as a whole to be resilient as a community and ecologically before the next wildfire threat. These efforts have the potential to not only reduce the risk to homes, critical infrastructure and other highly valued resources and assets but also to reduce the risk to human life and the community of Park City that many enjoy.

Table 4-3. Recommendations to enhance PCFD's wildfire response capacity. BP = best practices from the NFPA 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report (Haynes & Madsen, 2017).

Recommendation	Rationale	Alignment with Other Strategies
Competing Demands		
Make a department-wide commitment to enhanced wildland fire response through a formal statement demonstrating support for employee participation in wildfire assignments.	PCFD has elevated wildfire risk, and wildfires can easily transition into urban conflagration with rapid home-to-home fire spread. Other mutual aid resources, including the County Fire Warden, might be unavailable for several hours during initial attacks, particularly when there are multiple ignitions or ongoing incidents at the same time. Increasing department capacity to respond to wildfires will make residents in this community safer.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2021 PCMC CWPP: Goal B.1 (see Table 2).
Program Oversight		
Formalize and invest in a Wildland Fire Division with a dedicated wildland fire coordinator to manage all aspects. Structure the roles and responsibilities of additional leaders and participants to meet the needs of the program.	Management of the District wildland program has historically fallen on staff as a collateral duty, with responsibilities shared informally at multiple levels from Chief, Captain, Engineer, and Firefighter/Paramedic. Providing consistent and dedicated oversight, along with programmatic restructuring, would serve to increase clarity, enhance participation, and meet growing needs with higher levels of effectiveness.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2021 PCMC CWPP: Goal B.1 /B.4 (see Table 4-2). 2013 PCFD CWPP: In support of achieving all listed goals.
Staffing and Training		
Develop a depth and breadth of wildfire and prescribed fire qualifications and experience within PCFD by actively supporting off district and out-of-area deployments. Emphasize the importance of mid-level qualifications such as FFT1, engine boss, strike team and task force leader, and incident commander, to increase depth of critical	The best way to quickly develop wildfire experience is to support out-of-area deployments. Knowledge gained from deployments can help PCFD be even more effective with local initial and extended attacks. While PCFD requires all firefighters to hold Wildland Firefighter 2 (FFT2) qualifications, there are minimal qualifications within the district beyond this level or above. Thus, PCFD has built	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2021 PCMC CWPP: Goal B.1 (see Table 4-2).

leadership on incidents expanding beyond initial attack.	a normal where assistance from the outside is assumed beyond a low complexity initial attack wildfire. In the spirit of Interagency cooperation, making resources available to the interagency community supports the concept of shared resources and making a contribution for when PCFD will again need resources from outside of the district.	
Re-evaluate the potential to establish a 5-person seasonal crew to participate in fuel mitigation projects and wildfire assignments. Train and equip crew to respond to fires in limited access areas throughout the district that require hiking in with potential for limited support. PCFD previously determined such a crew would be cost-prohibitive, but this cost might be offset with grant funding and reimbursements from fire assignments (see recommendations on finances below).	A seasonal crew dedicated to fuel mitigation and wildfire assignments could rapidly expand PCFD's experience and response capacity. Small- to medium-sized fire departments throughout the west have seasonal wildland fire crews, such as Unified Fire Authority and Utah County in Utah, Boulder Mountain Fire, Lefthand Canyon, and Elk Creek Fire Protection Districts in Colorado, and have realized improvements in their department's capacity to respond to wildfire and to mitigate fuels in the community.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Resilient landscapes, fire adapted communities, and safe, effective, risk-based wildfire response. 2013 PCFD CWPP: Goal A (see Table 4-1). 2021 PCMC CWPP: Goal B.1 and Goal B.4 (see Table 4-2). NFPA 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report: Risk reduction activities BP 4.
Hire additional non-firefighter paramedics.	Hiring additional non-firefighter paramedics could help PCFD fulfill local EMS responsibilities when firefighters are on assignment.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2021 PCMC CWPP: Goal B.1 and Goal B.4 (see Table 4-2).
Utilize Recognition of Prior Learning (RPL) and prioritize out-of-area deployments for firefighters seeking to enhance their wildland fire qualification, especially when considering the position of Engine Boss (ENGB).	PCFD's capacity to participate in out-of-area deployments will be greatly enhanced by increasing the number of qualified Engine Bosses.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2021 PCMC CWPP: Goal B.1 and Goal B.4 (see Table 4-2).
Encourage firefighters to gain air-resource experience or open related task books (e.g. Helicopter Crewmember) and participate in a helitack assignment.	Air resources are crucial for addressing wildfires near the WUI, particularly around PCFD where engines cannot access remote and steep areas.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response.

	Additional experience communicating with aircraft could greatly benefit PCFD.	2021 PCMC CWPP: Goal B.1 and Goal B.4 (see Table 4-2).
Participate in annual wildfire-related training with adjacent fire protection districts and mutual aid partners.	Relationships built during interagency training can help local agencies coordinate more effectively during local incidents.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response.
Equipment		
Purchase large pumpkins as alternative water sources for portable pumps and dip sites for helicopters.	Parts of PCFD have hydrants with low water pressure, and bucket drops can be challenging if interstates need to be shut down. Portable water sources are important for nimble wildfire suppression operations.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response.
Finances		
Actively pursue reimbursements for out-of-area deployments.	Off-district assignments have potential to generate revenue for the PCFD. Fire departments should never lose money on deployments, and they can make money due to high reimbursement rates for engines and equipment.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response.
Write grants to support a 5-person seasonal fuel crew and other mitigation activities.	Several grants are available for fire departments to improve their ability to safety and effectively provide fire protection. See Item 2 for a list of available grants.	NFPA 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report: Risk reduction activities BP 6.
Work with PCMC and Summit County through the Administrative Control Board to explore the option of a mill levy on the local ballot to expand PCFD's budget for wildfire response.	Similar measures have been passed in other fire districts, Sunshine Fire Protection District Co and Boulder County Co, to support wildfire mitigation and emergency response.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response.
Preplans		
Update and expand preplans from 2008 to cover all areas in PCFD and prepare a plan for responding to wildfires of different sizes. Revised plans should include additional details, including maps, communication plans, and medical plans.	High-quality preplans can help fire departments respond rapidly to initial attacks and share important local information with incoming resources (e.g., maps with the location of values at risk, local hazards, evacuation routes, and water sources). Preplans are also an opportunity for PCFD to identify strengths and weaknesses in the Department's ability to respond to wildfires.	The 2013 Western Regional Action Plan: Goal 3.2, Action 3.2.a, Task 8, 10, and 11. Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2013 PCFD CWPP: Goal D (see Table 4-1).

		NFPA 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report: Strategies and tactics BP 5, 7, and 8.
Formalize alert levels for wildfire response	Preplans from 2008 include alert levels, and a reevaluation and formalization of these levels could help PCFD be prepared to rapidly mobilize as wildfires grow in size and complexity.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response.
Participate actively in evacuation planning for PCMC.	PCFD is not responsible for implementing evacuations, but a solid understanding of evacuation plans and protocols can help PCFD coordinate with law enforcement during wildfires. PCFD has valuable insights about access needs for emergency vehicles. During wildfires, PCFD can also help assess the safety of law enforcement officers and residents during evacuations and re-entry after.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Safe, effective, risk-based wildfire response. 2013 PCFD CWPP: Goal D (see Table 1).
Update the 2013 PCFD CWPP to align with recent CWPPs for PCMC and other communities. Update goals to reflect the current direction of PCFD.	Wildfire risk, response capacity, and strategic goals for PCFD have changed since 2013. While PCFD has worked with PCMC and individual HOAs to develop site specific CWPPs, an updated and overarching district CWPP is important to serve as foundation and document to tier from for more localized CWPPs. The 2013 CWPP does not incorporate findings from the recently updated Utah Wildfire Risk Assessment Portal or the PCMC CWRA that this report is part of, nor does it include lessons learned from recent wildfires, such as the 2021 Parleys Canyon Fire. It is important to assess progress and reevaluate goals from the 2013 CWPP. Some funding sources require CWPPs that are less than 10 years old, and updated CWPPs are also required for participation in the Utah CWS.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Fire adapted communities. NFPA 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report: Risk reduction activities BP 3.
Proactive Management		
Re-evaluate the potential to establish a 5-person seasonal crew to participate in fuel mitigation projects and wildfire assignments.	See explanation above under recommendations for staffing.	See strategic alignment under recommendations for staffing.
Continue funding and supporting the PCFD chipping program. Consider expanding the	The PCFD chipper program is highly valuable to the community and helps residents dispose of fuel around their homes. PCFD does an annual	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Fire adapted communities.

program if the local market and community needs change in the future.	SWOT analysis of the program and will be able to determine if this situation changes.	2013 PCFD CWPP: Goal A and Goal F (see Table 4-1). 2021 PCMC CWPP: Goal A and Goal C.1 (see Table 4-2).
Enhance the ability of PCFD in providing voluntary wildfire mitigation property and structure inspections. Advertise and promote these inspections widely across the community through HOAs and other groups.	Residents are often confused about what they need to do to mitigate hazards in the home ignition zone, and one-on-one consultations can help residents understand and prioritize actions to mitigate risk. Previous efforts occurred at the height of Covid-19 and could have impacted interest. PCFD plans on sponsoring a NFPA equivalent Wildland Fire Structure Assessment training in 2023 for staff and the public.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Fire adapted communities. 2013 PCFD CWPP: Goal A and Goal F (see Table 4-1). 2021 PCMC CWPP: Goal B.1 (see Table 4-2). NFPA 2017 Fire Department Wildfire Preparedness and Readiness Capabilities report: Risk reduction activities BP 7 and 8.
Evaluate existing fire codes and consider updating to incorporate WUI codes from IFC and NFPA.	Increase firefighter and resident safety and further develop a response environment that is proactively supportive of suppression response.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Fire adapted communities. 2013 PCFD CWPP: Goal E (see Table 4-1).
Ensure availability of department resources to the general public to provide direction and answer questions relating to wildfire risk, WUI issues, home hardening, etc.	Through the PCMC CWRA process the public's acknowledgement of PCFD's role in wildland fire management was recognized. In the Community Survey, the PCFD was acknowledged by a number of respondents for being a trusted source of wildfire information.	Cohesive Strategy and 2013 Utah Catastrophic Wildfire Reduction Strategy: Fire adapted communities. 2013 PCFD CWPP: Goal A and Goal F (see Table 4-1). 2021 PCMC CWPP: Goal B.2 (see Table 4-2).

Item 2. Funding opportunities for fire departments to expand their wildfire response capacity.

- **Assistance to Firefighters Grants (AFG)** help firefighters and other first responders obtain critical resources necessary for protecting the public and emergency personnel from fire and related hazards. (https://www.fema.gov/grants/preparedness/firefighters)
- **Fire Prevention & Safety (FP&S) Grants** support projects that enhance the safety of the public and firefighters from fire and related hazards. (https://www.fema.gov/grants/preparedness/firefighters/safety-awards)
- **Staffing for Adequate Fire and Emergency Response (SAFER)** grants directly fund fire departments and volunteer firefighter organizations to help increase their capacity. (https://www.fema.gov/grants/preparedness/firefighters/safer)
- **Community Wildfire Defense Grants (CWDG)** are funded annually through the US Forest Service and help communities create and update CWPPs while also implementing projects outlined in recent CWPPs. (https://www.fs.usda.gov/managing-land/fire/grants)
- **Utah Fire Department Assistance Grant Program** provides technical and financial assistance to the fire departments of Utah to improve their ability to safely and effectively provide fire protection and manage hazardous material incidents. (https://ffsl.utah.gov/fire/fire-grants/)

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5.0 Wildfire Risk Assessment

In This Chapter

5.1 Quantitative Wildfire Risk Process

Executive Summary

The purpose of the Park City Municipal Corporation's (PCMC) Quantitative Wildfire Risk Assessment (QWRA) is to provide information about wildfire hazard and risk to Highly Valued Resources and Assets (HVRAs) around Park City. HVRAs are simply the things that people care about. These can be critical services the community relies upon (e.g. electrical grid, water supply, etc.) or the surrounding natural areas such as forests and streams. A wildfire risk assessment is a quantitative analysis of how HVRAs are potentially impacted by wildfire.

The PCMC QWRA has been completed to inform local land managers and community stakeholders in wildland fire and fuels management and risk analysis within the PCMC Project Area. Our team of experts adopted this science-based strategy for PCMC highlighting areas with the highest probability of reducing wildfire risk based on fuel treatments.

Wildfire risk assessments are not in and of themselves decision-making tools (Calkin et al., 2011; Scott et al., 2013). Assessing wildfire risk under existing conditions provides baseline information on how risk is distributed across the assessment area and which HVRAs face the greatest expected loss (or benefit) from wildfire. This information may be used in the planning, prioritization and implementation of wildfire prevention, preparedness and risk mitigation strategies (Helmbrecht et al., 2019) for Park City.

The PCMC QWRA was a multi-phased process that used the Interagency Fuels Treatment Decision Support System (IFTDSS) as a platform. Integral datasets were derived by evaluating local fire and weather history and executing numerous wildfire simulations to establish baseline Fuel and Fire Behavior Models (datasets). Through community participation, particularly with local stakeholders and subject matter experts, a list of the most highly-valued resources and assets was developed for the Park City Project Area. These resources and assets included categories such as Critical Infrastructure, Recreational Infrastructure, Wildlife Habitat, among others. The final output of the QWRA process establishes an "Expected Weighted Net Value Change " which quantifies how the presence of wildfire may affect the resources and assets that the community values most, either in a positive or negative way. The data and corresponding maps provide a clear visual representation of where wildfire presents the highest threat, or may provide benefit - areas where forest restoration and/or fuels reduction projects may be most influential in reducing fire risk.

Background

Why does Park City need a Wildfire Risk Assessment?

Park City is at risk of severe consequences from wildfire based on its mountainous location surrounded by various ecosystems that are dependent upon fire. Due to a variety of risk factors, it has been found that Park City's probability of wildfire is greater than 91% of communities in the nation (USDA et al. 2023).

Figure 5-0-1. Park City is surrounded by a variety of ecosystems.

The CWRA project area is included within the Wasatch-Cache-Uinta National Forest's Fireshed. Firesheds are areas to plan for the management of fire and identify needed treatment zones. Out of ten priority firesheds in the region of Nevada, Utah, Idaho and Wyoming, this region ranked fourth in priority for mitigating fire risk to nearby communities (Ager et al. 2021).

Many people may not realize the risk of fire to their homes and communities. This is especially true if fires are infrequent or small and of short duration. In the case of Park City, there is a limited record of recent and historical large wildfires within the landscape area. In some ways it represents a fire shadow, similar to a rain shadow. The majority of wildfires that occur are human caused and easily accessible to fire personnel. Natural ignitions from dry thunderstorms are possible in the area, but most storms developing along the Wasatch Mountains bring precipitation. These precipitation events help to suppress ignitions or limit the size and extent of wildfires.

In the absence of live fire, modeling fire behavior and its effects to HVRAs is necessary to understand the potential risks. There are limitations of fire behavior models and some interpretation is necessary. A team of fire and natural resource professionals developed a science-based strategy that builds upon shared responsibility, strengths, and place-based relationships in alignment with the National Cohesive Wildland Fire Management Strategy.

Using the Utah Fire Viewer and Interagency Utah Fire History Points, 52 fires dating back to 1992 were found within the analysis area. There have likely been more fires as the dataset is incomplete. Most fires were reported at zero acres and the largest, the 2000 Ability Center Fire, at 25 acres. While relatively small in size at 541 acres and outside of the PCMC CWRA project area, the impacts of the Parleys Canyon Fire were far-reaching. The fire started under prolonged and exceptional drought conditions. Suppression costs exceeded $3 million ($4,600 per acre) and resulted in the evacuation of 8,000 residents. Since 1992, eight notable fires located outside of the immediate vicinity of Park City are captured on the following table (Table 5-1).

Table 5-1. Notable fires outside of the immediate vicinity of Park City.

YEAR	FIRE NAME	SIZE (ACRES)	NOTES
2022	Flat Line Fire	25	May fire in Gambel oak near Jordanelle Reservoir
2021	Parleys Canyon Fire	541	8,000 evacuated and over $3 million in costs
2020	Saddle Fire	630	Located near Midway; caused by a juvenile
2018	Tollgate Fire	287	Caused by a vehicle
2014	Rockport Estates Fire	120	200 homes evacuated
2013	Rockport Fire	5,000	Caused by lightning with eight structures burned
2012	Fox Bay Fire	500	Located near Jordanelle Reservoir in Wasatch County
1990	Wasatch Mountain Fire	2,962	Located near Midway. Resulted in two fatalities and 20 structures burned.

Forest Health and Disturbance

A combination of successful fire suppression over the past century resulted in forest health issues seen today caused by past timber harvest, grazing and mining practices (Hessburg et al., 2015). Though tree mortality from insects, disease, fire and weather-related events are natural processes that help forests change over time (Campbell and Leigel, 1996), these disturbances have greatly changed over the past few decades. Additionally, climate change and the rise of invasive plant species detrimentally affect forest health and contribute to hotter, more intense fires (Keyes et al., 2019; Coates et al., 2016). The results are increasing sizes of wildfires, longer durations of burning and more destruction to communities and natural ecosystems (USDA, 2022; Hessburg et al., 2015).

Figure 5-0-2. Forests around Park City are experiencing forest health issues.

In some areas, the forests around Park City are experiencing significant forest health issues. These issues are typically caused by dense forest conditions, insect infestations, sudden aspen decline, lack of rejuvenating fire, and invasive species. Insect infestations were the most recent cause of significant tree mortality, but drought, disease, and other disturbances all contribute.

The challenges and issues facing forests also affect the safety of nearby communities and peoples' experiences with the forest. Dead standing trees are highly visible on the slopes around the community, especially in Daly Canyon and across the Park City Mountain Zone. In time, these trees will fall and increase the fuel loading on the ground. This adds to the existing concentrations of down logs and tree branch material that are not quickly decomposing due to the aridity of this area. This down woody material can remain on the ground for decades. It will not quickly go away on its own without fire or human intervention.

Unfortunately, allowing natural fires to burn is not possible here. This leads to an increase in fuel loading and increases the likelihood that fires will burn hotter and more intense. While mortality is a natural life cycle of forests and provides wildlife habitat and nutrient cycling, much of it can be detrimental. It can negatively impact recreation, certain types of wildlife habitat (e.g. the loss of large, green trees for species that need dense cover), and make the control of fires very difficult or dangerous, among others.

Excessive density -- Both conifer (evergreen) and deciduous (broad-leaf) forests are experiencing stress from high density conditions, drought or lack of natural, healthy disturbance regimes.

Insect infestations -- In the mixed conifer forests, both the native fir engraver beetle (*Scolytus ventralis*) and the recent arrival of the non-native balsam woolly adelgid (*Adelges piceae*) have caused significant tree damage and mortality around this area (USDA Forest Health and Protection, 2022).

Sudden aspen decline -- Many aspen stands are stressed from climate change and recurring drought, past management practices, and fire suppression (Rogers, 2017). Normally one of the more fire-resistant forest types, the increase in conifers around aspen can change how fire interacts with them. This means that aspen forests, thought to be natural fuel breaks, may not act as such during a fire.

Lack of rejuvenating fire -- Gambel oak is another species that has evolved with fire. It sprouts vigorously following mixed-severity fires and maintains dominance for decades to a century following fire. However, as Gambel oak ages shoot mortality increases, and along with seasonal impacts like spring frost kill can add to fuel loading. This may lead to increased probability of ignition, fire spread and higher burn severity (Kaufman et al., 2016).

Invasion by exotic species – Sagebrush and grasslands are experiencing the invasion of the exotic cheatgrass (*Bromus tectorum*), an annual grass. Cheatgrass cures quickly and is available to burn earlier in the summer, often creating a highly flammable fuel bed of continuous light flashy fuels. This is quickly changing the fire behavior in the sagebrush ecosystems to more frequent, higher intensity burns (UoW / CSU 2013).

Like many other places, Park City may not have a long and storied history of frequent and large fires. However, in recent years the increasing number of fires is putting stressed forests, sagebrush and grasslands at risk for higher intensity fire events. In turn, this threatens homes, businesses and the highly valued resources and assets of the area.

Risk Overview

Unplanned wildland fires can result in significant, long-lasting impacts to ecological, social and economic systems. Therefore, it is necessary to identify and quantify the risk wildfire poses to those systems, in order to develop cost-effective mitigation strategies (Scott, 2013). Conducting a Wildfire Risk Assessment involves analyzing the three key components that make up wildfire risk:

Likelihood - Through analyzing the landscape of the project area, the history of predominant weather patterns and randomized possible ignition points of wildfires, assessing how likely a wildfire is to occur at any given point can be calculated.

Intensity - By analyzing the vegetation across the project area, and using science-based research of how fire tends to behave in the present vegetation types, the varying intensity across the landscape at individual points can be measured.

Susceptibility - Determining susceptibility is done by investigating what the community cares about, in terms of geographic features within the project area. Once identified, quantifying the value of those features comparatively, and the impacts wildfire would have on them allows susceptibility to be measured.

Figure 5-0-3. The three components analyzed in a wildfire risk assessment.

What is a QWRA?

Quantitative wildfire risk assessments (QWRA) are specialized risk analyses that quantify where fire is most likely to occur, the intensity at which they burn and how they may impact valuable assets and resources within a region or a community. QWRAs are also designed to provide land managers, fire personnel and other emergency responders the information they need to make risk-informed decisions. These include how to most effectively address wildfire risk, aid in emergency preparedness planning and guide forest restoration and fuel treatment priorities (Scott et al., 2013).

These values in the QWRA process are called ‘highly valued resources and assets (HVRAs) and are, in the simplest terms, the things that people care about. These can be critical services that the residents and business owners rely upon (e.g., electrical grid, water supply, etc.) or the surrounding natural areas like forests and streams. Not all HVRAs are threatened by fire, some may actually benefit, for example, certain types of fire-adapted ecosystems (i.e., aspen forests). While most wildfires are often more threatening than beneficial, there are places in a landscape where fire is helpful. Information about the difference between threat and benefit will help land managers target the areas with the highest need for fuel treatments or fire suppression response strategies. This will have far-reaching effects for emergency response planning, fuels reduction, forest restoration project planning and post-fire rehabilitation projects.

Key Findings

Key findings under this analysis pertain to:

1. Fire Behavior Modeling
2. Highly Valued Resources and Assets
3. Exposure Analysis
4. Relative Importance
5. Response Function
6. Risk Assessment

Each of the steps listed above produce datasets that provide value to land managers and emergency response personnel, while also creating data in sequence as part of the overall QWRA analysis. Key findings from each step are described through the following section and will culminate in a final Risk Assessment output to be incorporated into the overall CWRA.

Fire Behavior Modeling

Baseline fire behavior modeling is the first step to the QWRA. This was accomplished using the Landfire data and IFTDSS, along with both expert and local knowledge to refine datasets and modeling processes to more accurately depict existing conditions. The advantage of IFTDSS is that the platform is publicly available and can be replicated and compared in the future by individuals with knowledge of the IFTDSS program and fire behavior.

Multiple wildfire simulations used local weather history and random ignitions to initiate and calculate numerous fire behavior datasets. Outputs of the fire behavior modeling that were carried forward in the QWRA process include burn probability (BP), conditional flame length - intensity (CFL) and integrated hazard.

Burn Probability -- Burn probability indicates the likelihood that a point in space will burn. Probability is derived from the frequency in which that point in space burned under numerous wildfire simulations with random ignitions. Three areas of interest with elevated burn probability with values of higher (60-80 percent of maximum) to highest (80-100 percent of maximum) exist within the project area. Of highest concern is the Park City Mountain Zone, an area associated with forest health concerns and fuel buildup. The Deer Valley/Deer Crest Zone along the southern U.S. 40 Highway corridor is also significant because of Gambel oak and sagebrush that could experience rapid rates of spread and higher potential fire occurrence. The third area is sagebrush flats in the northeast corner of the Round Valley Zone, again due to potential for rapid rates of spread and higher potential fire occurrence.

Conditional Flame Length -- Conditional flame length (CFL) is the sum product of flame lengths across six fire intensity levels. The highest values of CFL (feet) within the project area largely correlate to susceptible vegetation types, specifically areas of dense conifer. But it also includes areas of Gambel oak, maple and other mature hardwood brush forests.

Integrated Hazard -- Integrated hazard combines BP and CFL into a categorical dataset that describes foundational hazard designation across the PCMC project area. This includes five categories ranging from 'lowest hazard' to 'highest hazard.' A foundational hazard designation prior to the implementation of community-valued resources and assets allows us to evaluate wildfires' effects equivocally across the project area based solely on expected wildfire behavior. Alongside BP and CFL, integrated hazard datasets are carried forward in the QWRA process to be input into further analyses. Areas that show elevated (higher-highest) integrated hazard corresponds to areas of high BP and CFL, including the Park City Mountain Zone, eastern Deer Valley Zone, western Bonanza Flats and the northeast portion of Round Valley.

Figure 5-0-4. Example of sub-HVRAs mapped as part of the Recreation Infrastructure Primary HVRA category.

Highly Valued Resources and Assets (HVRAs)

HVRAs are the physical values the Park City community cares about, values that can be displayed on a map. They are categorized as primary HVRAs, and sub-HVRAs. The initial list of primary HVRAs was modeled after the Federal Emergency Management Agency list of community lifelines, which are defined as the most fundamental services in a community that, when stabilized, allow all other aspects of society to function.

The finalized list of HVRAs was expanded beyond those identified as community lifelines by an assembled group of community stakeholders in order to include additional values tailored to the Park City community, such as recreational infrastructure (i.e., trails), resort infrastructure and wildlife habitat. The full list of primary and sub-HVRA's is shown in Table 5-2.

Table 5-2. All Primary and sub-HVRAs developed as part of the PCMC QWRA.

PRIMARY HVRAS	SUB-HVRAS
Critical Infrastructure	Transmission Lines, Local Distribution Lines, Utility Infrastructure, Water Infrastructure, Water Connectivity
Resort Infrastructure	Ski Lifts, Resort Day Lodges, Other Resort Infrastructure, Access Roads, Snow Making Ponds
Heritage Resources	Listed Historical Sites, Park City Historic District
Human Habitation	Low Medium and High WUI Density, Schools, Daycare Facilities & Senior Centers, Children's Camps
Ecological Integrity	Aspen Forests, Sagebrush/Grassland Range with Cheatgrass potential, Sagebrush/Grassland Range without Cheatgrass potential, Mountain Meadows, Mixed Conifer Forests, Mixed Conifer/Hardwood Forests, Oak Brush, streams wetlands and riparian area, Fire Dependent Ecologically Sensitive Areas, Fire Sensitive Ecologically Sensitive Areas
Recreation Infrastructure	Trail Systems, Public lands, Avalanche PRAs with Fixed Values, Avalanche PRAs without Fixed Values
Wildlife & Habitat	ESA Listed Species: Ute ladies'-tresses, Bonneville Cutthroat Trout, Western (Boreal) Toad, Flammulated Owl, High Value Elk Moose and Mule Deer Habitat, Wildlife Corridors, Indicator Species – Goshawk
Public Safety	Fire & Police Stations, Hospitals & Medical Center, Primary Evacuation Routes, Secondary Ingress/Egress, Richardson Flat Superfund Site, Contaminated Sites, Communication Towers
Watershed Health	High Drinking Water Importance and High Potential for Sediment Delivery, High Drinking Water Importance and Low Potential for Sediment Delivery, Surface Water

For a more detailed overview of the HVRA selection process see Detailed Methods section of this chapter.

Exposure Analysis

The outputs of the Fire Behavior Modeling and locations of HVRAs were used as inputs for the exposure analysis step of the QWRA. This step measures mean values for the landscape burn probability outputs (Burn Probability, Conditional Flame Length, and Integrated Hazard) within the geographic extent of each primary and sub-HVRA. The data is organized geospatially as well as in table and graphical format. Mean landscape burn probability (LBP) statistics for each HVRA are carried forward in the QWRA process. For a more detailed depiction of how the exposure analysis, fire behavior modeling and HVRAs interact, see Detailed Methods section.

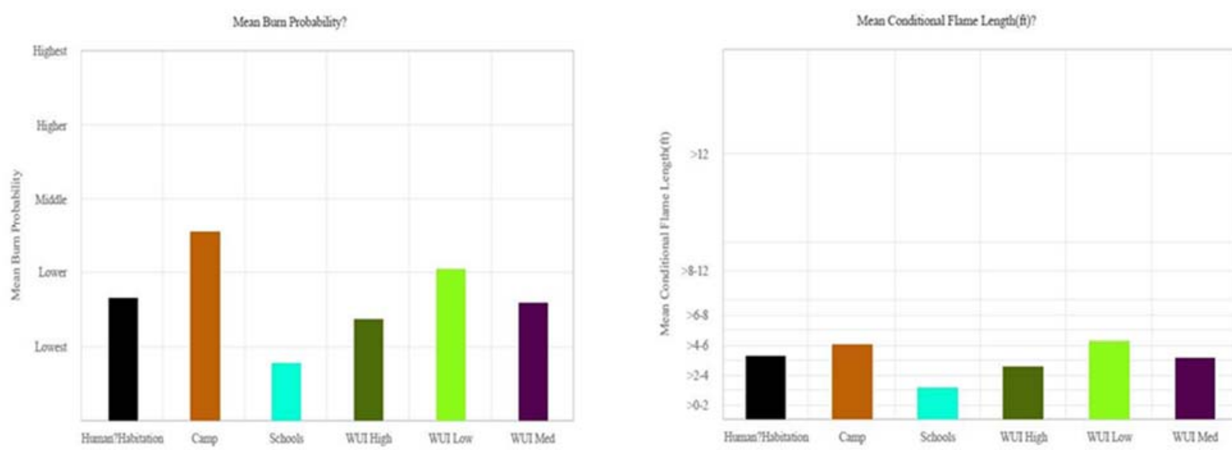

Figure 6-0-5. Mean BP and CFL for Human Habitation (Primary) and associated sub-HVRAs.

Relative Importance

In some Wildfire Risk Assessments, the Exposure Analysis may be used in isolation in order to inform fuel treatment location decisions. The Exposure Analysis process simply evaluates the presence (or absence) of an HVRA at any given location. It does not account for the existence of multiple overlapping HVRAs, or the degree of value the community may place on that HVRA. In order to assess wildfire risk quantitatively and account for the presence of numerous overlapping HVRAs and their respective value, a Relative Importance value is assigned to each HVRA. Relative Importance (RI) was calculated within the PCMC QWRA using ESRI Survey123, where community stakeholders assigned Relative Importance values to each Primary and Sub-HVRA. See figure XX for the top 10 sub-HVRAs with their corresponding Primary category and their RI values. Reference Methods (Detailed) for a full list of Project area HVRAs and their assigned RI.

The results of the RI yielded several key findings that reflect trends of what the Park City community cares about most in this assessment.

- While the economy of Park City is largely driven by tourism surrounding the ski resorts and summer trails network, 'Resort Infrastructure' and 'Recreation Infrastructure' were the two lowest ranking Primary HVRAs.
    - o This is very different from what respondents in the Community Survey reported. In the survey, over 90% of respondents were concerned that wildfire would be catastrophic to the resort economy. Additionally, nearly 80% of these same respondents were concerned about a loss of recreational opportunities.
- Protecting the water resources of the community is represented in several HVRA RIs. For example, 'Watershed Health' (i.e. drinking water and surface water) was ranked higher than 'Human Habitation'(i.e. Schools, Daycares, Wildland Urban Interface).
    - o This is similar to the views expressed in the Community Survey. More respondents were concerned about impacts to water resources than damage to homes, businesses, or property. However, this difference was slight (only a few percentage points).
- In the 'Ecological Integrity' HVRA, 'Streams, Wetlands, and Riparian Areas', was ranked as the single highest Sub-HVRA within that category.
    - o This is in alignment with the views expressed in the Community Survey. Most respondents ranked impacts to water resources over other types of ecological communities as being of higher concern.
- Overall RI for 'Wildlife & Habitat' is low (54), but wildlife corridors, crossings, and migration routes were the highest ranked Sub-HVRA in that category with an RI of 100, 30 points above the next highest (Elk, Moose and Deer Habitat).
    - o Community Survey respondents were overwhelmingly concerned about wildlife habitat - their concerns were higher for wildlife habitat than impacts to water, damages to structures, etc.

See Table 5-3 below for the Primary HVRA RIs, listed in order with their respective highest ranked Sub-HVRA. For the full list of RIs, see the Detailed Methods section.

Table 5-3. Primary HVRA RIs with respective highest-ranked sub-HVRA.

PRIMARY HVRA	RI	SUB-HVRA	RI
Public Safety	*100*	Hospitals & Medical Center	*100*
Critical Infrastructure	*88*	Water Infrastructure	*100*
Watershed Health	*85*	Watersheds with High Drinking Water Importance AND High Potential for Sediment Delivery Post-Fire	*100*
Human Habitation	*79*	Schools	*100*
Ecological Integrity	*64*	Streams, Wetlands, Riparian Area	*100*
Heritage Resources	*64*	Historic District - Main Street	*100*
Wildlife and Habitat	*54*	Wildlife Corridors, Crossings, Migration Routes, and other High Value Connecting Habitats	*100*
Recreation and Infrastructure	47	Avalanche - Potential Release Areas with values-at-risk	100
Resort Infrastructure	44	Ponds at Ski Resorts	100

Response Function

The physical characteristics and spatial extent of each HVRA are highly variable. For example, schools and homes are composed of structures that may be threatened by wildfire at a wide range of intensities. Mixed Conifer forests cover significant portions of the project area but may experience ecological benefit from the introduction of low-intensity fire. It is critical to capture these wildfire response differences in the analysis to make more informed decisions on risk mitigation strategies.

Each HVRAs' response to wildfire is integrated into the QWRA by assigning each sub-HVRA a response function (RF) value. RFs were developed by subject-matter experts in coordination with fire and fuels experts, and by referencing other QWRAs completed around the mountain west. Response function is assigned at each fire intensity level (FIL), Levels 1-6, derived from conditional flame length data. By integrating RF, decision makers are able to quantify what impact (positive or negative) wildfire will have on each HVRA, and distinguish that impact based on the intensity of fire. Each geographic component of a given sub-HVRA is assigned "value change" (-100 - +100) for each corresponding FIL. See Table 5-4 below for RFs assigned to human habitation and ecological integrity primary HVRAs for the PCMC QWRA. For the full list of sub-HVRA RFs, and additional details about the assigned values, see Detailed Methods section.

Table 5-4. RFs assigned to Human Habitation and Ecological Integrity Primary HVRAs for the PCMC QWRA.

Primary HVRA	Sub-HVRA	Response Function					
		FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Human Habitation	WUI Low Density	-10	-30	-50	-80	-100	-100
	WUI Moderate Density	-10	-40	-60	-80	-100	-100
	WUI High Density	-20	-50	-80	-100	-100	-100
	Schools	-10	-20	-50	-70	-90	-100
	Daycare Facilities & Senior Center	-20	-50	-80	-100	-100	-100
	Children's Camps - Girl Scout Camp	-20	-50	-80	-100	-100	-100
Ecological Integrity	Aspen Forests	80	100	100	70	50	40
	Sagebrush/Grasslands Range - With Cheatgrass Potential	-30	-60	-90	-100	-100	-100
	Sagebrush/Grasslands Range - Without Cheatgrass Potential	30	10	-20	-40	-60	-80
	Mountain Meadows	100	80	50	30	0	-20
	Mixed Conifer Forests	60	50	20	0	-20	-40
	Mixed Conifer/Hardwood Forest Vegetation	100	80	50	30	0	-20
	Oak Brush	60	80	100	50	20	-20
	Streams, Wetlands, and Riparian Areas	20	10	0	0	-10	-20
	Conservation Easements - Fire Dependent	80	100	100	70	50	0
	Conservation Easements - Fire Sensitive	0	0	-20	-40	-60	-80

Quantitative Wildfire Risk Assessment (QWRA)

The risk assessment phase of the QWRA is the culmination of the fire behavior modeling outputs and HVRA locations into a dataset which depicts how any given point across the project area will be impacted by wildfire. This dataset is represented by **expected weighted net value change (eNVC).** eNVC is calculated using the LBP data, the geographic extent of the HVRA datasets, the summation of their response functions (value change) and their corresponding relative importance.

eNVC identifies where the highest likelihood of fire would occur based on what HVRAs are present and subsequently what impact (positive/benefit or negative/threat) fire would have at any given point across the project area. eNVC is a unitless value which is further displayed categorically across the landscape (see figure 5-0-6).

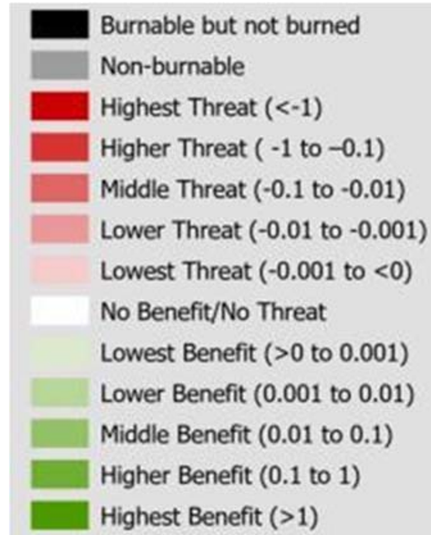

Figure 5-0-6. Range of eNVC values.

The highest positive and highest negative (benefit/threat) values are depicted independently in Figure 5-0-7. This allows us to visualize trends across the project area of what areas would benefit the most from fire, and what areas would be the most threatened. For example, the northeast corner of the project area shows significantly more area of ‘highest threat’ comparatively. In the western part of the project area, the outputs show a more even distribution of ‘highest threat’ and ‘highest benefit.’

Limitations and Uncertainties

Data and Modeling Limitations

As with all models, there are various limitations and assumptions that go into the analysis that are considered when interpreting the data. When using a chained modeling approach, errors in one model can be passed on to subsequent steps in a modeling framework (Keane et al., 2013; Drury et al., 2014; Hyde et al., 2015). The base data used by IFTDSS in wildfire behavior is complex, and models are a simplification of reality.

For example, the base input data used in IFTDSS Fire Behavior analysis, LANDFIRE, is delivered at a 30-meter pixel resolution. LANDFIRE products are not intended to replace local-scale data products (U.S. Department of Agriculture, 2023). For the purposes of this project, the data is useful for assessing relative risk across an entire project area and is not intended to assess specific fire behavior in a specific location such as the location of individual homes. Additionally, it is not feasible to predict every possible combination of fire weather conditions, ignition locations, and suppression activities that might occur during a wildfire. Uncertainty will always remain about where and how a wildfire might behave until a fire is actually occurring. Even then, fire behavior can be erratic and unpredictable.

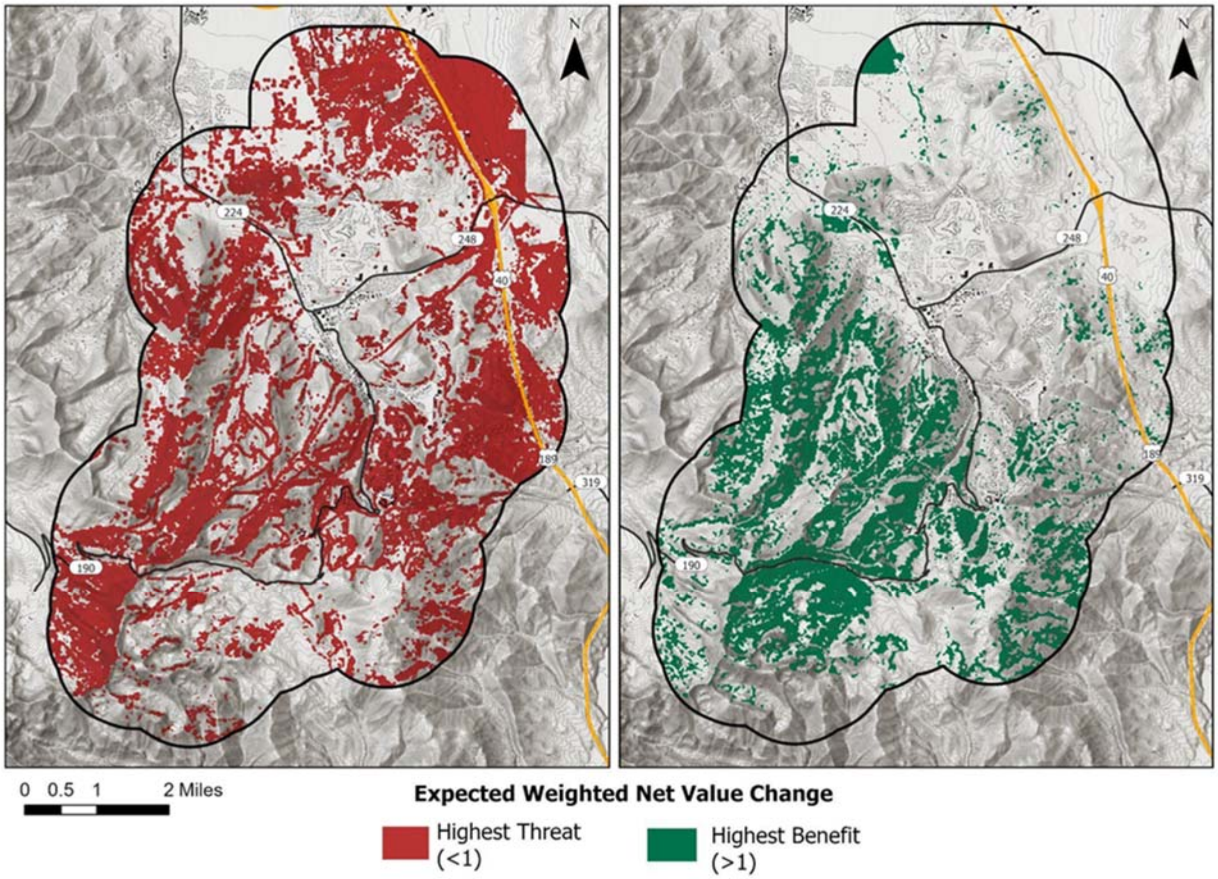

Figure 0-7. The highest positive and highest negative (benefit/threat) values depicted independently in the project area.

HVRA Development

The stakeholders group, who developed the HVRA list and respective relative importance, represent a diverse collection of entities that manage and make decisions in the Park City area. This group's decisions regarding the relative importance of HVRAs may implicitly be viewed as consistent with the general public's values. However, based on findings from the community survey, that is not always the case.

Additionally, the relative importance survey was only completed by 10 of the more than 30 individuals identified as community stakeholders. The respondents of the survey did represent an adequate level of diversity across the community; however, surveys are always more reflective of reality with more responses. It is also important to note that the relative importance and HVRAs are a snapshot in time. Thus, the overall design of the project was based around the ability to replicate the process in the future as many of the input factors will inevitably change.

Recommendations and Conclusions

Utilizing the output eNVC data, quantitative comparisons can be made between parcels or neighborhoods and allow for effective prioritization of forest restoration and fuels treatment project planning. A prioritization of PCMC-owned lands was performed as part of this CWRA and is included in chapter 6.0. How the eNVC data may be used to inform prioritization of areas that are in need of fuel treatment is also outlined in the following chapter. It is available to land managers within the Project area upon request.

While the information is quantitative and conclusive, the scale at which the input data is derived is only appropriate for identifying target areas across the entire project area. It should not be used to define property-scale treatment areas. The base data used by IFTDSS in wildfire behavior (used in the calculation of eNVC) is complex, and these models are a simplification of reality. Thus, smaller scale assessment of vegetation and how it is distributed, is integral to development of effective treatment plans for individual parcels and neighborhoods within the project area. This can be done using a high resolution drone or remote sensing imagery to gather an accurate high-resolution local-scale analysis of what vegetation conditions are on the ground.

Input and output datasets of the QWRA process may also be used by land managers, fire planners, fire responders, land use planners, environmental assessors, among others. The QWRA process and its associated platforms are publicly available and designed to be updated and repeated as conditions change over time. Keeping essential data for vegetation, HVRAs and weather up to date and relevant is a recommended part of the risk assessment process.

In combination with other modeling and expert knowledge, the QWRA can help address fire risk by directing Park City Municipal Corporation and private landowners to areas of greatest concern. In doing so, the community can begin to take actions using the tenets of the National Cohesive Wildland Fire Management Strategy. This could lead to them serving as a model within Utah and the west to follow the vision: "*To safely and effectively extinguish fire when needed; use fire where allowable; manage our natural resources; and as a nation, learn to live with wildland fire.*"

Detailed Methods

The Interagency Fuels Treatment Decision Support System (IFTDSS) platform was used to develop potential wildfire hazard data within the PCMC CWRA project area. An overview of the QWRA process, as implemented by IFTDSS, is shown below in Figure 5-0-8.

Fire Behavior Modeling

As wildfire is often unpredictable in its behavior, modeling wildfire involves various limitations and assumptions which should be considered when interpreting data outputs. For geographic extents like the CWRA project area (33,000+ acres), the IFTDSS framework is useful in interpreting relative risk across the landscape. It is not used for assessing the risk in a specific location at the structure-scale. IFTDSS relies on data sourced from LANDFIRE (XX) datasets including terrain, tree canopy and surface fuels at a 30m x 30m pixel resolution. A full 'Fuels and Fire Behavior Report' is included in Appendix X.X. Fire behavior modeling workflow is generalized below (Figure 5-0-8).

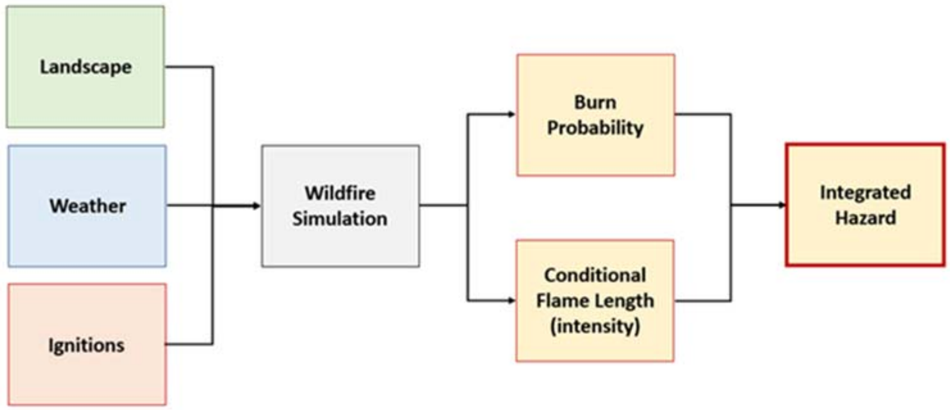

Figure 5-0-8. Landscape evaluation process.

The foundational landscape stage defines the area of analysis as well as associated landscape characteristics including elevation, aspect, slope, fuel type datasets. The area of analysis was run with a standard buffer supplied within the IFTDSS system but was narrowed to an area of interest (AOI) including only the PCMC project area. The Park City Urban Core Zone was deliberately omitted from analysis due to the absence of contiguous burnable fuel types, and the presence of dense development makes fire modeling impossible using the methods described.

Fuel Model (40) categorically assigns a fuel type to each 30m x 30m pixel within the landscape, provided by LANDFIRE (2016) datasets. In comparison to manually derived vegetation datasets developed within other stages of the PCMC project, as well as local fuels knowledge, adjustments to the fuel models were made prior to further analysis. This best represents the existing condition (EC). In developing an EC, 215 acres of fuel model TL8 (long-needle pine litter, e.g., ponderosa) were identified by LANDFIRE primarily within the interior of the mixed conifer stands experiencing a significant level of forest decline.

A small area of fuel model TL8 was identified in an area of Gambel oak above and southeast of Park City proper. Considering the limitations of IFTDSS, global changes are required and all TL8 was changed to SB2 – slash-blowdown (SB2). The reason for this global change is that TL8 is defined as a moderate load long-needle pine litter with a moderate spread rate and low flame length. Except for the occurrence of limber pine, there are no known long-needle pines within the project area.

The TL8 – long-needle pine litter fuel model was globally changed within the project area to SB2 to represent the significant insect-caused dead standing and down woody material in the existing condition of mixed conifer. The primary carrier of fire in SB2 is moderate dead and down light blowdown. Fine fuel load is 7 to 12 tons/acre, evenly distributed across all diameter classes up to 3 inches in diameter with a depth of about 1 foot. Blowdown is scattered, with many trees still standing exhibiting moderate spread rate and flame length.

The TL3 fuel model – timber litter - moderate load, conifer litter is showing up in alpine areas above treeline, avalanche chutes and where short grass with scattered trees are present. A global change was made for 2,211 acres to the GR1 fuel model - short, sparse dry climate grass (dynamic). It is anticipated there will be minimal impact on fire behavior as TL3 has a very low rate-of-spread (ROS) and low flame length with GR1 identified as low for both outputs. There is a small area of open and younger aspen and small area of willow identified as TL3 that was adjusted, as changes are global, but should not significantly impact overall fire behavior outputs.

Fifty-three acres of humid climate shrub, grass and timber-shrub were also suspected, but not changed within the fuels dataset due to small spatial extent and minimal impact on overall fire behavior output datasets. The largest of 47 acres of Moderate Load, Humid Climate Shrub appears to be associated with transitions into aspen.

A breakdown of fuel types within the AOI is outlined below in Table 5-5. Burnable area based on the project-adjusted fuel models is approximately 29,761 acres out of 31,913 total analysis area acres

Table 5-5. Fuel types within the project area of interest (AOI).

Fuel Model	Fuel Description	Acres	Percent
GS2 (122)	Grass-Shrub - Moderate Load, Dry Climate Grass-Shrub (Dynamic)	6,156	19%
TU5 (165)	Timber-Understory - Very High Load, Dry Climate Timber-Shrub	4,308	13%
TU1 (161)	Low Load Dry Climate Timber-Grass-Shrub (Dynamic)	4,018	13%
SH7 (147)	Shrub - Very High Load, Dry Climate Shrub	3,282	10%
GS1 (121)	Low Load, Dry Climate Grass-Shrub (Dynamic)	3,119	10%
GR1 (101)	Short, Sparse Dry Climate Grass (Dynamic)	3,108	10%
GR2 (102)	Grass - Low Load, Dry Climate Grass (Dynamic)	2,248	7%
NB1 (91)	Urban/Developed	1,654	5%
TL5 (185)	Timber Litter - High Load Conifer Litter	1,285	4%
TL6 (186)	Timber Litter - Moderate Load Broadleaf Litter	1,277	4%
NB9 (99)	Bare Ground	340	1%
TL2 (182)	Timber Litter - Low Load Broadleaf Litter	280	1%
SB2 (202)	Slash-Blowdown - Moderate Load Low Load Blowdown	215	1%
NB3 (93)	Agricultural	197	1%
SH5 (145)	High Load, Dry Climate Shrub	136	1%
SH2 (142)	Moderate Load Dry Climate Shrub	118	1%
TL9 (189)	Timber Litter - Very High Load Broadleaf Litter	59	0%
NB8 (98)	Open Water	51	0%
SH3 (143)	Moderate Load, Humid Climate Shrub	47	0%
TL1 (181)	Low Load Compact Conifer Litter	7	0%
GR3 (103)	Low Load, Very Coarse, Humid Climate Grass	5	0%
SH1 (141)	Low Load Dry Climate Shrub (Dynamic)	2	0%
TU2 (162)	Moderate Load, Humid Climate Timber-Shrub	1	0%
Total		31,913	100%

Weather History

Local weather data inputs were derived from the nearest and/or most representative Fire Remote Automated Weather Stations (RAWS). While RAWS do not exist within the PCMC project area, nearby stations exist within representative elevations (6,100-11,153 feet amsl) including Pleasant Grove (5,200 feet amsl), Norway Flats (8,280 feet amsl) and Ray's Valley (7,300 feet amsl) (see Table 5-6).

Table 5-6. Fire RAWS closest to Park City.

Fire RAWS	Elevation (feet)	Distance from Park City (miles)	Direction from Park City
Pleasant Grove	5,200	20	SW
Norway	8,280	22	E
Ray's Valley	7,300	39	SSE

Weather data was analyzed in Fire Family Plus 5.0. Fire Family is a software package used to calculate fuel moistures and indices from the U.S. National Fire Danger Rating System (NFDRS). It uses hourly or daily fire weather observations primarily from RAWS. A significant interest group (SIG) of the three RAWS was created to determine extreme fuel and weather conditions at the 97th percentile and used as the input into IFTDSS. For example, 97th percentile weather conditions represent extreme conditions that are not exceeded in terms of hotness and dryness except for 3 percen of the days during the typical fire season (May-October). Comparisons were made with local live and dead fuel moisture sampling conducted by the Uinta-Wasatch-Cache National Forest as reported in the National Fuel Moisture Database.

Wind directions and speeds were developed based on weather station wind data from several stations around the Park City area, and gridded using WindNinja (USFS 2018) to compute spatially varying wind fields for landscape modeling inputs.

Fire Behavior Model Outputs

1. *Landscape Fire Behavior* (LFB) - Numerous geospatial datasets and report summaries are generated as part of the LFB output including flame length (ft), rate of spread (chains/hr), crown fire activity (type), among others. They serve as standalone supplementary resources under the scope of the QWRA process and are not used further in any quantitative analysis for the PCMC QWRA. For a detailed summary of LFB outputs as applied to the project area, reference Appendix (Fuel and Fire Behavior Report).
2. *Landscape Burn Probability* (LBP) - Landscape burn probability includes a relative likelihood of fire occurring and its intensity under the input set of weather and fuel moisture conditions. This information is expressed in burn probability (BP) as a proportional value (0-1) representing the number of simulations in which that location burned versus the total number of simulations executed. Conditional flame length (Intensity) (CFL) is expressed as the mean value (ft) of flame lengths observed in all model runs from varying ignition source locations. Both of these outputs are numerical datasets used to further derive integrated hazard. Integrated hazard is expressed as a categorical designation for each individual pixel within the project area, ranging from lowest to highest hazard. These integral outputs are carried forward in the QWRA process.

Highly Valued Resources or Assets (HVRAs)

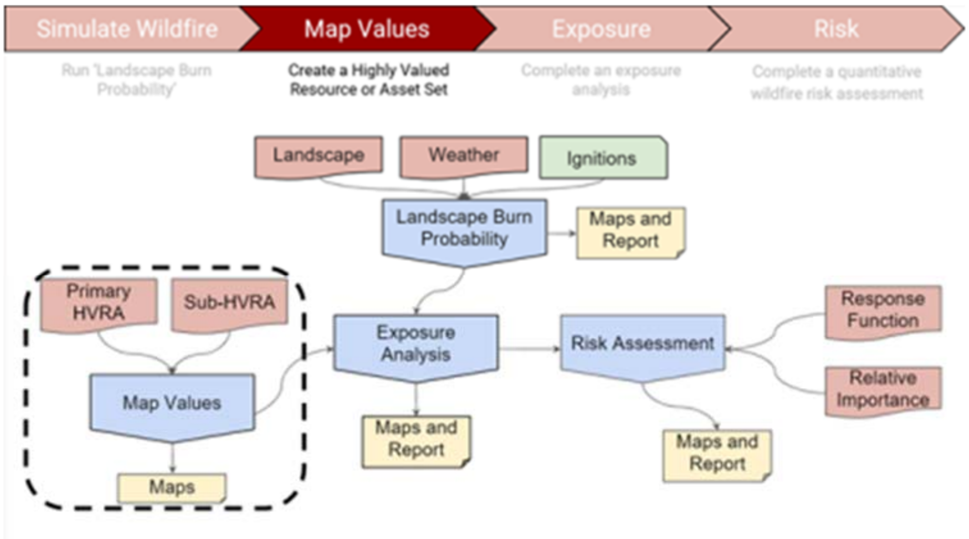

Figure 5-0-9. Identifying map values in a quantitative wildfire risk analysis process.

HVRAs are things the community cares about within the analysis area that can be displayed as geographic features (geospatial data). HVRAs are categorized in **primary HVRA** groupings and contain individual **sub-HVRAs**. For example, the **primary HVRA** could be 'critical infrastructure,' the **sub-HVRA** would be 'power line.' **Sub-HVRAs** are the geospatial components that are used in risk assessment calculations.

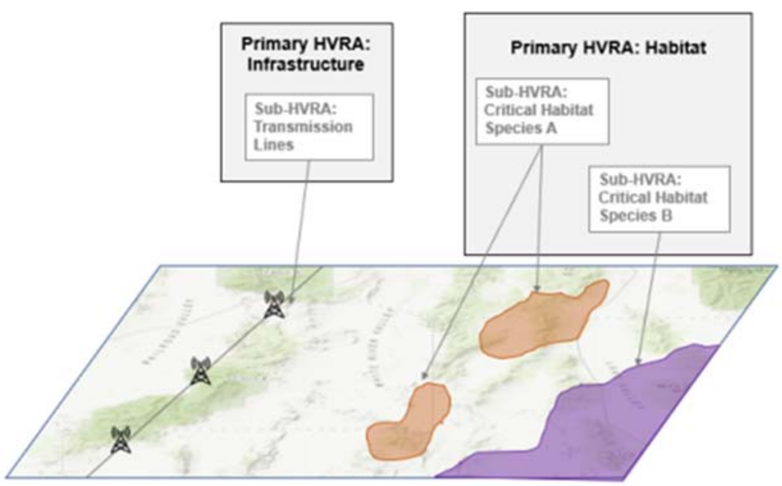

Figure 5-0-10. HVRAs are things the community cares about within the analysis area that can be displayed as geographic features.

Development of PCMC HVRAs

The initial framework for HVRA development was modeled after the FEMA Community Lifelines framework to include the community components necessary for the continuous operation of critical government and business functions (FEMA). In the development of the Park City Community Wildfire Risk Assessment, HVRAs were then refined or newly derived from community members and local stakeholders representing community groups and organizations. Stakeholders included representatives from Park City Municipal Corporation, Summit County, local ski resorts, Park City Fire District, utility infrastructure representatives, local land managers and conservation organizations.

A finalized list of nine primary HVRAs categories were identified and include 49 sub-HVRAs, as shown below in Table 5-7 along with data sourcing information.

Table 5-7. Final list of nine primary HVRA categories and 49 sub-HVRAs with data sourcing information.

Primary HVRA	Sub-HVRA	Data Source
Critical Infrastructure	Transmission Lines	Direct from Utility Provider
	Local Distribution Lines	Direct from Utility Provider
	Utility Infrastructure (i.e. substations)	Direct from Utility Provider
	Water Infrastructure (pumps, springs, tanks, treatment plants)	USEPA FRS; digitized from 2006 Bureau of Reclamation Report, Utah Geospatial Resource Center, National Hydrography Dataset (USGS)
	Water Connectivity (tunnels, culverts)	Utah Geospatial Resource Center
**Utility infrastructure GIS datasets included in risk assessment, but not represented in maps within this report - for reasons of provider security and/or confidentiality*		
Resort Infrastructure	Ski Lifts	Developed by Alpine Forestry, sourced from ski resort websites and aerial imagery
	Resort Day Lodges	Developed by Alpine Forestry, sourced from ski resort websites and aerial imagery
	Other Resort Infrastructure (i.e., pumphouses, maintenance shops and other buildings)	Developed by Alpine Forestry, with supporting non-geospatial map products supplied by ski area representatives
	Access Routes on all Resorts	Developed by Alpine Forestry, with supporting non-geospatial map products supplied by ski area representatives
	Ponds at Ski Resorts	Developed by The Ember Alliance, with supporting non-geospatial map products supplied by ski area representatives
Heritage Resources	Listed Historical Sites (Federal, State, and Park City)	Park City Municipal Historic Site Inventory, digitized by Alpine Forestry

	Historic District - Main Street	Park City Municipal Corp. GIS Zoning Map
Human Habitation	WUI Low Density	Utah Geospatial Resource Center / The Ember Alliance (Density Class)
	WUI Moderate Density	Utah Geospatial Resource Center / The Ember Alliance (Density Class)
	WUI High Density	Utah Geospatial Resource Center / The Ember Alliance (Density Class)
	Schools	Utah Geospatial Resource Center
	Daycare Facilities & Senior Center	Utah Geospatial Resource Center
	Children's Camps - Girl Scout Camp	Developed by Ember Alliance sourced from Google Maps, Utah Geospatial Resource Center
Ecological Integrity	Aspen Forests	LANDFIRE Existing Vegetation Type (EVT)
	Sagebrush/Grasslands Range – With Cheatgrass Potential	LANDFIRE Existing Vegetation Type (EVT), Early Estimates of Exotic Annual Grass (USGS)
	Sagebrush/Grasslands Range - Without Cheatgrass Potential	LANDFIRE Existing Vegetation Type (EVT), Early Estimates of Exotic Annual Grass (USGS)
	Mountain Meadows	LANDFIRE Existing Vegetation Type (EVT)
	Mixed Conifer Forests	LANDFIRE Existing Vegetation Type (EVT)
	Mixed Conifer/Hardwood Forest Vegetation	LANDFIRE Existing Vegetation Type (EVT)
	Oak Brush	LANDFIRE Existing Vegetation Type (EVT)
	Intermittent and perennial streams, wetlands, and riparian (include buffer 150 feet)	National Hydrography Dataset (USGS, Utah Dept. of Natural Resources, US Fish and Wildlife Service)
	Ecologically Sensitive Areas - Fire Dependent - Conservation Easements	Utah Geospatial Resource Center, National Conservation Easement Database, Park City Corp. GIS, Utah Open Lands, Summit Land Conservancy
	Ecologically Sensitive Areas - Fire Sensitive - Conservation Easements	Utah Geospatial Resource Center, National Conservation Easement Database, Park City Corp. GIS, Utah Open Lands, Summit Land Conservancy
Recreation Infrastructure	Trail Systems	Utah Geospatial Resource Center
	Public Lands (Only Land Owned by State, Federal, or PCMC)	Bureau of Land Management (BLM)
	Avalanche - Potential Release Areas with values-at-risk	Resilient Landscapes (Chapter 2) - Developed by Alpine Forestry
	Avalanche - Potential Release Areas, no values-at-risk	Resilient Landscapes (Chapter 2) - Developed by Alpine Forestry

Wildlife & Habitat	ESA Listed Species: Ute ladies'-tresses	Developed by Sageland Collaborative with LANDFIRE Existing Vegetation Type (EVT)
	Bonneville Cutthroat Trout	National Hydrography Dataset (USGS)
	Western (boreal) Toad	Developed by Sageland Collaborative with LANDFIRE Existing Vegetation Type (EVT)
	Flammulated Owl	Developed by Sageland Collaborative with LANDFIRE Existing Vegetation Type (EVT)
	High Value Elk, Moose, and Mule Deer habitat	Utah Division of Wildlife Resources
	Wildlife corridors, crossings, migration routes, and other high value connecting habitats.	Developed by Sageland Collaborative, Snyderville Basin General Plan (2015)
	Indicator Species – Goshawk	Developed by Sageland Collaborative with LANDFIRE Existing Vegetation Type (EVT)
Public Safety	Fire Stations - Police Stations	Utah Geospatial Resource Center
	Hospitals & Medical Centers	Utah Geospatial Resource Center
	Primary Emergency Routes - 224 & 248	Utah Department of Transportation Open Data GIS
	Secondary Ingress/Egress - Other Connecting Through Streets	Developed by Alpine Forestry, sourced by Utah Department of Transportation Open Data GIS
	Richardson Flat Superfund Site	USEPA Geospatial Data Download Service
	Contaminated Sites (mine tailings, etc.)/Prevent from Burning	USEPA Geospatial Data Download Service
	Communication Towers - Repeaters, Radio Towers, Cell Towers	Homeland Infrastructure Foundation-Level Data (HIFLD)
Watershed Health	High Drinking Water Importance and High Potential for Sediment Delivery Post Fire	Resilient Landscapes (Chapter 2) - Developed by The Ember Alliance
	High Drinking Water Importance and Low Potential for Sediment Delivery Post Fire	Resilient Landscapes (Chapter 2) - Developed by the Ember Alliance
	Surface Water (lakes, streams, springs)	Utah Geospatial Resource Center

Exposure Analysis

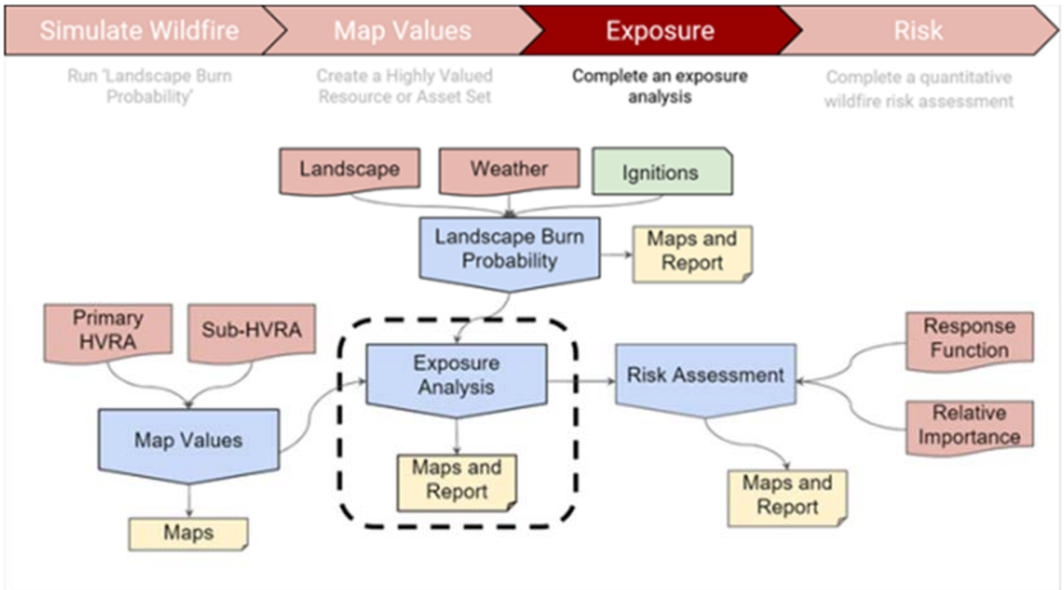

Figure 5-0-11. Exposure analysis in a quantitative wildfire risk analysis process.

Using IFTDSS, exposure analysis takes the datasets from landscape burn probability outputs and characterizes them across the geographic extent of the HVRAs. This process calculates the following outputs of the landscape burn probability for each HVRA.

- Mean Burn Probability
- Mean Conditional Flame Length
- Mean Integrated Hazard
- Mean of product of Burn Probability and Conditional Flame Length
- Relative Extent
- Expected Area Burned

See figures below for an example of the data from 'Public Safety.'

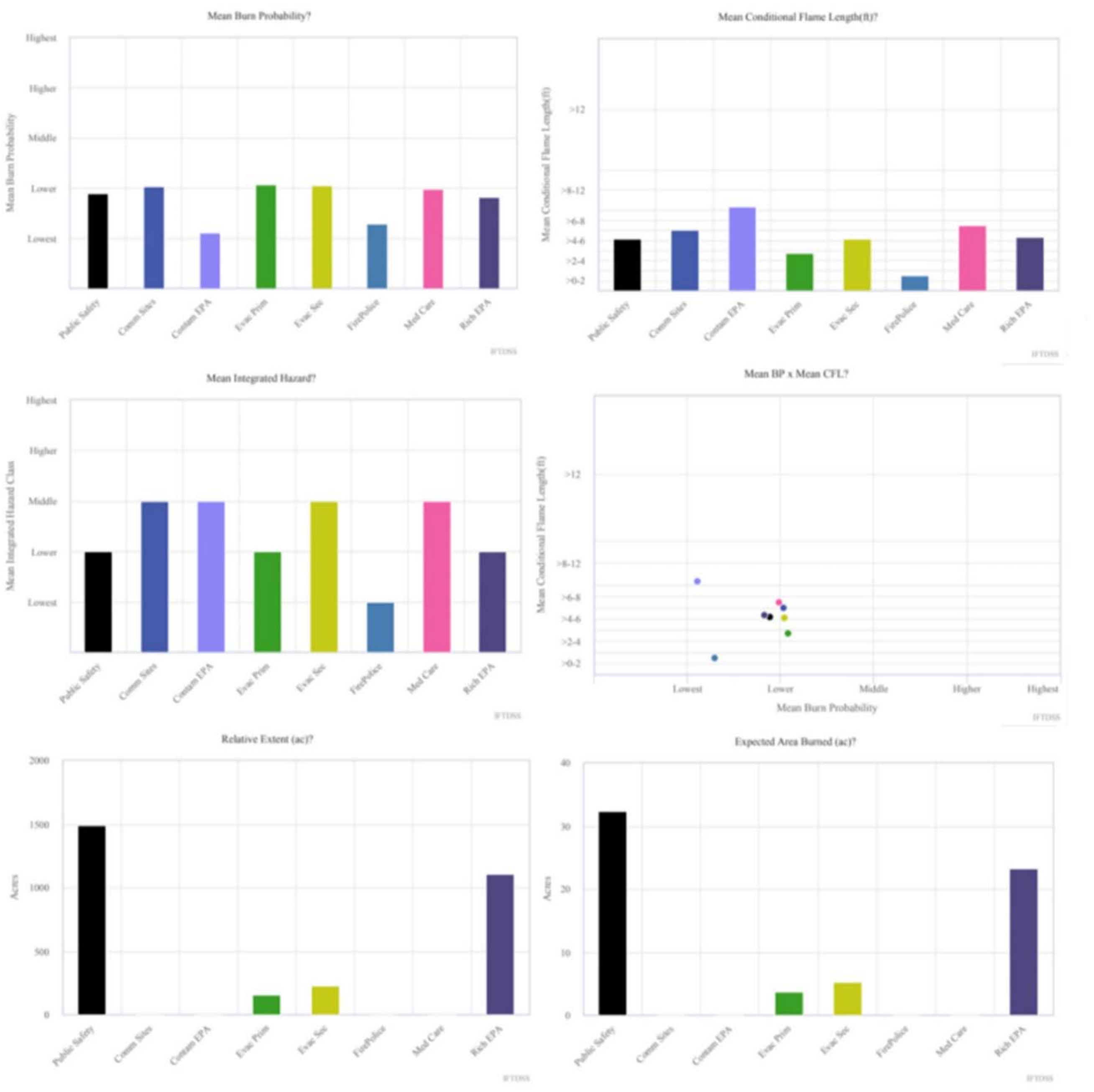

Figure 5-0-12. Example data from 'public safety.'

The resulting datasets from the exposure analysis can be and are used independently to provide context and inform treatment decisions as they provide spatial context to where fire behavior will intersect with HVRAs. However, it is solely a qualitative analysis and insufficient for the overall goal of the QWRA. For the purposes of conducting the QWRA, the exposure analysis output is a necessary step in the process as it, 1) summarizes the output landscape burn probability data within the geographic extent of each HVRA individually, and 2) converts the geospatial HVRA data into raster format which is required for further analysis. The quantitative component is the process of viewing landscape burn probability with all the HVRAs together.

Quantitative Wildfire Risk Assessment

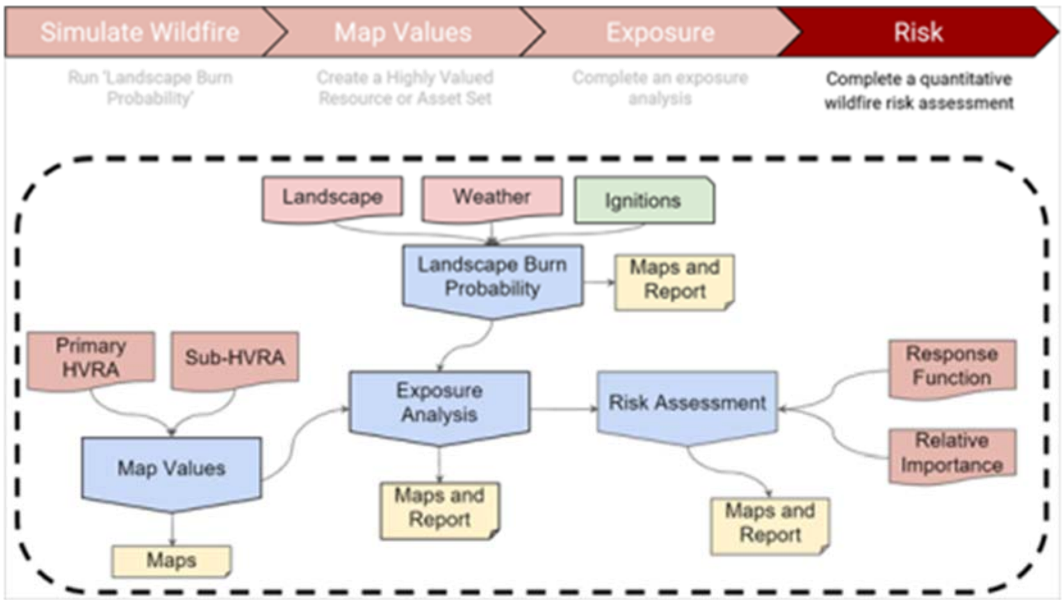

Figure 5-0-13. Quantitative wildfire risk analysis process

The QWRA is the culmination of the landscape burn probability, HVRA development and exposure analysis to assess wildfire risk quantitatively. The process is done within IFTDSS by inputting the mean burn probability and the mean conditional flame length from the fire behavior report, the dataset of the HVRAs from the exposure analysis, and two additional pieces of quantitative data (relative importance and response function).

Relative Importance (RI) of HVRAs

HVRAs can be assessed as they relate to wildfire risk individually with the summary report of the exposure analysis. However, when looking at multiple overlapping HVRAs, all created by stakeholders with differing resource management objectives, the issue of weighting importance comes in. Once the HVRA list was finalized, a survey was sent to the stakeholder group asking them to give each HVRA and sub-HVRA a score between 0 and 10. They were also asked when scoring the sub-HVRAs, to give their top choice in each category a score of 10. Stakeholder RI values were then averaged and multiplied by a factor of 10 for input into the QWRA analysis. This allowed us to characterize and summarize risk to a given area where multiple HVRAs exist.

Table 5-8. Relative importance value of each primary and sub-HVRA.

PRIMARY HVRA	RI	SUB-HVRA	RI
Critical Infrastructure	88	Transmission Lines	73
		Local Distribution Lines	68
		Utility Infrastructure (i.e. substations)	72
		Water Infrastructure (pumps, springs, tanks, treatment plants)	100
		Water Connectivity (tunnels, culverts)	87
Resort Infrastructure	44	Ski Lifts	48
		Resort Day Lodges	53
		Other Resort Infrastructure (i.e., pumphouses, maintenance shops and other buildings)	56
		Access Routes on all Resorts	68
		Ponds at Ski Resorts	100
Heritage Resources	64	Listed Historical Sites (Federal, State, and Park City)	74
		Historic District - Main Street	100
Human Habitation	79	WUI Low Density	66
		WUI Moderate Density	74
		WUI High Density	83
		Schools	100
		Daycare Facilities & Senior Center	87
		Children's Camps - Girl Scout Camp	44
Ecological Integrity	64	Aspen Forests	50
		Sagebrush/Grasslands Range – With Cheatgrass Potential	57
		Sagebrush/Grasslands Range - Without Cheatgrass Potential	57
		Mountain Meadows	56
		Mixed Conifer Forests	59
		Mixed Conifer/Hardwood Forest Vegetation	66
		Oak Brush	50
		Intermittent and perennial streams, wetlands, and riparian (include buffer 150 feet)	100
		Ecologically Sensitive Areas - Fire Dependent - Conservation Easements	72
		Ecologically Sensitive Areas - Fire Sensitive - Conservation Easements	72
Recreation Infrastructure	47	Trail Systems	51
		Public Lands (Only Land Owned by State, Federal, or PCMC)	69
		Avalanche - Potential Release Areas with values-at-risk	100
		Avalanche - Potential Release Areas, no values-at-risk	70
Wildlife & Habitat	54	ESA Listed Species: Ute ladies'-tresses	61
		Bonneville Cutthroat Trout	68
		Western (Boreal) Toad	68
		Flammulated Owl	61
		High Value Elk, Moose, and Mule Deer habitat	70
		Wildlife corridors, crossings, migration routes, and other high value connecting habitats.	100
		Indicator Species – Goshawk	63
Public Safety	100	Fire Stations - Police Stations	91

		Hospitals & Medical Centers	100
		Primary Emergency Routes - 224 & 248	91
		Secondary Ingress/Egress - Other Connecting Through Streets	75
		Richardson Flat Superfund Site	59
		Contaminated Sites (mine tailings, etc.)/Prevent from Burning	60
		Communication Towers - Repeaters, Radio Towers, Cell Towers	77
Watershed Health	85	High Drinking Water Importance and High Potential for Sediment Delivery Post Fire	100
		High Drinking Water Importance and Low Potential for Sediment Delivery Post Fire	87
		Surface Water (lakes, streams, springs)	82

HVRA Response to Wildfire (Response Functions)

Simulating how a given HVRA will respond to wildfire is a difficult task and is subject to substantial uncertainty (Scott, Joe H.; Thompson, Matthew P.; Calkin, David E. 2013). Depending on the intensity of wildfire, current conditions, past and future impacts of climate change and other dynamic processes, the responses to wildfire can and will vary greatly across the list of HVRAs.

No one person or group can be privy to the host of variables that determine an HVRA's response to wildfire. Therefore, subject-matter experts were assigned to each HVRA and tasked with defining the **response function (RF)** for the subsequent sub-HVRAs. For example, avalanche specialists, wildlife specialists and fuels specialists worked in coordination to develop response functions for specific primary or sub-HVRAs in which their specialty is best suited. Several workshops took place among the subject-matter experts incorporating individual subject-matter expertise combined with comparable RFs in other QWRAs until response function values were finalized. RFs are expressed quantitatively to identify **"value change" (-100 - +100)** to each HVRA based on different levels of fire intensity.

A RF of -100 indicates a strong loss of value to that HVRA, and a RF of +100 indicates a strong gain, where occurrence of fire may provide benefit. The RFs for an HVRA may vary based on the landscape burn probability output scale (**fire intensity level (FIL)** 1-6) from the fire behavior section. This variability in RF accounts for the fact that a given HVRA will have a different response to wildfire based on different fire intensity levels. An example showing the different RFs and variable FILs is shown below in Table 5-9.

Figure 5-0-14. Response functions are expressed quantitatively.

Table 5-9. Response functions for a partial collection of the sub-HVRAs. For example, "Ecologically Sensitive Areas - Fire Dependent" only stands to benefit or remain unaffected by the various fire intensity, while "WUI High Density" only shows a loss across the fire intensity level scale. For a full list of response functions see Appendix XX.

Primary HVRA	Sub-HVRA	Response Function					
		FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Critical Infrastructure	Transmission Lines	0	0	-20	-40	-60	-80
	Local Distribution Lines	-10	-20	-40	-60	-80	-100
	Utility Infrastructure (i.e. substations)	0	-10	-30	-50	-70	-90
	Water Infrastructure (pumps, springs, tanks, treatment plants)	-10	-20	-40	-60	-80	-100
	Water Connectivity (tunnels, culverts)	0	0	0	-20	-40	-40
Resort Infrastructure	Ski Lifts	20	10	0	-20	-50	-80
	Resort Day Lodges	-20	-40	-60	-80	-100	-100
	Other Resort Infrastructure (i.e., pumphouses, maintenance shops and other buildings)	-10	-20	-50	-70	-90	-100
	Access Routes on all Resorts	-10	-20	-50	-70	-90	-100
	Ponds at Ski Resorts	0	0	-20	-40	-50	-80
Heritage Resources	Listed Historical Sites (federal, state, Park City)	-40	-60	-80	-100	-100	-100
	Historic District - Main Street	-40	-60	-80	-100	-100	-100
Human Habitation	WUI Low Density	-10	-30	-50	-80	-100	-100
	WUI Moderate Density	-10	-40	-60	-80	-100	-100
	WUI High Density	-20	-50	-80	-100	-100	-100
	Schools	-10	-20	-50	-70	-90	-100
	Daycare Facilities & Senior Center	-20	-50	-80	-100	-100	-100
	Children's Camps - Girl Scout Camp	-20	-50	-80	-100	-100	-100
Ecological Integrity	Aspen Forests	80	100	100	70	50	40
	Sagebrush/Grasslands Range - With Cheatgrass Potential	-30	-60	-90	-100	-100	-100
	Sagebrush/Grasslands Range - Without Cheatgrass Potential	30	10	-20	-40	-60	-80
	Mountain Meadows	100	80	50	30	0	-20
	Mixed Conifer Forests	60	50	20	0	-20	-40
	Mixed Conifer/Hardwood Forest Vegetation	100	80	50	30	0	-20
	Oak Brush	60	80	100	50	20	-20
	Streams, Wetlands, and Riparian Areas	20	10	0	0	-10	-20
	Conservation Easements - Fire Dependent	80	100	100	70	50	0
	Conservation Easements - Fire Sensitive	0	0	-20	-40	-60	-80
Recreation Infrastructure	Trail Systems	20	10	0	-10	-30	-50
	Public Lands (Only Land Owned by State, Federal, or PCMC)	20	10	0	-10	-30	-50
	Avalanche - Potential Release Areas with values-at-risk	-20	-40	-60	-80	-100	-100
	Avalanche - Potential Release Areas, no values-at-risk	0	-20	-40	-60	-80	-100
	ESA Listed Species: Ute ladies'-tresses	100	100	80	50	20	0

Wildlife & Habitat	Bonneville Cutthroat Trout	10	0	-20	-70	-100	-100
	Western (Boreal) Toad	100	100	70	50	30	10
	Flammulated Owl	0	0	0	-30	-80	-100
	High Value Elk, Moose, and Mule Deer habitat	50	20	10	-10	-20	-40
	Wildlife corridors, crossings, migration routes, and other high value connecting habitats.	30	20	0	0	-10	-10
	Indicator Species – Goshawk	70	50	0	0	-50	-80
Public Safety	Fire Stations - Police Stations	-10	-20	-50	-70	-90	-100
	Hospitals & Medical Centers	-10	-20	-50	-70	-90	-100
	Primary Emergency Routes - 224 & 248	-10	-20	-50	-70	-90	-100
	Secondary Ingress/Egress - Other Connecting Through Streets	-10	-30	-60	-80	-100	-100
	Richardson Flat Superfund Site	-10	-20	-50	-70	-90	-100
	Contaminated Sites (mine tailings, etc.)/Prevent from Burning	-10	-20	-50	-70	-90	-100
	Communication Towers - Repeaters, Radio Towers, Cell Towers	-10	-30	-60	-80	-100	-100
Watershed Health	High Drinking Water Importance and High Potential for Sediment Delivery Post Fire	10	0	-20	-50	-80	-100
	High Drinking Water Importance and Low Potential for Sediment Delivery Post Fire	10	10	0	-20	-50	-80
	Surface Water (lakes, streams, springs)	10	10	0	-30	-60	-90

The addition of the quantitative component to the assessment allows for more effective land management decisions by summarizing the predicted benefit or loss from wildfire on overlapping values across the landscape through the calculation on **expected weighted net value change (eNVC).**

eNVC represents the overall change (positive/benefit or negative/threat) on a given pixel. while factoring in Landscape Burn Probability outputs and the geospatial HVRA dataset with response functions, and relative importance of each. This was done in IFTDSS and yields the following outputs:

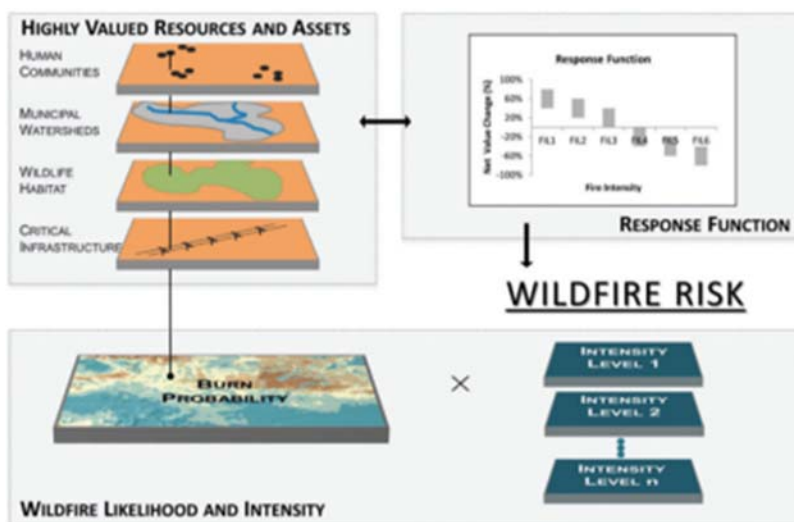

Figure 5-0-15.

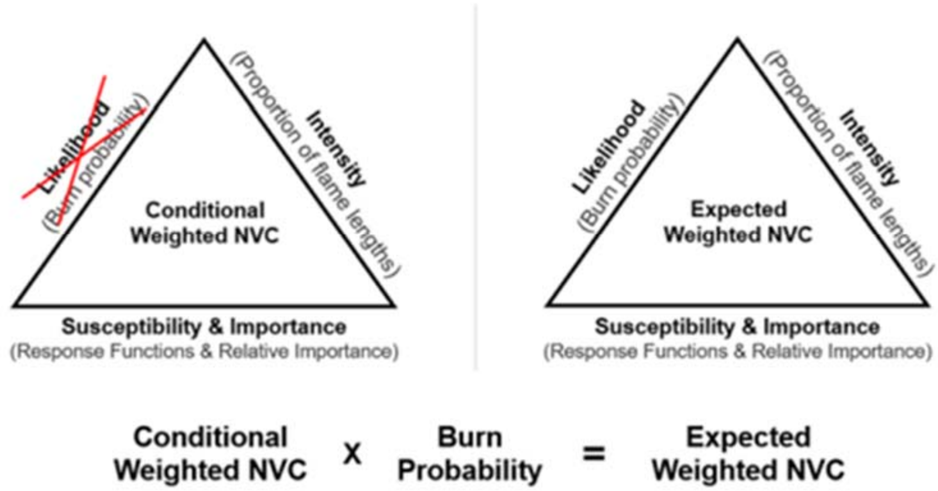

Figure 5-0-16.

Conditional Weighted NVC: This dataset highlights the NVC to the HVRAs with the assumption that fire will happen (Burn Probability=1.0). This can be useful in areas with greater frequency of fire. It is expected that eventually the entire project area will burn. In the case of Park City, with less fire history and many values at risk of any intensity wildfire, leaving Burn Probability out of the equation is not useful for strategic planning.

Expected Weighted NVC (eNVC): This dataset is the product of Conditional Weighted NVC and Burn Probability. According to IFTDSS, it is the single best dataset to use for identifying areas to conduct hazardous fuels treatments. It allows land managers to better understand where to focus mitigation and strategic planning efforts to lower risk, improve forest health, and increase the overall resilience of the community and surrounding environment. This was the dataset carried forward in the subsequent implementation chapter to prioritize treatment areas for Park City Municipal Corporation.

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6.0 Planning and Resources

In This Chapter

6.1 Implementation Planning

Executive Summary

The Community Wildfire Risk Assessment (CWRA) follows guidance provided by the National Cohesive Wildland Fire Management Strategy, also known as "The National Strategy." This strategy describes ways that local governments and residents can make their community safer. This chapter focuses on the "Resilient Landscapes" goal for lands owned by Park City Municipal Corporation (PCMC) within the project area. Within this goal, fuel treatments are recommended as a way to change fire behavior. Treatments can help safeguard community assets and values by aiding in fire control during a wildfire.

The National Strategy calls for the prioritization of fuel treatments to reduce fire intensity, structure ignition and extent of overall damage to communities. Anything that can burn is fuel for a fire. Fuel treatments are actions that reduce the amount of material ready to burn. This means any plant material such as grasses, shrubs, trees, dead leaves and pine needles can help a fire spread. When these materials pile up over time, fires can burn hotter, larger, longer and faster, making control of fires more difficult and dangerous (U.S. Department of the Interior, 2022).

PCMC has an opportunity to directly affect fire behavior and its effects simply because the city owns so much land. City-owned lands account for 5,898 acres. This represents approximately 18% (or nearly 1 of every 5 acres) of the total project area. Further analysis of PCMC and other lands across the four zones indicates a strong need for fuel treatments. A lack of vegetation management over the past few decades coupled with high forest cover indicates that there are more than 2,700 acres of PCMC-owned land at high-priority levels. An additional 2,400 acres of PCMC-owned land was categorized as medium to lower priority. These areas may be treated after the high-priority areas are complete, or there may be areas where maintenance treatments may keep the impacts from fire low.

Objectives for treatments fall into two general categories focused on: 1) wildland-urban interface (WUI) and 2) natural resources. The WUI treatments would address the direct protection of homes, businesses and other structures. Conversely, treatments designed to enhance natural resources would benefit from fire or fuel treatments to restore benefits of fire to ecosystems. Treatments in certain areas may benefit both objectives.

A combination of findings from other reports within the CWRA, fire modeling, the Quantitative Wildfire Risk Assessment (QWRA) and field work have resulted in a roadmap for where and how city managers should focus forest restoration and fuel reduction projects. This information was analyzed and mapped with geographic information systems (GIS). A team of subject-matter experts developed a prioritization method and interpreted model outputs. Additional findings from field surveys were all compiled to form implementation plans.

In wildfire risk management, higher integrated risk and more aggressive fire behavior is generally associated with forested/vegetated areas. ESRI ArcGIS Pro was used in order to extract information about integrated risk and expected net value change from the QWRA outputs. This information was applied to areas of treatable (i.e., forested) land on PCMC-owned properties. This process identified priority areas for fuel treatments categorized from lowest to highest priority.

Field visits to PCMC-owned lands provided current information about which plant or tree species occur and the general health of forests. Satellite-derived data (e.g., LANDFIRE) is useful for modeling and telling us where conifer or deciduous forests occur. However, this computer-derived data is implemented at the landscape-scale. We utilized on-the-ground observations to collect more reliable descriptions of tree species, tree size, tree density, growth under overstory canopies and the presence of insects and disease.

The implementation plans frame the outputs of the QWRA in prioritization values, creating a prioritization model for PCMC lands. They also apply modeled outcomes to the existing conditions observed in the field, developing resources and recommendations for the city as well as community stakeholders.

Background

The impacts caused by wildfires to human life, property, wildlife habitat and water resources have increased in the last few decades. Communities in the wildland-urban interface (WUI), like Park City, are becoming increasingly at-risk as development expands further into surrounding natural areas. These adjacent wildlands are burning at high intensities and the result is more lives in danger, structures lost and impacts to valuable ecosystems that support wildlife and water resources.

The Community Wildfire Risk Assessment (CWRA) follows the framework provided by the National Cohesive Wildland Fire Management Strategy, also known as “The National Strategy.” It describes ways that local governments and residents can make their community safer. This chapter focuses on actions PCMC can take to support the “Resilient Landscapes” goal. Within this goal, fuel treatments are used to reduce the likelihood of high-intensity wildfire and reduce potentially negative impacts, slow rates of spread and aid in containment efforts.

Fuel treatment planning for the Park City-owned land includes:

1. Prioritizing where fuel treatments should take place. This is a quantitative analysis derived from the QWRA (Chapter 5) and treatable acreage that includes forest vegetation.
2. Field observations by technical specialists used to validate findings from modeling software. These field surveys provide more context about the relative wildfire risk.
3. Information about fuel treatment types, how they may benefit the community and ways to protect valuable assets and resources during implementation.

Wildfire Risk

Summit County, Utah, is listed as high priority for broad-scale fuels management and community planning and coordination within the National Strategy. This places an emphasis on managing fuels around communities where there is a threat from wildfire, where there exists fire-adapted vegetation and where communities are concentrated with a broader wildland landscape (National Strategy).

How Park City Municipal Corporation (PCMC) Can Address Wildfire Risk

PCMC owns 5,898 acres within the 33,074 acres of the project area (See Table 6-1). This area represents approximately 18 percent (or nearly 1 in every 5 acres), allowing the city a unique opportunity to directly address the threat of catastrophic wildfire impacts to the community. The size of parcels ranges from less than one acre to 1,534 acres. Many of these parcels are adjacent to one another, creating large blocks of continuous city property.

Table 6-1. Land ownership in the project area.

LAND OWNERSHIP	ACRES	PERCENT OF PROJECT AREA
Park City Municipal Corporation (open space, conservation easements)	5,898	18%
Landowners who own more than 10 acres (low density WUI, resorts, etc.)	14,329	43%
Small landowners (less than 10 acres), includes medium to high density WUI	12,847	39%

Well planned fuel treatments may also mitigate the potential for post-fire effects to over one thousand homes or businesses, wildlife habitat, riparian areas and other valuable resources described in other reports within the CWRA.

What is the need for fuel treatments around Park City?

There is a need to address wildfire risks in every zone in the project area. This need, however, varies across the project landscape and can include factors beyond implementing fuel treatments. Each zone has differing objectives in what fuel treatments would achieve based on the resources at risk, forest and vegetation characteristics, and how much land is owned by PCMC (Table 6-2). GIS-derived priorities provide systematic and quantitative prioritization. However, further evaluation during field surveys offers refinement of priorities at the zone-scale based on these varying characteristics.

Primary objectives considered:

1. Community protection (“WUI”) mainly targets the protection of homes, businesses, and important city infrastructure.
2. Increasing the ability for forests, streams, wildlife, and other natural resources to withstand or bounce back from fire (“Natural Resources”) or,
3. A combination of WUI and natural resource protection.

Table 6-2. The amount of PCMC-owned lands by zone, extent of PCMC influence on the landscape, and primary treatment objectives.

Zone	Zone Area (ac)	PCMC Owned Land (ac)	Percent of Total Area Owned by PCMC	Primary Treatment Objective	Description
Round Valley	7392	2431	32	WUI	Home and business protection, wildfire response review
Deer Valley	9163	1018	11	WU	Home, business and resort protection
Bonanza Flat	7255	1534	21	Natural resources	Forests, water and wildlife would benefit from fuel treatments or fire; smaller, focused WUI protection
Park City Mountain	8094	790	9	WUI and natural resources	Home, business and resort protection; protect city water supply

Community Support for Using Fuel Treatments to Address Fire Risk

In general, fuel treatments are supported by residents and stakeholders in the community as represented by the community survey (Chapter 3.0). This presents a major opportunity for PCMC to start planning more fuel treatments. The majority of respondents agreed with the use of prescribed (controlled) burning, cutting or limbing trees or other wildfire risk-reduction activities. Furthermore, a group of stakeholders involved in the process broadly expressed their support for a variety of measures, including fuel treatments, to safeguard important HVRAs.

How Fuel Treatments Work

The National Strategy (2011) calls for the prioritization of fuel treatments to reduce fire intensity, structure ignition and the extent of overall damage to communities. Anything that can burn is fuel for a fire. Fuel treatments are actions that reduce the amount of material ready to burn. This means any plant material such as grasses, shrubs, trees, dead leaves and pine needles can help a fire spread. When these materials pile up over time, fires can burn hotter, larger, longer and faster. This makes control of fires more difficult and dangerous (U.S. Department of the Interior, 2022).

The three primary means of managing fuels are prescribed fire, managing wildfire and non-fire treatments involving mechanical (e.g., thinning), biological (e.g., grazing) or chemical (e.g., herbicide) methods (The National Strategy). There is a need to use these actions where economically viable and where they meet landowner objectives. It will also take the active involvement of community members to promote wildfire mitigation strategies.

It is not a one-size-fits-all plan, but one that recognizes the need for communities to assess their wildfire hazards from the inside out, from urban areas to surrounding wildlands. The CWRA only covers the use of prescribed fire and using non-fire treatments. Managing wildfires is outside the scope of this document (The National Strategy).

There are numerous examples of how fuel treatments have helped to reduce fire intensity, aided in fire control and prevented loss of life and property across the western U.S. (Buffalo Fire in CO, 2018; Golf Course

Fire in CO, 2018; Wallow Fire in AZ and NM, 2011; San Juan Fire in AZ, 2014; Angora Fire in CA, 2007; East Troublesome Fire in CO, 2020). Regionally, completed fuel treatments on lands administered by the Bureau of Land Management in Utah resulted in reduced fire behavior in areas where wildfires crossed those treatments. This was demonstrated through ongoing monitoring and data logging from sites. Furthermore, it has been found that treatments are more likely to result in benefits that exceed costs, such as minimizing post-fire damage to infrastructure and reducing the likelihood of post-fire debris flows (Hunter and Taylor, 2022; Sediment Delivery Report).

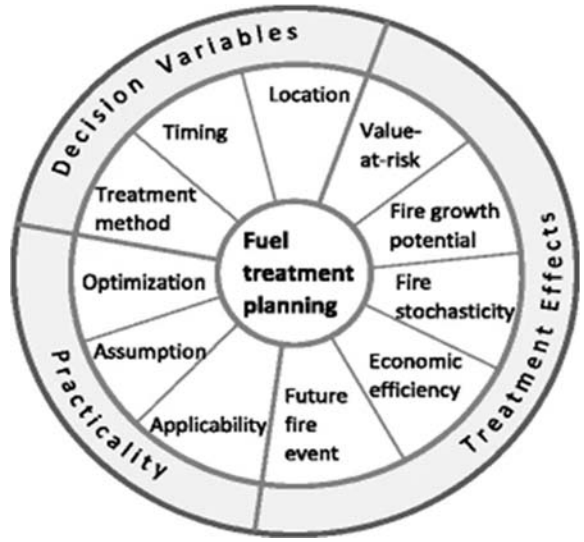

Figure 6-0-1. The complexity of decision making in designing fuel treatments (Chung, 2015).

Studies show that fuel treatments are effective at reducing the rate of spread, extent and severity of wildfires within and outside treated areas. Fuel treatments were found to help reduce the cost of suppression activities by changing fire behavior (Jain et al., 2021). Fuel treatment effectiveness is also based on the types (thinning, burning or a combination of both) and longevity of treatment. Vegetation patterns, topography, climate, spatial organization and extent of treatments, fire behavior and timing, and fire weather during the event also play a part (Jain et al., 2021; Ott et al., 2023; Kalies and Yocom, 2016; Martinson and Omi, 2013; Prichard et al., 2020; Prichard et al., 2021; Moghaddas et al., 2010).

Further research has shown that smaller, but strategically placed, treatments on a fraction of the landscape can reduce fire spread across the greater area (Tubbesing et al., 2019). This shows that while the effectiveness of fuel treatments is based on a complex web of interconnected factors (Figure 6-0-1), the careful planning of treatments may result in positive outcomes for communities.

Fuel Treatment and Benefits to Humans and Natural Resources

The benefits to communities do not stop with the containment of wildfires. Treatments may produce positive outcomes to forests and other resources across a wide range of climates and landscapes, even in the face of climate change (Burke et al., 2020; Sohn et al., 2016). Fuel treatment activities may:

- Reduce the amount of fuel ready to burn and emit less smoke than wildfires (Liu et al., 2017)
- Affect fire intensity while providing critical wildlife habitat and protecting water resources (Kennedy and Johnson, 2014; Stream Conditions Report; Dwire et al., 2016)
- Minimize long-term impacts to soils (Alcañiz et al., 2017)
- Decrease the susceptibility of forests to drought, insects and disease and undesirable fire effects (The National Strategy, 2016 Environmental Protection Agency).

Methods

Foundational Goals

GIS data from the QWRA (Chapter 5) and field surveys were utilized in evaluating the need for forest restoration and fuel treatments across the project area. These tools also support the development of methodology for setting priorities. The resulting data will provide a roadmap for city managers and local land managers identifying where forest restoration and fuel treatments projects may have the greatest impact.

Other aspects considered in treatment planning included information from the following:

- Avalanche Terrain Assessment
- Post-fire Sediment Delivery
- Stream Condition Surveys
- Fire Behavior Model Outputs.

Field Surveys

Field visits to PCMC-owned lands were completed in 2022 and 2023. These visits provide validation of fuel models and the general health of forests. Remotely-sensed data (e.g., LANDFIRE) is useful for modeling and differentiating forest types across at a landscape scale. However, ground-truthing or manual edits to input fuel models are integral components of fuels and fire behavior modeling. This satellite-derived data is not intended to be used for high-resolution detection of on-the-ground forest conditions (i.e., individual tree species, tree size, stem densities, understory composition and presence and diagnosis of insects and disease). Information from field visits can supplement quantitative prioritization methods. They will assist with continually refining priorities for fuel treatments across the project area moving forward through implementation and individual project planning.

Verification of modeling accuracy was completed by collecting field data to determine:

- Fuel loading (e.g., descriptions of what fuels and fuel loading looks like such as logs or branches),
- Types and abundance of plant and tree species,
- Tree density (how many trees are growing in an area),
- Tree mortality (dead trees that contribute to current and future fuel loading),
- Tree regeneration (seedlings)
- Forest health issues (insects and disease, or weather-related die off)

These estimates captured information in targeted areas that were representative of the larger landscape. “Walk-through” field visits would be considered a biased sample because the sample is not random or statistically accurate. However, they provided valuable information about overall forest conditions at a larger scale.

Equipment used for informal surveys included ESRI Field Maps software to locate photo points and add descriptions of forested areas. The data recorded in field mapping software included species composition, estimates of tree density in a basal area and trees per acre (using an angle gauge and logger’s tape), and tree size using a diameter tape.

Figure 6-0-2. Heavy conifer fuel loads located east of Bloods Lake on the Bonanza Flats parcel - identified in Fuel Models as Mixed Conifer Forest and Woodland (###) - September 2022.

These field reviews either confirmed or changed conclusions about high-risk areas from modeling software, mapping and other reports in this risk assessment. Modeling and remotely-sensed data contain some amount of error. Personal knowledge of the area helps refine the message of what the modeled data is telling us. The information gathered during field visits generally supported the reports, modeling and mapping to-date, but went one step further in determining additional details regarding fuel treatments over time. This does not provide exact acreages or boundaries of potential treatments, rather it validates prioritization methodologies and further identifies parcels needing more immediate attention versus others that could be treated in future years.

There are many ways to determine the need for fuel treatments across a large landscape. Using all available tools such as reports, reviews, additional mapping, and field visits refined our key findings for priority treatments. This is designed to be a more holistic approach, considering many different outcomes to prepare for wildfire.

GIS Methodology

Expected weighted net value change (eNVC), outlined in Chapter 5.0, quantitatively identifies how wildfire may affect any point within the project area, both negatively and positively. The eNVC values include negative values (threat) and positive values (benefit) and are displayed categorically. Fuels and fire experts, in conjunction with GIS technicians, recognize that **areas of high threat or high benefit should be targeted, as forest restoration and fuel treatments in both of these areas will have the greatest impact to overall forest health and wildfire resiliency.**

Negative pixel values (threat) for eNVC were converted to positive values and are displayed in conjunction with areas of benefit as a 'prioritization value' dataset. The prioritization values remain consistent with the original eNVC output values from IFTDSS, with all values displayed as positive numbers, and can be visualized across the project area independent of parcel ownership.

Using ESRI ArcPro Spatial Analyst, each individual PCMC parcel (as a geospatial feature class) was assigned the following data:

- Mean numerical values for **eNVC 'benefit'** and **eNVC 'threat'**
- **'Cumulative prioritization value' (CPV)**
  Mean Threat Value (eNVC)(-1) + Mean Benefit Value (eNVC)) = Cumulative Prioritization Value*
- **Treatable acreage** within PCMC-owned parcels, i.e., acreage of vegetative cover or combustible fuels available for treatment within each parcel.

Table 6-3. The highest CPV values among the 309 PCMC-owned parcels and associated stored data (see Table 6-12 for full parcel list).

Parcel ID	Location	Parcel Acreage	Treatable Acreage (est.)	Mean Threat Value E(wNVC)	Mean Benefit Value E(wNVC)	Cumulative Prioritization Value
PC-224-B-X	Prospector Ridge	8.6	3.8	-78.0	1.54	79.5
PC-364-A	Treasure Hill	60.8	59.2	-76.5	1.94	78.5
THILL-5-X	Treasure Hill	42.6	30.4	-42.9	1.8	44.7

The cumulative (summation) method for CPV calculation weighs priority of parcels that meet the following criteria:

- Parcels with the highest values of threat
- Parcels with the highest values of benefit
- Parcels with medium to high values of both benefit and threat

Based on CPV, PCMC-owned parcels were distributed equally (quantile distribution) into five categories ranging from 'highest priority' to 'lowest priority' (Table 6-4).

Table 6-4. Five categories of PCMC-owned parcels ranging from 'highest' to 'lowest' priority.

Category	Description
Highest Priority	PCMC owned parcels in the 80th percentile or greater for 'Cumulative Prioritization Value'
Higher Priority	PCMC owned parcels within the 60-80th percentile for 'Cumulative Prioritization Value'
Medium Priority	PCMC owned parcels within the 40-60th percentile for 'Cumulative Prioritization Value'
Lower Priority	PCMC owned parcels within 20-40th percentile for 'Cumulative Prioritization Value'
Lowest Priority	PCMC owned parcels in the 20th percentile or below for 'Cumulative Prioritization Value'

Key Findings

City and stakeholder land managers need to know: Where do we start? This can be overwhelming when faced with many options to reduce the threat of fire with fuel treatments. It takes time to enact change, acquire the needed funding and to find people to do the work. In addition, implementing effective fuels treatments may require cross-boundary partnerships among multiple landowners to best serve the goals of the greater community.

Project-wide Prioritization

'Prioritization values' create a visual representation of priority, incorporating both values for threat and benefit. This will allow land managers access to the QWRA results for their own project prioritization purposes, as well as to visualize opportunities to work towards implementation of cross-boundary forest restoration and fuel-treatment projects with their neighboring land managers.

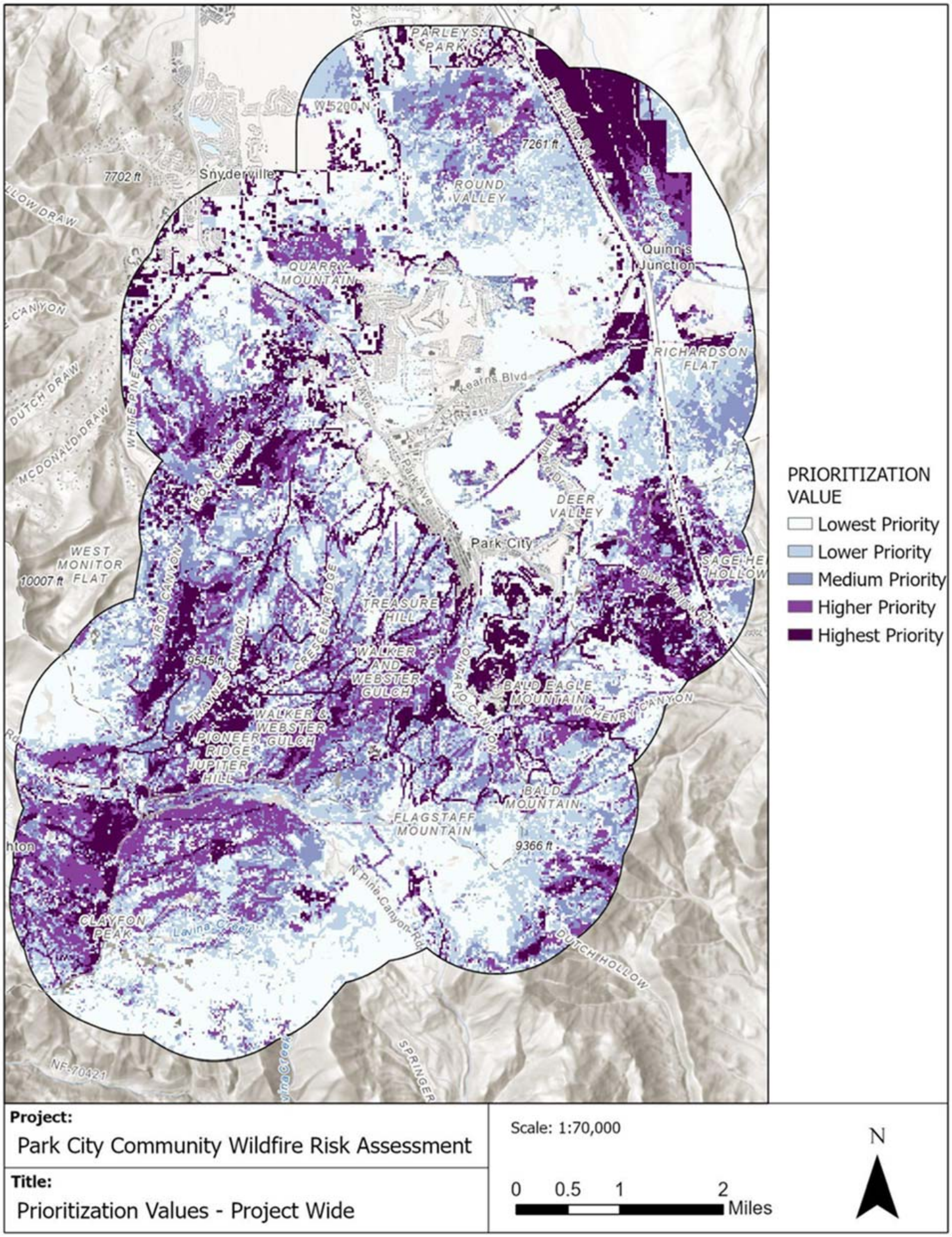

Figure 6-0-3. Prioritization values across the project area.

Prioritization of PCMC-Owned Lands

'Cumulative prioritization values' and subsequent categorization for each PCMC-owned parcel identifies parcels that meet the following criteria:

- Parcels with the highest values of threat
- Parcels with the highest values of benefit
- Parcels with medium to high values of both benefit and threat

Table 6-5. Distribution of PCMC-owned parcels among the five categories of CPV and parcels that were deemed 'non-burnable' by either the IFTDSS fuel model or a higher-resolution custom PCMC vegetation map.

PRIORITY LEVEL	NUMBER OF PARCELS	TOTAL ACRES	TOTAL TREATABLE ACRES
Highest Priority	14	492	410
Higher Priority	16	2,288	1,487
Medium Priority	17	1,134	731
Lower Priority	15	730	374
Lowest Priority	16	502	374
No Priority (Non-Burnable)	229	741	--

Parcel prioritization based on CPV is included in Table 6-12. Additional data associated with each parcel allows for reorganization as needed, based on other criteria (i.e., treatable acreage) for project scaling and budgetary planning. It's important to note that the majority of CPV values are derived from mean 'threat,' as the majority of HVRAs identified within the PCMC QWRA are negatively influenced by wildfire at varying intensities.

Table 6-6. Top 10 'cumulative prioritization values' among PCMC-owned parcels.

PARCEL ID	LOCATION	PARCEL ACREAGE	TREATABLE ACREAGE (EST)	'CUMULATIVE PRIORITIZATION VALUE'	RANK
PC-224-B-X	Prospector Ridge	8.6	3.8	**79.5**	1
PC-364-A	Treasure Hill	60.8	59.2	**78.5**	2
THILL-5-X	Treasure Hill	42.6	30.4	**44.7**	3
MCL-A-X	McLeod Creek	3.1	1.4	**30.7**	4
WLR-A-X	Willow Ranch	10.3	1.4	**22.2**	5
PCA-7-1-A-X	'Guardsman Connector'	1.5	1.5	**18.2**	6
PC-S-55-X	Empire Canyon	1.7	1.7	**18.1**	7
PCA-103-C-X	Willow Ranch	27.5	4.4	**12.4**	8
PP-25-C	Thaynes Canyon	139.3	139.3	**11.9**	9
PP-25-3-X	Iron Canyon	110	108.4	**114**	10

Table 6-7. Top 10 'Treatable Acres' and associated prioritization among PCMC-owned parcels.

Parcel ID	Location	Parcel Acreage	Treatable Acreage	Cumulative 'Prioritization Vaue'	Prioritization Category
	Bonanza Flat	1,344.1	**1,015.4**	8.2	Higher Priority
SS-57-A-X	Round Valley	368.2	**222.7**	4.7	Higher Priority
PP-25-C	Thaynes Canyon	139.3	**139.3**	11.9	Highest Priority
PCA-62-G-X	Round Valley	208.6	**135.4**	2.2	Lower Priority
PP-26	Richardson Flat	130.2	**115.3**	3.5	Medium Priority
PP-25-3-X	Iron Canyon	110	**108.4**	11.4	Highest Priority
SA-S-35-X	Prospector Pocket Park	112.1	**107.3**	2.2	Medium Priority
SS-62-A-X	Florence Gilmore OS	117.6	**91.1**	2.5	Medium Priority
SA-254-1-X	Aerie Open Space 2	93.9	**87.4**	0.4	Lowest Priority
SS-106-A-X	Iron Mountain	83.2	**83.2**	2.8	Medium Priority

Summary of Key Findings by Zone

Round Valley Zone

The Round Valley zone is the northernmost area in the project boundary where PCMC owns 2,431 acres, or approximately 32 percent of the land area. This zone has the highest number of city-owned acres in the project area. However, there is limited opportunity for fuel treatments compared to the other zones. Fuel breaks should be considered around homes and businesses while a thorough review of suppression tactics and continued community fire prevention emphasis are needed.

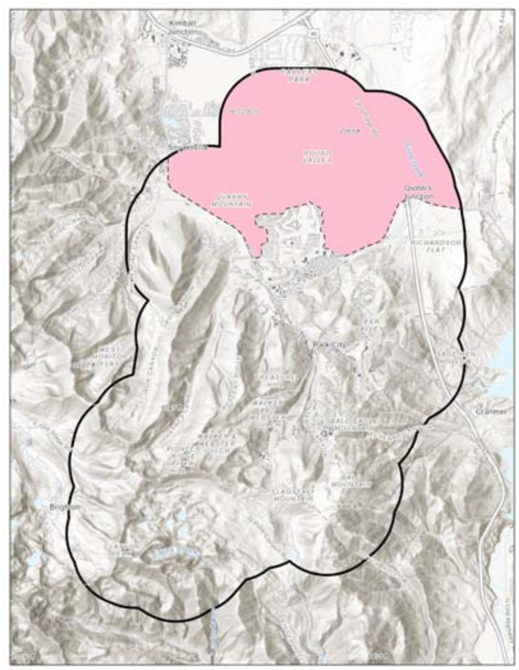

Figure 6-0-4. Round Valley Zone.

Current Condition:

This area has seen a sharp increase in the expansion of the WUI in the past few decades due to its land use, terrain and accessibility. Structures almost fully surround PCMC-owned properties.

This zone and associated PCMC lands can be characterized as being highly exposed to wind. Topography is predominantly gentle and does not have the steep profile like the other three zones. The most abundant vegetation is sagebrush (with cheatgrass potential) and Gambel oak, both of which grow well on these drier sites. A majority of PCMC land here is covered with low-lying, shrubby Gambel oak and sagebrush with smaller areas of taller, tree-like (grows more upright) Gambel oak.

As expected, modeled fire behavior indicates there would be high rates of spread in the lighter, flashier fuels. This is problematic to the structures built on all sides of city parcels. It also poses a risk to other highly valued resources that cross the area. While the lighter fuels can allow for a more effective suppression response, resources need to be in place for initial attack and the potential to burn out where threats to other values are not compromised.

ROUND VALLEY CROSS-BOUNDARY OPPORTUNITIES

Summit County

Utah State University (Swaner)

Snyderville Basin Recreation

Park City School District

Priority Treatment Areas in Round Valley:

QWRA data indicates that most of the PCMC-owned lands in Round Valley are mostly middle to highest threat due to the modeled fire behavior, vegetation, highly valued resources and assets, and the surrounding wildland-urban interface. Although a need exists for treatment in this zone, there are fewer options for fuel treatments when compared to other areas due to the type and structure of the vegetation (i.e., grasses and sagebrush).

Table 6-8. Top five priority PCMC-owned parcels within the Round Valley zone.

Parcel ID	Location	Parcel Acreage	Treatable Acreage	Cumulative 'Priority Value'	Category	Overall Project Ranking
MCL-A-X	McLeod Creek Sub.	3.10	1.45	30.68	Highest Priority	4
WLR-A-X	Willow Ranch Sub.	10.29	1.37	22.18	Highest Priority	5
PCA-103-C-X	Willow Ranch	27.45	4.38	12.43	Highest Priority	8
SS-57-2-A	Round Valley	29.07	11.50	7.37	Highest Priority	16
PCA-18-A-X	Quarry Mtn	22.62	13.98	7.20	Highest Priority	17

There are areas where specific treatments may be applied with good success, but this is generally limited across the Round Valley zone. The application of fuel breaks can provide some buffer between structures and vegetation. Another example is the Willow Creek Ranch parcels. These parcels, located adjacent to Hwy 224 and Meadows Dr., are considered “highest priority” due to the water resources and fire adapted conservation values of the area, but treatment options are limited within these riparian areas.

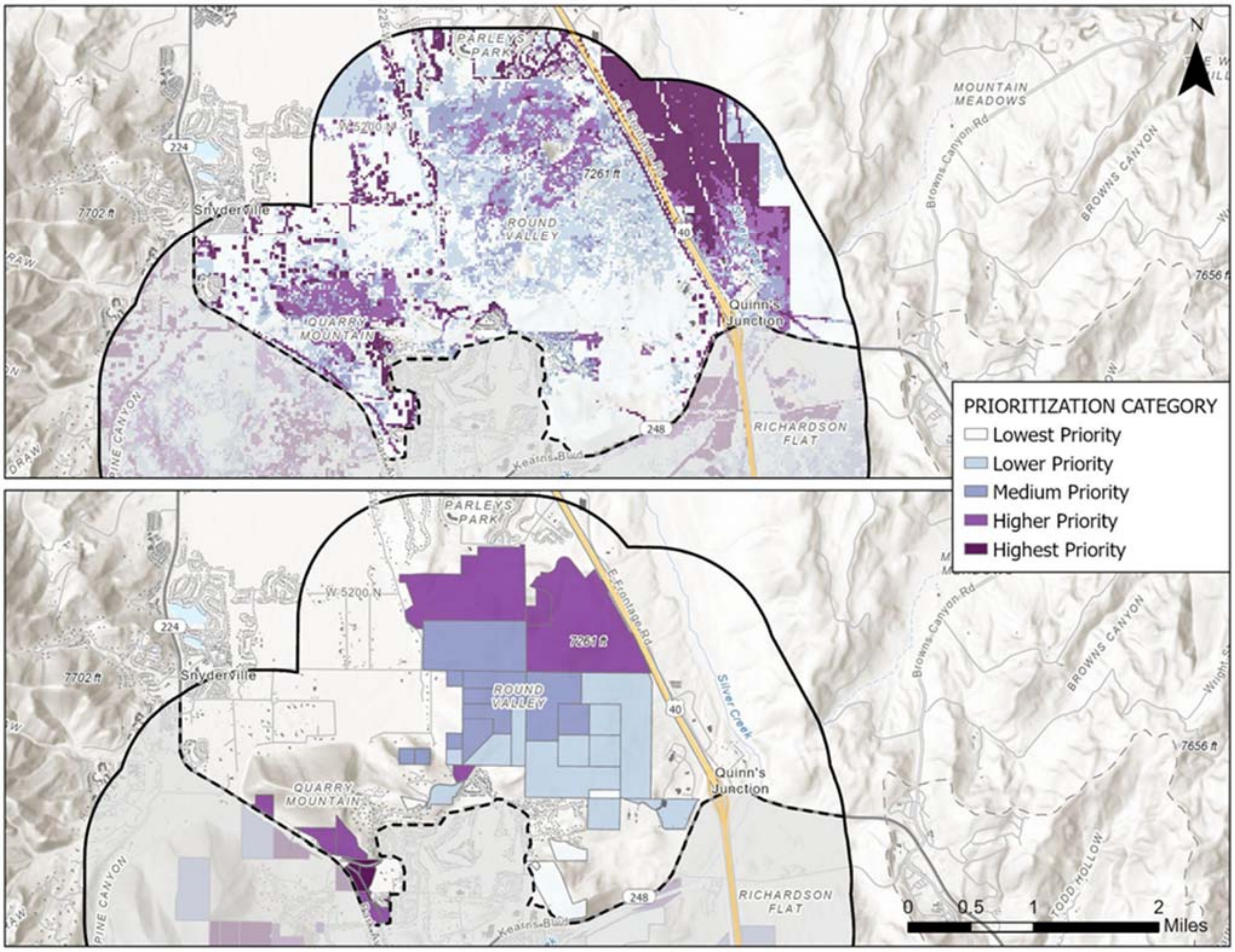

Figure 6-0-5. Distribution of prioritization values (top) and PCMC-owned parcel prioritization (bottom) within the Round Valley zone.

Deer Valley/Deer Crest Zone

The Deer Valley/Deer Crest zone ('Deer Valley zone') is the eastern portion of the project area and contains 1,018 acres of PCMC-owned land. There is a need to implement fuel treatments to protect the dense WUI areas built both within steep canyons and along ridgelines. The largest landowner is Deer Valley Resort, who owns and leases its lands for snow sports in the winter and multiple use trails in the summer. It is especially important to highlight that Deer Valley Resort manages or owns most of the conifer and deciduous forest within the zone, where they have undertaken small-scale management activities since the 1980s

<u>Current Condition</u>:

This area is defined by its varied topography, both steep and gentle elevation profiles, and the significant amount of medium- to high-density WUI. Expansion of the WUI has been somewhat constrained by ownership and land use (ski resorts). However, topography has not been a limiting factor as residential, hotel and resort structures have been built within tight canyons and on ridgelines.

The infrastructure located here is of high economic value, both in building material and the tourism economy.

The small, narrow and winding roads with dense shrub and tree vegetation may present real challenges in these dense WUI areas during a wildfire evacuation. The main roads within this zone are often congested during normal summertime activities.

This zone includes all vegetation types growing along a wide range of elevations and aspects. They include: low-lying sagebrush areas near Highway 40, Gambel oak and mixed conifer-hardwood forest in the mid elevations, areas on Bald Mountain where limber pine grows on rocky soils with little surrounding vegetation. Each of these vegetation types has a different fire regime, though fires in each often affect neighboring vegetation.

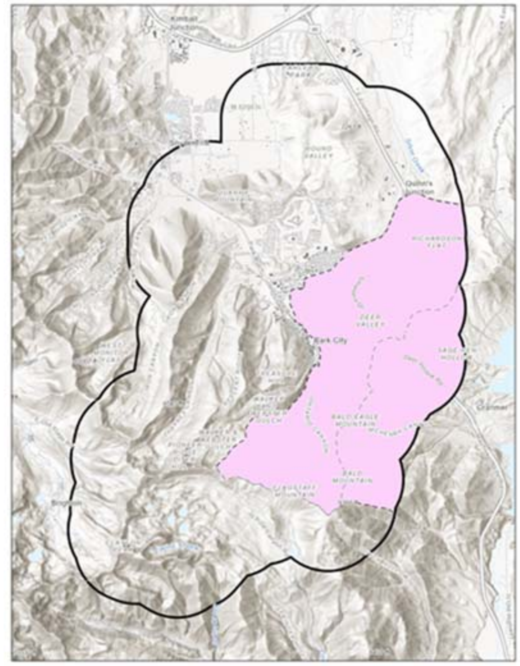

Figure 6-0-6. Deer Valley/Deer Crest Zone.

Adjacent (westside) to Highway 40:

The city owns close to 260 acres of land between Highway 40 and the Morning Star and Park City Heights subdivisions. The PCMC parcels are ranked as mostly middle to highest in terms of integrated risk of fire. Despite a ‘medium priority' ranking, short-term fuel treatment will serve as some protection from ignition caused by traffic on Highway 40.

The elevation profile and the frontage along Highway 40 present a difficult problem for this zone. Probability of ignition along Highway 40 is elevated and any fires that start in this lower, drier vegetation may gain momentum and run upslope into deciduous and conifer forests. Upslope vegetation is fragmented by roads and ski terrain. However, these roads and ski runs may not stop fire spread, but could provide better access to areas and allow for the use of snowmaking infrastructure to aid in suppression.

The vegetation is Gambel oak-dominated with sagebrush on the lower slopes adjacent to the highway (with and without cheatgrass potential). There is a risk of invasive vegetation - cheatgrass and another invasive, Dyer's Woad, have already been found in this area.

There remains lengthy frontage landscapes along the highway corridor owned by private landowners where PCMC activities will have no effect on fire behavior.

Solamere/Aerie:

The largest block of city-owned land is located around and between the Solamere and Aerie neighborhoods. The area is covered in dense, mixed hardwood vegetation and shrubs with small patches of conifer, aspen, grasses and sagebrush.

Integrated risk for most PCMC-owned lands is lowest to low hazard. However, field surveys of this area conclude that the model may be underestimating risk on the north-facing slope below the Aerie neighborhood.

The homes on Aerie Drive and Mellow Mountain Road are built at the slope break of steep terrain and have a continuous, thick layer of mixed hardwood and shrub vegetation downslope.

Smaller properties owned by PCMC:

Due to a relative lack of PCMC-owned parcels, there is less opportunity to reduce the risk of fire and negative resource impacts around Daly Canyon, Empire Canyon, Rossi Hill, Bald Eagle Mountain, Ontario Canyon and Glencoe Canyon. These areas are at high risk for sediment delivery following a fire, if one occurs (Sediment Delivery, Resilient Landscapes - Chapter 2.0). The development in these areas consists of high-density WUI with many small landowners/condominium/single residences and large tracts of open land under lease for ski operations by Deer Valley and Mayflower resorts. Modeling shows fire behavior in this zone has a greater potential for high intensity fire with higher potential for crown fire, faster rates of spread and long flame lengths.

DEER VALLEY CROSS-BOUNDARY OPPORTUNITIES

Solamere

Deer Valley Resort

Mayflower Resort

Deer Crest HOA

MIDA

Bald Eagle HOA

Priority Treatment Areas:

Mapping indicates that most of the PCMC-owned lands in the Deer Valley zone are mostly middle to highest threat due to the modeled fire behavior, vegetation, highly valued resources and assets, sediment delivery potential and the surrounding wildland-urban interface.

The highest priority parcels in the Deer Valley Zone are listed in Table 6-9.

Table 6-9. The top five prioritized PCMC-owned parcels within the Deer Valley/Deer Crest Zone.

Parcel ID	Location	Parcel Acreage	Treatable Acreage	Cumulative 'Priority Value'	Category	Overall Project Ranking
PC-224-B-X	Prospector Ridge	8.6	3.8	79.5	Highest Priority	1
PCA-7-1-A-X	Guardsman Connector	1.5	1.5	18.2	Highest Priority	6
RO-OPEN-X	Royal Oaks Sub. Ph. 1	3.8	2.4	8.3	Highest Priority	14
PCA-S-98-II-X	Montage Water Tank	3.0	1.7	5.5	Higher Priority	20
PCA-S-46-98-X	Ontario Mine	23.2	10.4	5.4	Higher Priority	21

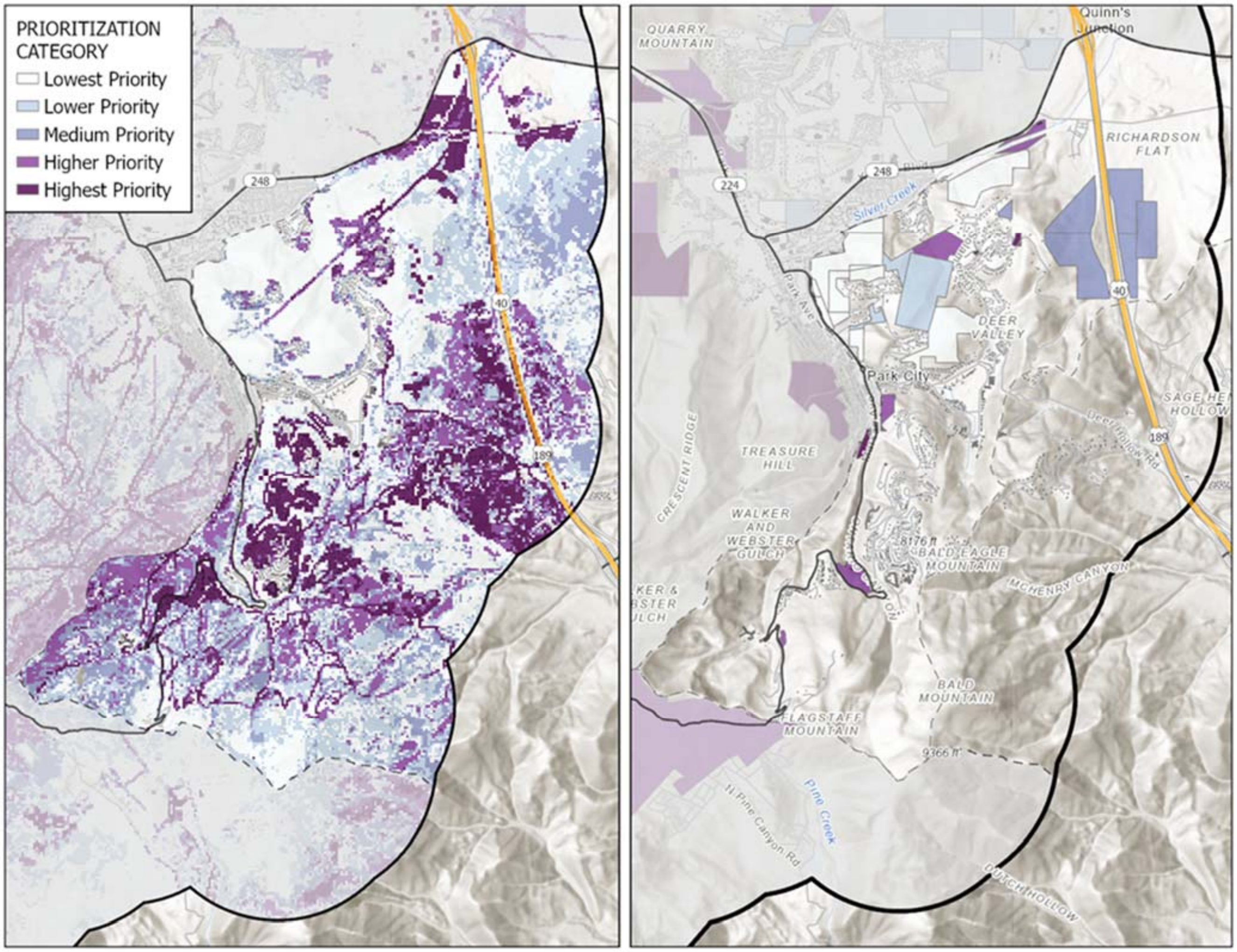

Figure 6-0-7. Distribution of priority values (left) and PCMC-owned parcel priority (right) within the Deer Valley/Deer Crest Zone.

Many of the parcels in this zone are relatively small in area. Even so, small-scale fuel treatments on PCMC-owned parcels targeting WUI protection could be implemented downslope of developments (e.g., below Rossi Hill) to maintain a low integrated risk over time.

There are significant forest health issues in and around Daly Canyon, apparent due to the abundance of dead and dying conifers covering the canyon slopes.

Bonanza Flat

The Bonanza Flat zone covers the southernmost portion of the project area and contains 1,534 acres of PCMC-owned land within a single parcel. The Bonanza Flat Conservation Area Adaptive Management and Stewardship Area Plan (2019) sets forth the vision and management strategies for this area. A key tenet of this plan is the need to improve and maintain the area's diversity. Active management techniques (e.g., thinning, burning, etc.) for vegetation communities is permitted.

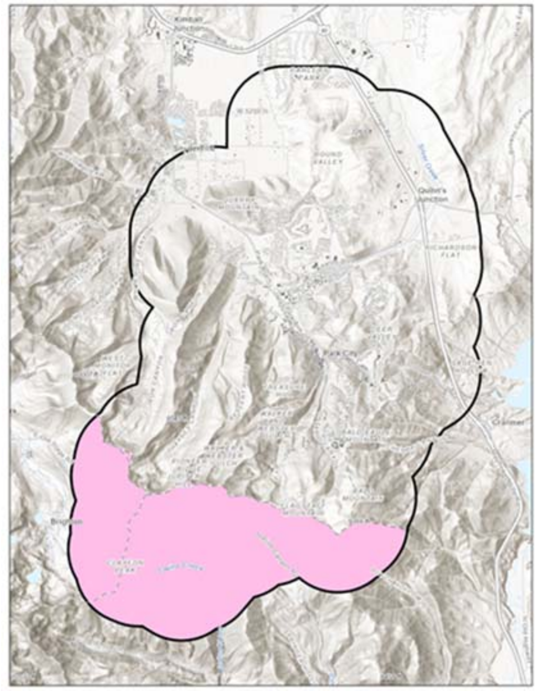

Figure 6-0-8. Bonanza Flat Zone.

Fuel treatment objectives in this zone would primarily benefit the natural resources of the area. The area of WUI is much smaller when compared to other zones, but small-scale fuel treatments would help protect Brighton Estates and Camp Cloud Rim (Girl Scouts of America).

<u>Current Condition</u>:

This area consists primarily of aspen and high elevation conifer forests growing on gentle to steep terrain, but the vegetation is widely variable throughout the zone (Figure XX). The slope gradient steadily increases towards the south and west where rocky mountains and ridges tower over the area.

Most of these steep areas are potential avalanche release zones. Limber pine grows along the bare ridgetops where this zone meets the Deer Valley and Park City Mountain zones. A reservoir lies in the southeast and a series of lakes dot the interior portion of the zone, surrounded by large spruce trees. Forest health issues affect all tree species here, but mainly subalpine fir with lesser damage to spruce and aspen. However, these forest health issues are not as readily visible as in the Park City Mountain Zone. Outside of the aspen groves and extensive conifer forest are areas of grass and sagebrush lining the roads that bring a high number of visitors to enjoy the scenery here.

There is very little WUI in this zone. The structures in Brighton Estates are directly adjacent to the property boundary and the Camp Cloud Rim is situated in the middle of Bonanza Flat. Limited evacuation options exist and fuel treatments along these routes may create safer conditions for evacuation during a wildfire.

This zone is a high-value water supply area for Salt Lake and Wasatch counties.

BONANZA FLAT CROSS-BOUNDARY OPPORTUNITIES

USFS

USFS (Brighton Ski Resort)

Wasatch State Park

Mayflower Resort

Girl Scouts of Utah

In the past, natural fire impacted this area in a variety of ways, from low-severity to high-severity (stand-replacing) fires that maintained the various forest types and patterns. This is one part of the project area where the expected net value change is largely a benefit to highly valued resources than other zones.

A significant portion of the zone is lower to lowest integrated hazard, the highest being near the Girl Scout camp and lakes, affecting the coniferous forests.

Modeled fire behavior in this zone shows higher intensity fire, with longer flame lengths, higher rates of spread and greater crown fire potential occurring in the conifer forests. On the other hand, the aspen forests are predicted to act more like a fuel break or create conditions for a low intensity fire.

Figure 6-0-9. All vegetation types are represented in the Bonanza Flat zone, from grasses and sagebrush to deciduous and conifer forests.

Aspen forests along south side of 224 and North Pine Canyon roads:

- The sizable aspen groves here are mostly healthy with many ages of trees. Aspen is expected to flourish here for the foreseeable future. It has dominated the site for a long time, even with few disturbances.
- Vegetation closest to the main roads includes a mixture of grasses, sagebrush and aspen groves. Many of the aspen groves adjacent to 224 and portions of North Pine Canyon Road do not contain a lot of conifer encroachment. These stands are more likely to act as “fire breaks” in the event of a fire.

Boundary with Brighton Estates:

- The aspen groves adjacent to Brighton Estates have a significant number of conifers growing underneath the main overstory. These ladder fuels contribute to the potential for crown fire and can complicate the control of a wildfire adjacent to this area of WUI.

The lakes region (Blood’s, Brimhall, Silver Lake Islet):

- The spruce-dominated forests that surround the lakes are more likely to experience a high-severity fire. This could impact Camp Cloud Rim, trail systems, high-use recreation area, and adjacent ski areas (Brighton ski area).

Priority Treatment Areas:

Table 6-10. The single PCMC-owned parcel within the Bonanza Flats zone.

Parcel ID	Location	Parcel Acreage	Treatable Acreage	Cumulative 'Priority Value'	Category	Overall Project Ranking
--	Bonanza Flat	1,344.1	1,015.34	8.21	Higher Priority	15

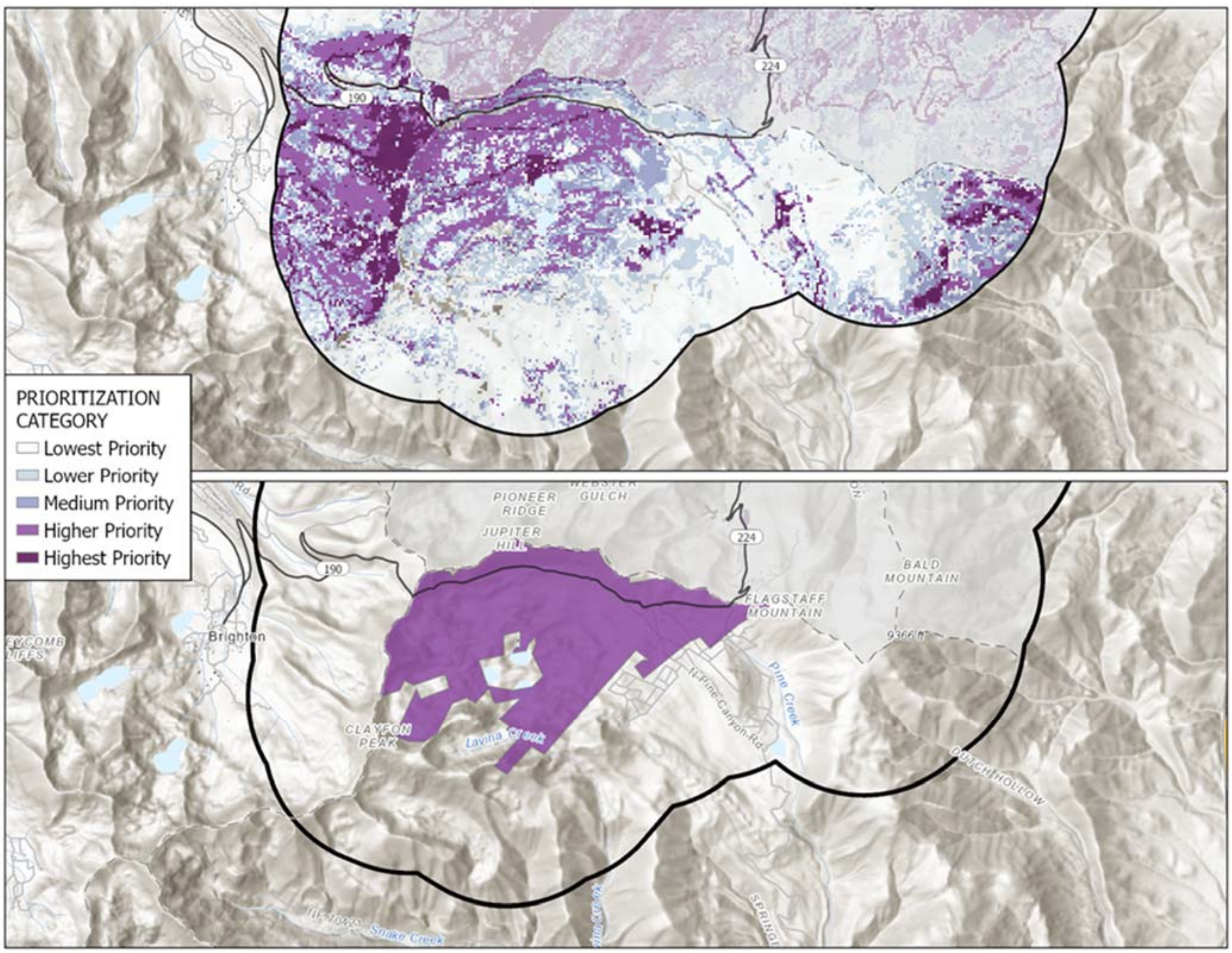

Figure 6-0-10. Prioritization of the single PCMC-owned parcel in the Bonanza Flats zone.

Park City Mountain Zone

The Park City Mountain zone is the western portion of the project area and contains 790 acres of PCMC-owned land, with the largest contiguous portion located on Iron Mountain. This is higher priority for implementing fuel treatments to protect dense WUI areas, the city water supply, ski resort and recreation infrastructure, and address forest health issues.

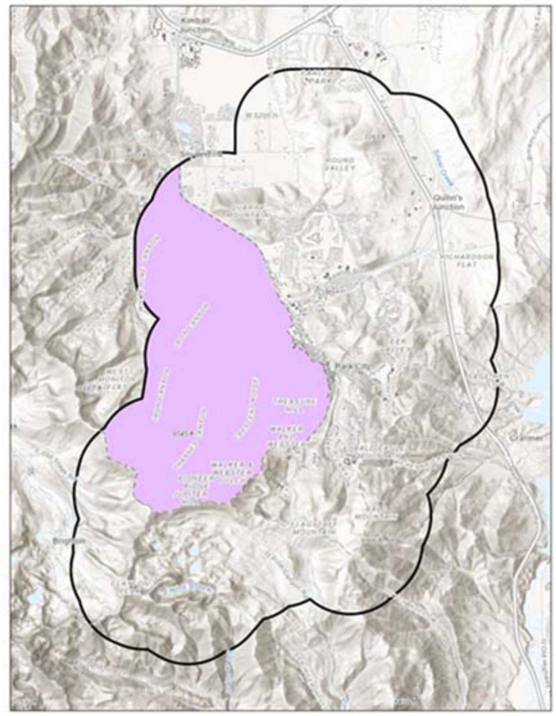

Figure 6-0-11. Park City Mountain Zone

Similar to the Deer Valley zone, the Park City Resort leases a vast expanse of land for snow sports and multi-use trails where most of the forested cover is located. Resort management recently initiated some small-scale forest management projects.

<u>Current Condition</u>:

This zone is dominated by complex terrain with a large elevation profile and steep slopes. Unlike the other zones, this area contains the least amount of gentle topography. Conifer and deciduous forests cover this area and the many dead and dying trees provide evidence of significant forest health issues. In comparison to the other zones, the Park City Mountain area has the most visible forest health issues. In turn, the continuous patterns of forest cover, dead and down trees, and the varied fuel types all contribute to the high fire hazard here.

The Suppression Difficulty Index (SDI) is a product of the Risk Management Assistance (RMA) dashboard from the Wildland Fire Management Research, Development, and Application. It factors in topography, fuels, expected fire behavior under 97th percentile weather conditions, fireline production rates in various fuel types with and without heavy equipment, and access via roads, trails or cross-country travel. The Park City Mountain Zone has the largest percentage rated as highest difficulty (>100) within the analysis area.

PARK CITY MOUNTAIN CROSS-BOUNDARY OPPORTUNITIES

Talisker

Vail Resorts

Iron Mountain Association

The Colony HOA

Utah Department of Natural Resources

Nearly all of the PCMC-owned lands involve open space and much of the city's high value water supply is located here. Many of the canyons in this zone are at an elevated risk of post-fire erosion, potentially affecting the medium to dense WUI below (Sediment Delivery Report). The slopes and canyons are oriented toward Old Town and the Park City Urban core, a high density WUI area. Although the larger zone area contains a lower concentration of hotels and high density WUI overall when compared to the neighboring Deer Valley zone, the infrastructure in this zone is also vital to the town economy. Evacuation of recreation users and residents from developed areas is an important consideration.

All recorded fuel types in the project area are found here. The forests are a dense mixture of conifer and deciduous trees with many ski runs breaking up the forest canopy. Within the mixed conifer stands there is a significant amount of dead and dying trees with high fuel loading in the understory. The potential exists for high-intensity fire across the zone, long-range spotting, and a high suppression difficulty. Very little forest management has been don over the years, although Park City Resort is doing work in some forested areas to enhance ski terrain while removing fuels.

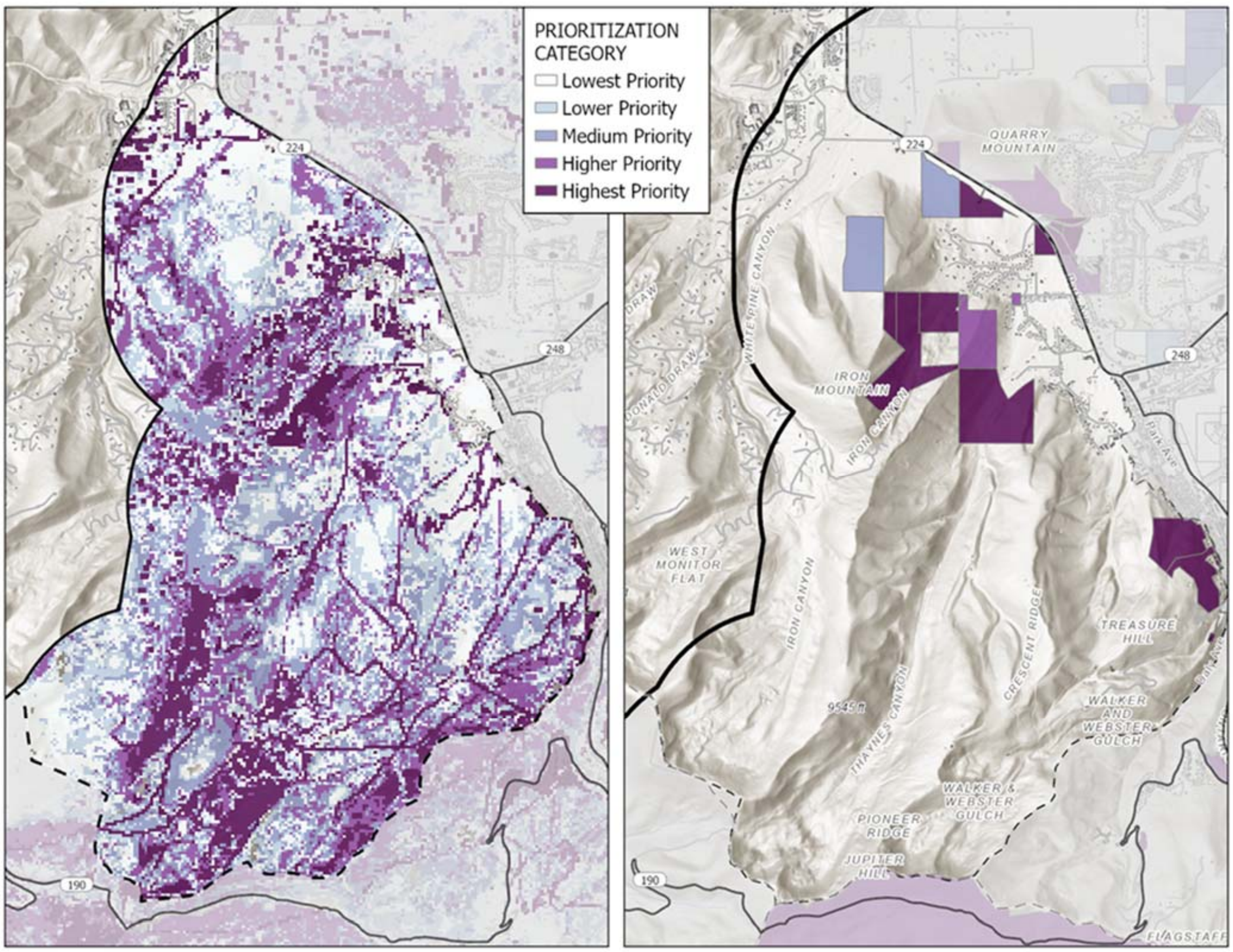

Figure 6-0-12. Distribution of priority values (left) and PCMC-owned parcel prioritization within the Park City Mountain zone.

<u>Priority Treatment Areas</u>:

Table 6-11. Top five rated PCMC-owned parcels by CPV within the Park City Mountain zone.

Parcel ID	Location	Parcel Acreage	Treatable Acreage	Cumulative 'Priority Value'	Category	Overall Project Ranking
PC-364-A	Treasure Hill	60.8	59.2	78.5	Highest Priority	2
THILL-5-X	Treasure Hill	42.6	30.4	44.7	Highest Priority	3
PC-S-55-X	Daly Canyon	1.7	1.7	18.1	Highest Priority	7
PP-25-C	Thaynes Canyon	139.3	139.3	11.9	Highest Priority	9
PP-25-3-X	Iron Canyon	110.0	108.4	11.4	Highest Priority	10

Major findings on PCMC lands from field surveys are detailed below.

Iron Mountain:

Priority values are high in this area based on the eNVC being mostly higher or highest threat. Integrated risk is mainly higher to highest hazard in the parcels closest to WUI. The remaining parcels are a mix of low to highest integrated risk.

Figure 6-0-13. View of the conifer and deciduous forests in the Iron Mountain parcels.

- A variety of vegetation types grow on this property. Large swaths of aspen, patches of large, healthy conifers, sprawling Gambel oak (both shrub and tree form) and mixed shrub (mountain mahogany, chokecherry, ash, oak, ninebark, snowbrush) grow here.
- There are areas of unhealthy aspen where up to half the stems in a clone/grove have died. These stems will later fall and increase the amount of fuel loading on the ground.
- Patches of conifer forest include white fir, Douglas-fir, subalpine fir and Engelmann spruce. Many of these areas are dense with trees, but they are currently healthy despite the lack of disturbance. Many trees are large which adds to the visual appeal of the area and fire resistance of trees (depending on species) and is beneficial for wildlife habitat. These conifer stands may not remain this healthy and dense under current or future climate scenarios.
- The eastern portion of the property that towers above adjacent homes is steep, shrubby and high risk for severe fire. However, Thaynes Canyon has aspen groves and the immediate area around the trailhead (located within the Iron Canyon Subdivision) has areas of Gambel oak, aspen and grasses.
- Rock outcroppings help break up the continuity of vegetation in the northern portion of the property and could impact fire spread.

Treasure Hill:

Recent treatments on Treasure Hill reduced fuel loading, removed a majority of dead standing trees, removed ladder fuels and increased the height from the ground to tree crowns through limbing practices (monitoring photos and aerial imaging). Gambel oak was thinned around homes, mining towers and the Town Lift. The result of these treatments is fewer hazard trees, reduced ground and ladder fuels and more space between tree canopies.

Based on the methods for prioritization, these parcels are in the highest category of Cumulative Priority Value due to the eNVC being either higher or highest threat, and higher or highest benefit.

McPolin Barn Area:

There is a stand of deciduous forest at the western end of the property, situated at the base of the slope of the mountains above it. The grasses here increase the likelihood of rate of spread and could carry it into the forests above. The stream condition survey notes that the streams here have been the subject of restoration efforts, making them more resilient to fire if one should occur.

Park City Golf Course:

This area has little to no threat from fire as it is a golf course where grass is trimmed and irrigated. Large pixel resolution of the 'Treatable Area' dataset resulted in a small area of the Park City Golf Course being included as a 'higher priority' parcel, but it has subsequently been removed from the priority parcel dataset

Recommendations and Conclusion

Park City has significant opportunities to alter fire behavior and minimize the risk and impacts of wildfire through the use of fuel treatments. Reducing the amount of fuels - any material ready to burn - is key to protecting valued assets of the community. The recommendations and considerations presented here are based upon findings in this CWRA and are designed to help Park City determine next steps for implementation planning.

Project-Wide Recommendations

Collaboration

- Strengthen community and landowner relations. This will inspire further cross-boundary collaboration to achieve mutually beneficial outcomes. Fire does not stop at political or property boundaries. Fuel treatments in one area may lessen the impacts from fire on a neighboring parcel.
    - Strong partnerships increase the likelihood of receiving funding from wildfire protection grants.

Education

- Inform residents and stakeholders about wildfire mitigation. Information from other planning efforts could alleviate knowledge gaps between different community groups.

    - For example, build upon recommendations outlined in the 2022 Pre-Disaster Mitigation Plan for Summit, Utah and Wasatch Counties to implement a fuels management program for local government and residents alike.
- Showcase fuel treatments completed on PCMC-owned lands. Doing so may encourage other landowners and homeowners to do similar actions. This continued education allows all parties to see what works and does not work for a particular area.
- Use interpretative signage and other outreach methods to explain objectives of fuel treatments and provide updates. This will help people understand what is occurring on specific projects.
- Continue educating residents about the threat of fire and fuel treatments. Provide information about how fuel treatments can mimic past fires or other disturbances.
    - Include education about how prescribed fire and fire in general can have a beneficial effect on the landscape. This is sometimes lost in the narrative surrounding wildland fire.
    - Include planning from the 2022 Pre-Disaster Mitigation Plan (Summit, Utah, and Wasatch Counties) which places emphasis on making maps of fire risk readily available and reviewed yearly.
    - Use FireWise Programs where applicable.

Management Actions

- Continue planning fuel treatments. Results from the community survey indicate a majority of residents agree with various types of fuel treatments such as prescribed fire, piling, and removal of some trees.
- Consider the full range of fuel treatment actions (e.g., thinning, brush cutting, piling, burning, mowing, herbicides, etc.). This will increase the likelihood of treatment success based on vegetation patterns, location, resource values, and available funding.
- Consider actions that would minimize the risk to historic structures (e.g., old mining structures) around Park City. Home-ignition-zone concepts could be used to determine appropriate actions.
- Visit potential fuel treatment areas prior to implementation. Site-specific information about vegetation and values-at-risk is needed to refine objectives and protect other resources.
    - Site visits can determine the amount of forest mortality and fuel loading in a specific area.
    - Field visits also confirm the level of threat for undesired outcomes during a fire, the threat to firefighter safety. Recreational user safety is also a concern in areas where dead standing trees pose a risk to safety.
- Use data from the avalanche report, stream condition surveys, wildlife habitat mapping, sediment delivery and quantitative wildfire risk aassessment to build site-specific objectives and resource protection plans prior to implementing fuel treatments.
    - The GIS datasets contain locations of high-value wildlife corridors, habitat for sensitive/threatened/endangered/species of concern, avalanche potential release areas, critical infrastructure (lift lines, power lines, gas lines, drinking water supply, etc.) and historical site data to mitigate risks to these resources from treatment activities.

Monitoring

- Monitor previously completed fuel treatments in other places. For example, the treatments in Gambel oak on USFS/Salt Lake County in Parley's Canyon can provide valuable lessons on outcomes of certain fuel treatments.
- Monitor lands for changes and risk factors over time. What may not be viable or high priority now could be different at future times with continued vegetation growth, noxious weed invasions, or forest health decline.

While fuel treatments can work very well in addressing the risk of fire, there are some possible shortcomings that need to be considered in planning (Davis et al., 2001; Collins et al. 2009). This should be included in broader education and outreach so people may understand why actions are taken in one area, but not another.

- Cost and available funding: Fuel treatments can be very expensive and communities often do not have the needed funding to initiate treatments and maintain them.
- Size: Larger treatments have greater potential to reduce fire behavior and slow fire spread.
- Location: adjacency to WUI may mean more issues with traffic, noise, and smoke.
- Resource protection: Wildlife habitat, riparian areas, water supply, infrastructure, historical sites, and other valued resources need protection. This will sometimes alter treatment intensity or prohibit treatments altogether.
- Access and terrain: the topography may be a barrier to widespread treatments.
- Availability of Labor: there may be difficulty in finding operators who can do the work, depending on season and availability.

Recommendations for Park City-Owned Parcels Specific to Zone

Round Valley Zone

- Focus fuel treatments around the WUI. This can be done by creating fuel breaks around homes and businesses in the higher priority treatment parcels identified in key findings and Table 6-12.
- Consider defensible space improvements up to 200 feet around structures adjacent to mature Gambel oak stands.
    - Consider fuel breaks in sagebrush around Trailside/Silver Summit in the northern portion of Round Valley.
- Consider using the full range of fuel treatment actions. These include, but are not limited to: thinning, brush cutting, mowing, prescribed fire in the short- and near-term.
- Analyze the use of herbicides. This is an effective method to control invasive cheatgrass establishment following treatment.
    - Herbicides are currently not used by PCMC.
- Review and update (as needed) the suppression response and strategy for this area.
- Emphasize continued wildfire prevention education and awareness. Areas of high recreational use and WUI density may benefit from improved community outreach.
- Periodically assess some lower-priority areas located close to values and assets. Just because they are not high priority or ready for treatment now, does not mean that will be the case in a few years.

  - Treatments that benefit Silver Creek and protect Ute ladies' tresses among other conservation values.
  - Parcels adjacent to the cemetery.
  - Areas covered by mature Gambel oak in the next five or more years.
- Coordinate with the EPA and Utah DEQ. This is especially true for ongoing management of the Richardson Flat Site.

Deer Valley/Deer Crest Zone

- Fuel treatments would address WUI concerns - protecting homes and businesses. Many parcels in this zone are high priority for treatment (Table 6-9).
  - The area of U.S. Highway 40 (below Rising Star) has a high probability of ignition and is covered with flammable vegetation that could directly affect the surrounding structures. Coordinate with UDOT to ensure active vegetation management in the highway right-of-way.
  - Treatments along Marsac Avenue would protect areas of high historic value and homes situated on the ridge.
- Address the spread of invasive weeds. There are known expanding populations of Dyer's woad along U.S. Highway 40. Invasive weeds can increase the risk of fast-moving wildfires.
- Prioritize treatments that increase defensible space (within 200 feet) around homes and other structures.
  - Aerie, Hidden Meadows, Rossi Hill, Masonic Hill, Daly Canyon, lower Deer Valley; Solamere, Morning Star, Snow Park, upper Deer Valley; American Flag, Bald Eagle, Empire Pass, Silver Lake, Deer Crest, Deer Valley Resort.
- Review evacuation route safety and effectiveness. Promote messaging that the Deer Valley zone could benefit from removal of vegetation along roads.
- While outside of PCMC jurisdiction, in Daly Canyon PCMC should emphasize the need to protect forests and drinking water. Actions taken here could create conditions for a safer evacuation.
- Consider fuel treatments around the transmission lines operated by Rocky Mountain Power. The company is in the process of hardening those lines and additional work on the ground would help reduce the risk of impacts to the power grid during a fire.
- Partner with Deer Valley resort. Doing so will build a larger vision for landscape-scale restoration. Deer Valley administers the land under lease which contains the most conifer and deciduous forest in this zone.
  - Opportunities exist to address multiple goals and objectives of both fuels management while enhancing the skier experience through thinning, limbing and removing fuels to enhance ski terrain.
- Share information about potential fire behavior and risk. Ensuring stakeholders and residents understand how to use this document will strengthen its usefulness.
  - Inform people about primary and secondary evacuation routes.
- Emphasize continued wildfire prevention education and awareness. Areas of high recreational use and WUI density may benefit from enhanced community outreach.
- Initiate actions that maintain the health and resiliency of Silver Creek along Kearns Boulevard and south of PC Hill.
  - This area is vital for a safe evacuation.
  - Treatments may provide benefit to habitat for Ute ladies' tresses orchid.

Bonanza Flat Zone

- Reference the Bonanza Flat Adaptive Management Plan prior to fuel treatment planning to ensure management goals and strategies are met.
- Prioritize treatments around WUI and transmission lines.
  - WUI areas include Brighton Estates and Camp Cloud Rim.
  - The transmission lines are owned and operated by Rocky Mountain Power.
- Treat other areas for ecological benefits:
  - This is the one zone in the project area where low intensity, prescribed fire would largely benefit the aspen that grows here.
  - There is an elevated risk of sediment delivery from Blood's Lake drainage to Provo River.
  - Fuel treatments could focus on maintaining a high level of benefit to this area and its ecosystems, habitat, water supply, and recreational opportunities. Fuel treatments that mimic fire effects could have beneficial effects.
- Examine opportunities to maintain or increase safety of evacuation routes.
  - Remove dead standing trees around Pine Canyon and 224.
  - Plan for future removal of dead trees along road corridors. This will continually reduce fuel loading and maintain public safety over the next 5 to 10 years.
- Treat aspen groves in ways that mimic natural processes that may also stimulate aspen growth.
- Establish good relations and continually meet with operators/owners of Mayflower resort to address forest health issues that could affect PCMC property.
- Evaluate work accomplished on Wasatch State Park. This could be helpful to determine which treatment methods may be best used in Bonanza Flat.

Park City Mountain Zone

- Plan fuel treatments that would protect the city's water supply.
- Address the highest priority parcels.
  - Portions of Iron Mountain and Thaynes Canyon areas have a high potential for post-fire sedimentation.
  - Treatments may be used to stimulate growth and reduce mortality in aspen stands, further increasing fire resistance.
- Look for opportunities to maintain the low fire risk in the parcels along 224. While not a high priority for reducing fire risk now, there is a need to monitor vegetation and stream conditions over time.
- Continue building relationships with Park City Resort managers for potential cross-boundary restoration planning. Prioritize ways to reduce the fuel hazard and address forest health concerns. Park City Resort owns the most area of contiguous conifer and deciduous forests in this zone and is a vital partnership opportunity.
- Find opportunities to address multiple goals and objectives of both fuels management and enhancing the recreational experience. Activities using thinning, limbing, and reduced fuel loading increase the area of enjoyable ski terrain, vistas, and human safety.
- Capitalize on the educational showpiece of the Treasure Hill parcel. There is a lot to learn from the activities that took place there.
  - Since there is a high number of visitors to Treasure Hill, consider using a trail(s) for a self-guided interpretive route concerning forest management, natural resources, fuels reduction and how they affect wildfire risk.

- Emphasize continued wildfire prevention education and awareness. Areas of high recreational use and WUI density may benefit from enhanced community outreach.
- Consider fuel treatments around the transmission lines operated by Rocky Mountain Power. The company is in the process of hardening those lines and additional work on the ground would help reduce the risk of impacts to the power grid during a fire.

Additional Tables and Figures

Table 6-12.

Parcel ID	Location	Parcel Acreage	Treatable acreage	Mean Threat Value (eNVC)	Mean Benefit Value (eNVC)	Cumulative Prioritization Value	Prioritization Category	Project Zone	Priority Ranking
PC-224-B-X	Prospector Ridge	8.6	3.8	-78.0	1.5	79.5	Highest Priority	Deer Valley/Deer Crest	1
PC-364-A	Treasure Hill	60.8	59.2	-76.5	1.9	78.5	Highest Priority	Park City Mountain	2
THILL-5-X	Treasure Hill Subd Phase 1 & Amended	42.6	30.4	-42.9	1.8	44.7	Highest Priority	Park City Mountain	3
MCL-A-X	McLeod Creek Sub.	3.1	1.4	-29.6	1.1	30.7	Highest Priority	Round Valley	4
WLR-A-X	Willow Ranch Sub.	10.3	1.4	-19.5	2.7	22.2	Highest Priority	Round Valley	5
PCA-7-1-A-X	Guardsman Connector	1.5	1.5	-17.6	0.6	18.2	Highest Priority	Deer Valley/Deer Crest	6
PC-S-55-X	Walker and Webster	1.7	1.7	-16.7	1.4	18.1	Highest Priority	Park City Mountain	7
PCA-103-C-X	Willow Ranch/ Meadows Drive	27.5	4.4	-11.6	0.8	12.4	Highest Priority	Round Valley	8
PP-25-C	Thaynes Canyon	139.3	139.3	-8.5	3.4	11.9	Highest Priority	Park City Mountain	9
PP-25-3-X	Iron Mountain	110.0	108.4	-8.7	2.7	11.4	Highest Priority	Park City Mountain	10
PP-25-1-XX	Iron Mountain	39.2	39.2	-6.4	2.5	8.9	Highest Priority	Park City Mountain	11
PP-25-2-X	Iron Mountain	14.7	14.7	-7.0	1.7	8.7	Highest Priority	Park City Mountain	12
PCA-18-B-X	McPolin Farm OS	29.3	1.9	-7.3	1.2	8.5	Highest Priority	Park City Mountain	13
RO-OPEN-X	Royal Oaks Sub. Ph. 1	3.8	2.4	-7.5	0.8	8.3	Highest Priority	Deer Valley/Deer Crest	14
--	Bonanza Flat	1,344.1	1,015.4	-5.0	3.2	8.2	Higher Priority	Bonanza Flats	15
SS-57-2-A	Round Valley	29.1	11.5	-6.1	1.3	7.4	Higher Priority	Round Valley	16
PCA-18-A-X	TEST	22.6	14.0	-5.1	2.1	7.2	Higher Priority	Round Valley	17
PCA-19-A-X	McPolin Farm (East)	128	9.3	-6.3	0.6	7.0	Higher Priority	Round Valley	18
SS-108-A-X	Iron Mountain	65.4	64.2	-4.3	2.6	6.9	Higher Priority	Park City Mountain	19
PCA-S-98-II-X	Montage Water Tank	3.0	1.7	-4.1	1.3	5.5	Higher Priority	Deer Valley/Deer Crest	20
PCA-S-46-98-X	Ontario Mine	23.2	10.4	-4.3	1.1	5.4	Higher Priority	Deer Valley/Deer Crest	21
HM-1-ROS-1-X	Hidden Meadow Sub.	34.8	34.6	-4.9	0.3	5.2	Higher Priority	Deer Valley/Deer Crest	22
PCA-9-95-N-X	Rail Trail	17.2	2.5	-4.8	0.3	5.1	Higher Priority	Deer Valley/Deer Crest	23
SS-57-A-X	Round Valley	368.2	222.7	-3.5	1.2	4.7	Higher Priority	Round Valley	23
EP-IV-A-X	Eagle Pointe Sub. Ph. IV	10.9	1.4	-4.4	0.3	4.6	Higher Priority	Round Valley	25

PARCEL ID	LOCATION	PARCEL ACREAGE	TREATABLE ACREAGE	MEAN THREAT VALUE (ENVC)	MEAN BENEFIT VALUE (ENVC)	CUMULATIVE PRIORITIZATION VALUE	PRIORITIZATION CATEGORY	PROJECT ZONE	PRIORITY RANKING
GILLMOR-4-X	Round Valley	291.4	47.7	-3.9	0.7	4.6	Higher Priority	Round Valley	26
PCA-108-C-X	Rotary Park	28	1.2	-4.3	0.3	4.6	Higher Priority	Park City Mountain	27
PC-S-27-X	Virginia Mining Claim	13.0	11.6	-3.9	0.4	4.3	Higher Priority	Deer Valley/Deer Crest	28
SSC-A-X	Sandstone Cove Sub.	29.6	25.7	-3.6	0.7	4.3	Higher Priority	Round Valley	29
PCA-900-A-X	Huntsman Os	20.2	13.7	-3.3	0.4	3.8	Higher Priority	Round Valley	30
PP-26	Park City Heights	130.2	115.3	-2.2	1.3	3.5	Medium Priority	Deer Valley/Deer Crest	31
SS-61-B-2-X	Round Valley	10.4	10.4	-2.6	0.8	3.4	Medium Priority	Round Valley	32
SS-61-B-4-X	Round Valley	10.3	10.3	-2.5	0.8	3.3	Medium Priority	Round Valley	33
PP-26-A-1	Richardson Flats (South)	44.0	22.6	-1.8	1.3	3.1	Medium Priority	Deer Valley/Deer Crest	34
SS-62-D	Crianbrosk	40.2	25.0	-2.2	0.9	3.1	Medium Priority	Round Valley	35
SS-61-X	McMillian OS	86.1	56.9	-2.4	0.6	3.0	Medium Priority	Round Valley	36
HM-1-ROS-5-X	Hidden Meadow Sub.	6.1	4.9	-2.5	0.4	2.9	Medium Priority	Deer Valley/Deer Crest	37
SS-61-B-12-X	Round Valley	10.4	9.4	-2.1	0.7	2.8	Medium Priority	Round Valley	38
SS-59-X	Florence Fillmor Open Space	213.8	36.2	-2.0	0.9	2.8	Medium Priority	Round Valley	39
SS-121	Park City Heights / Richardson Flats (South)	126.1	64.5	-1.5	1.4	2.8	Medium Priority	Deer Valley/Deer Crest	40
SS-106-A-X	Iron Mountain	83.2	83.2	-1.9	0.9	2.8	Medium Priority	Park City Mountain	41
PCA-19-B-X	McPolin Farm	53.6	17.6	-0.8	1.9	2.7	Medium Priority	Park City Mountain	42
SS-61-B-11-X	Round Valley	10.2	9.8	-1.7	1.0	2.7	Medium Priority	Round Valley	43
SS-62-A-X	Florence Gillmor OS	117.6	91.1	-1.4	1.1	2.5	Medium Priority	Round Valley	44
SS-61-E-X	Round Valley	40.6	27.5	-2.1	0.2	2.3	Medium Priority	Round Valley	45
SS-61-F-X	RV OS	38.7	28.7	-1.8	0.5	2.3	Medium Priority	Round Valley	46
SA-S-35-X	Prospector Pocket Park	112.1	107.4	2.0	0.2	2.2	Medium Priority	Deer Valley/Deer Crest	47
PCA-62-G-X	Round Valley	208.6	135.4	-1.2	1.0	2.2	Lower Priority	Round Valley	48
SS-61-D-X	Round Valley	37.4	22.4	-1.3	0.8	2.1	Lower Priority	Round Valley	49
OOT-HSTONE-OS-X	Overlook at Old Town, The Sub.	10.4	9.5	-1.9	0.1	2.1	Lower Priority	Deer Valley/Deer Crest	50
PCRC-1-X	F. Gillmor (Donate) P.C Recreation Complex Sub	36.4	9.3	-1.2	0.8	2.0	Lower Priority	Round Valley	51
SS-62-B-X	RV OS	40.1	31.1	-0.7	1.2	1.9	Lower Priority	Round Valley	52

PARCEL ID	LOCATION	PARCEL ACREAGE	TREATABLE ACREAGE	MEAN THREAT VALUE (ENVC)	MEAN BENEFIT VALUE (ENVC)	CUMULATIVE PRIORITIZATION VALUE	PRIORITIZATION CATEGORY	PROJECT ZONE	PRIORITY RANKING
PCA-97-A-1-X	ED Gillmor OS	41.0	8.3	-1.3	0.5	1.8	Lower Priority	Round Valley	53
SS-61-B-9-X	Round Valley	10.3	7.8	-0.8	1.0	1.7	Lower Priority	Round Valley	54
SS-62-E-X	Grover	40.0	37.4	-1.1	0.7	1.7	Lower Priority	Round Valley	55
EP-IV-B-X	Eagle Pointe Sub. Ph. IV	21.9	11.7	-1.2	0.4	1.6	Lower Priority	Round Valley	56
SS-62-C-X	RV OS	40.0	9.2	-0.9	0.6	1.6	Lower Priority	Round Valley	57
SS-61-C-X	Round Valley	43.2	20.2	-1.2	0.4	1.6	Lower Priority	Round Valley	58
SS-62-A-1-A-X	McMillian OS	143.4	44.1	-1.0	0.5	1.5	Lower Priority	Round Valley	59
SA-254-BLM-L17-X	Aerie Sub.	18.5	17.4	-1.2	0.2	1.4	Lower Priority	Deer Valley/Deer Crest	60
PCA-110-X	Park City Cemetery	30.4	8.5	-1.2	0.0	1.3	Lower Priority	PC Urban Core	61
PCRC-3-X	Park City Recreation Complex Sub	8.6	0.9	-0.6	0.6	1.2	Lower Priority	Round Valley	62
SS-62-A-1-X	Round Valley	10.6	1.6	-0.6	0.5	1.1	Lowest Priority	Round Valley	63
SA-400-4-X	Aerie/Dsd Open Space	12.2	3.0	-0.9	0.1	1.0	Lowest Priority	Deer Valley/Deer Crest	64
SA-400-B-2-X	April Mountain	12.9	10.7	-0.9	0.1	0.9	Lowest Priority	Deer Valley/Deer Crest	65
SA-254-BLM-L1-X	Aerie Sub.	3.6	3.6	-0.5	0.4	0.8	Lowest Priority	Deer Valley/Deer Crest	66
SA-224-2-X	City Park/Aerie OS	4.9	2.8	-0.7	0.0	0.8	Lowest Priority	Deer Valley/Deer Crest	67
HM-1-ROS-4-X	Hidden Meadow Sub.	86.0	80.3	-0.1	0.4	0.6	Lowest Priority	Deer Valley/Deer Crest	68
PC-551-BLM-X	Solamere (Gambel Oak Cons. Easement)	89.8	69.0	-0.3	0.3	0.5	Lowest Priority	Deer Valley/Deer Crest	69
FHE-REC-X	Fairway Hills Estates Ph. 1	22.7	22.0	-0.3	0.2	0.4	Lowest Priority	Round Valley	70
SA-254-2-F-X	Aerie Sub.	16.2	15.9	-0.1	0.3	0.4	Lowest Priority	Deer Valley/Deer Crest	71
SA-254-1-X	Aerie Open Space 2	93.9	87.4	-0.2	0.2	0.4	Lowest Priority	Deer Valley/Deer Crest	72
SCCS-C-X	Hidden Meadow Sub.	20.0	9.4	-0.3	0.0	0.3	Lowest Priority	PC Urban Core	73
HM-1-ROS-2-X	Hidden Meadow Sub.	8.1	6.2	0.0	0.3	0.3	Lowest Priority	Deer Valley/Deer Crest	74
PCA-98-C-1-X	PC Hill Parcel	73.4	21.9	-0.2	0.1	0.2	Lowest Priority	Round Valley	75
SA-254-1-B-X	Aerie Open Space 1	25.2	24.2	-0.1	0.1	0.2	Lowest Priority	Deer Valley/Deer Crest	76
PCA-3-3000-X	Prospector	15.3	14.2	0.0	0.1	0.2	Lowest Priority	Deer Valley/Deer Crest	77
EP-II-B-X	Eagle Pointe Sub. Ph. 2	7.3	3.0	0.0	0.1	0.1	Lowest Priority	Round Valley	78

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6.2 Implementation Guidelines, A Community Resource

Implementation guidelines are intended to be a community resource to understand best practices around planning, implementing and monitoring forestry projects. There is a growing need for active land management, forest restoration and hazardous fuel reduction to address our communities' exposure to wildfires and other natural occurrences. As part of the Park City Community Wildfire Risk Assessment (CWRA) project, these guidelines were developed to assist land managers, property owners and residents apply a best-practice approach to forestry projects.

Forestry is considered a "practice," meaning that tools and methods are expected to change over time. In that sense, this document could be considered as living and evolving, and information presented here may be subject to changes or modifications. It is imperative to monitor landscapes and forests in order to drive future management decisions. Preserving the long-term quality of the environment and resources around us is largely dependent upon the actions land managers take.

The information included in this report is by no means comprehensive. Rather, the concepts and guidelines presented are intended to kick start project development and spur further analysis, planning and refinement. The material presented is also targeted at the most common resource considerations, fuels and treatment types that would be found in the CWRA project area.

As with many industries or specialties, the world of forestry, natural resources and fuels management carries its own terminology and jargon. Towards the end of this document is a glossary of some commonly used terms, with most definitions coming from the Society of American Foresters Dictionary of Forestry, literature from the US. Forest Service, or subject-matter experts.

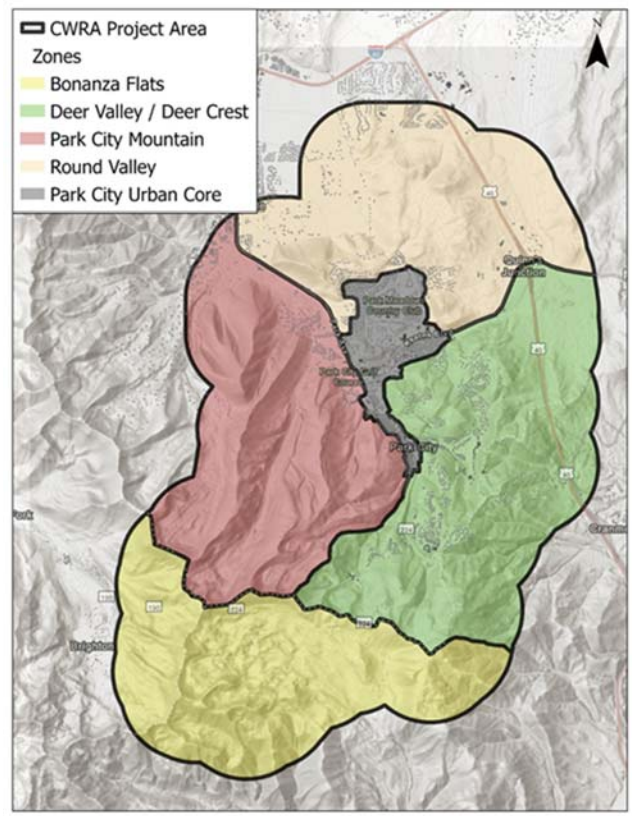

Figure 6-0-14. The CWRA project area with project zones identified.

Project Planning

Planning successful forestry projects can be a challenging task. Desired outcomes must be balanced with land-use objectives, effects to other resources and seasonal constraints, among other factors. Regulations, codes and ordinances may apply and must be followed. This section includes some common planning processes and considerations that are useful. Subject-matter experts in forestry, natural resources, natural hazards or compliance can be beneficial as consultants during the planning process. A sample project planning template is included at the end of this report, as a tool to prompt a careful and comprehensive approach.

Regulatory Compliance

A handful of federal, state and local regulations may apply to project implementation. Land managers must understand what these are and how to comply before implementing projects. Some common regulations and plans are listed here for consideration, although there are a myriad of project types and requirements which vary by jurisdiction. At the local regulatory level, the PCMC CWRA project area spanned three counties (Summit, Wasatch, Salt Lake) and one incorporated area (Park City), hosting a number of plans and ordinances worth researching during project planning but not included here.

Federal:

- Clean Air Act
- Clean Water Act
- Endangered Species Act
- Migratory Bird Treaty Act

State:

- Land Use, Development, and Management Act (LUDMA)
- Utah Forest Practices Act
- State Smoke Management Plan
- National Historic Preservation Act of 1966 -Section 106, code 90844
- Utah Forest Water Quality Guidelines

Baseline Documentation

It is recommended to create baseline documentation before project work initiates. Information about the current work site, such as its vegetation type, health and distribution, as well as improvements (e.g., structures), should be documented during an initial field survey. This can be further accomplished using basic photography or by aerial methods, such as UAV-derived orthomosaic imagery. Georeferenced images can prove useful as they allow for replication of specific photos or survey plots in the future. Mapping applications such as Gaia or ArcGIS Field Maps can be useful, as well as photography applications like Solocator. This documentation is valuable for the project archive to monitor changes and effectiveness.

Figure 6-0-15. Baseline information about vegetation type, health and distribution will help communities monitor change.

Protection of Natural Resources

Forestry projects may cause unwanted effects to essential and valued natural resources such as soil, wildlife, vegetation and watersheds. Careful evaluation of these resources can help mitigate any potential negative effects. This is a critical element of project planning that should not be overlooked, and often justifies the use of natural resource specialists to make assessments and recommendations. Some common considerations are listed here, although this is not fully comprehensive for every project type and project area.

Table 6-1. Common effects and mitigation considerations when planning forestry projects.

Natural Resource	Potential Effects	Mitigation Strategies	Information
Soil	Compaction from equipment Increased erosion	Use low ground pressure equipment and techniques to limit affected areas. Limit equipment use in steep terrain. Avoid using mechanical equipment during wet soil conditions. Rehabilitate disturbed areas with organic material, native seed and erosion-control structures.	Utah Forest Water Quality Guidelines (Gropp & McAvoy, n.d.)
Water	Reduction in quality	Avoid driving equipment through or working adjacent to streams or wetlands where possible (e.g., use of riparian “buffers”).	Utah Forest Water Quality Guidelines (Gropp & McAvoy, n.d.)
Air	Reduction in quality from prescribed fire smoke	Adhere to smoke management best practices for good dispersion.	State Smoke Management Plan (Utah DEQ, 2020)
Wildlife	Altering habitat or behaviors Disrupting breeding and nesting or denning cycles	Identify the wildlife species that use the project area and consider treatment strategies to prevent negative impacts. Identify times of the year where fewer or no activities can be done to protect sensitive time frames for birds and mammals. Consider a site-specific assessment by a certified wildlife or aquatic biologist prior to implementation.	Utah Wildlife Action Plan (2015) Utah Guidelines for Raptor Protection (Romin & Muck, 2002) Endangered Species Act (1973)
Vegetation	Attraction and increased population of forest pests Encouraging advancement of noxious weeds	Limit the amount of slash (branches, stems) on the ground following treatment to reduce insect breeding habitat. Avoid creating green slash during certain times of the year (peak flight). Use pheromone traps to identify insects and disrupt breeding cycles Eradicate weeds on-site prior to project work.	Balsam woolly adelgid facts (Rideout et al., 2023) Fir engraver facts (Utah Division of Forestry, Fire & State Lands, n.d.) MCH pheromone treatment in Douglas fir (Ross et al., 2015)

		Avoid using personnel and equipment during peak seeding periods. Wash incoming equipment prior to use. Reseed disturbed areas with native plant mixes.	Utah Noxious Weed List (Utah Department of Agriculture and Food, 2023) Summit County Cooperative Weed Management Area (2023)

Interacting Hazards

Changes to forest structure from restoration or fuel reduction projects can increase the risk of avalanches and potentially threaten values downslope. In many places around the mountainous environment, the relationship between forest structure and steep terrain influences avalanche behavior. Forest density, canopy cover and ground roughness are all vegetation characteristics that affect snow slab and weak layer formation. During the PCMC CWRA, a comprehensive mapping exercise was completed to identify potential avalanche release areas and avalanche hazard indication within the project area. This generated a robust data set that can be utilized for forestry planning purposes. See chapter 2 of the CWRA for the full Avalanche Terrain Assessment report.

Figure 6-0-16. Avalanching on open slopes where avalanche frequency has prevented the regeneration of adequate "protective forest."

When designing and implementing forestry projects in mountainous terrain where adequate snow supply exists, potential release areas (PRAs) under a variety of forest conditions must be evaluated for the protective effects that the vegetation may provide to that area. Using technical mapping tools, data collection methods, ground analysis, dynamic modeling and expert knowledge, project areas can be assessed for negative avalanche effects. Desired project specifications may need to be changed to avoid altering avalanche behavior in areas where desired treatments and avalanche hazard areas overlap. Based on a path-scale avalanche hazard analysis, adjustments may be recommended in one of three ways:

1. The identified area should be completely avoided, as to not change forest structure.
2. The identified area can be included in the project, but with altered specifications to manage forest structure changes and subsequent "protective effect."
3. The identified area can be included in the project with no changes to the specifications, as changes to vegetation will result in unchanged avalanche hazard.

Monitoring

Monitoring treatment activities ensures objectives are being met and if changes to planned treatments are needed. The monitoring plan should include on-site assessments of project activities during all phases of treatment (before, during and after). Types of things landowners or managers may want to monitor are based on their treatment objectives. A few examples of what could be monitored are:

1. The change (if there is more or less) in surface fuels such as branches and stems,
2. Which tree or plant species remain following treatment, how many there are per acre and how well they are growing,
3. The amount of ground disturbance and the need for soil erosion prevention strategies.

Findings can be documented by using photos, written notes or a combination of methods. It depends on what a landowner decides is necessary to help inform future actions.

The Utah Department of Natural Resources, Division of Forestry, Fire and State Lands, can also assist with monitoring activities as part of their business operations.

Treatment Types and Methods

There are often multiple ways to accomplish forestry work, some better than others for a given area. Factors such as access, vegetation composition, terrain and project objectives usually determine what treatment type would be most effective. Many projects utilize multiple treatment types in conjunction. Other project areas may require more than one treatment over time in a phased approach to accomplish objectives. These subsequent treatments are called entries, and sometimes the initial treatment type is chosen intentionally to set up the project area for a different treatment in the next entry. Discussed here are some common fuel treatment types, along with some best practices associated with a chosen method.

With some overlap, treatment types can be categorized in three ways:

1. Manual treatments - utilizing a workforce with tools to cut and arrange biomass.
2. Mechanical treatments - utilizing equipment to move, arrange, process or remove biomass.
3. Prescribed fire - utilizing managed fire to remove biomass.

Table 6-2. Common fuel treatment types and best practices.

Manual Treatments				
Treatment Type	Description	Best Utilized	Best Avoided	Considerations
Lop and Scatter	Material is cut, slashed, and left in place to decompose. Overall fuel loading is not reduced in the short term, but they are rearranged.	In smaller or lightly distributed vegetation.	In larger fuels or heavily loaded areas. In areas where immediate fuel reduction is desired.	Cut material can take years to decompose. The closer it remains to the ground the faster this process takes place. Target cut material to be slashed so it sits no more than 2-3 feet from the ground.
Cut and Haul	Material is cut and hauled away from closest access points to be processed and disposed off site.	In areas of easy access and smaller quantities of vegetation to be removed. In areas of limited options for on-site disposal.	In areas with limited access. In areas with high quantities of vegetation to be removed. In areas of significant distance to biomass processing facilities or landfills.	Dragging cut material by hand is an incredibly labor intensive task. Without dedicated biomass processing facilities, green waste material is destined for landfills which can have detrimental effects.
Cut and Chip	Material is cut and chipped to be hauled away or broadcast chipped on site, from roadsides with tow behind machines or over the landscape with tracked machines.	In roadside areas. In areas with gentle terrain making equipment access viable. In areas of relatively smaller fuels and lighter loading, making it viable to broadcast chips in a light layer.	In areas of large material and heavy fuel loading. In areas with steep or off camber terrain where equipment can't operate.	When broadcast chipping, keep chips well spread and depth no more than 4 inches to decompose quicker and not suffocate soils, grass, and forbs. Rehabilitate any significant ground disturbance from equipment.
Cut and Pile	Material is cut and formed into piles on site to burn at a later time, typically in spring or fall. Piles are situated away from trees and in open breaks in the canopy to minimize heat impacts to	In areas of difficult access for equipment. In fuel types that benefit from fire.	In areas that may be sensitive to the smoke from future burning.	Project managers should pursue the viability of pile burning before committing to piling projects. For clean and efficient burning, proper pile construction techniques should be utilized.

	trees. Piles can be built by hand or machinery, typically hand piles are about 6' x 6' and machine built piles are larger.	In areas of heavy fuel loading to make the greatest impact with the least amount of effort.		This is a technical and regulated process and should be managed by professionals. Consult certified prescribed fire managers for further details.
MECHANICAL TREATMENTS				
Treatment Type	**Description**	**Best Utilized**	**Best Avoided**	**Considerations**
Mulching	Material is cut and ground by machinery, usually by an implement attached to tracked loaders or excavators.	In terrain that is viable with equipment. In areas of light to medium brush density and height. Could be useful in some aspen stands depending on the level of disturbance desired.	In steep or rocky terrain. In areas of heavy fuel loading that would leave thick layers of biomass behind. In the height of fire danger as the metal cutting heads can easily start fires.	Wash machinery before and after work on the project site to reduce the spread of noxious weeds. Monitor the finished product at the work site, biomass should be at ground level and mixed well with dirt for rapid decomposition. Rehabilitate areas of disturbed soil with native seed.
Mowing	Material is cut and ground by an implement pulled behind machinery.	In terrain that is viable with equipment. In grassy areas along roads or trails.	In steep or rocky terrain. In any fuels other than grass with occasional short brush. In the height of fire danger as the metal cutting heads can easily start fires.	Wash machinery before and after work on the project site to reduce the spread of noxious weeds.
Over-the-snow	Material is pulled or winched, dragged, and piled over the snow by sno-cats, resulting in little to no ground disturbance.	In areas around resort ski runs, roads and trails. In the springtime after closures but while the snow coverage is good for machines to ride on and drag material.	When there is too much or too little amounts of snow for efficient operations.	If timed right with site conditions, this method is very effective to minimize ground disturbance during equipment operations. Resort towns in particular have the right equipment and a unique application for this.

Harvesting	Material is felled and moved to access points by forestry equipment such as harvesters, skidders, and forwarders. In general logging equipment is not widely used in fuel reduction projects in this area.	In terrain that is operable and safe for equipment. When the objective is to remove the stems or whole trees. In some restoration work it could be useful to move large amounts of biomass off site or to central locations.	In project areas with no marketable timber resources or mills to take the material.	Wash machinery before and after work on the project site to reduce the spread of noxious weeds Rehabilitate areas of disturbed soil with erosion control and native seed.
PRESCRIBED FIRE (CONTROLLED BURNING)				
Treatment Type	**Description**	**Best Utilized**	**Best Avoided**	**Considerations**
Pile Burning	Burning pre-built piles under conditions that limit the fire spread potential to just the piled fuels.	In areas of heavy fuel loading to reduce large amounts of biomass on site. In areas with limited or no access for equipment	In areas sensitive to the smoke from burning. In areas of relatively short burn windows or lack of qualified resources.	This is a technical and regulated process and should be managed by professionals. Consult certified prescribed fire managers for further details. Pile burned areas can be reseeded to boost recovery.
Broadcast Burning	Burning pre-identified and prepared areas under conditions where you can manage the fire behavior to meet objectives. This is often completed in smaller sections at a time, and could be low or high intensity depending on objectives.	In aspen stands to reduce conifer and shrub encroachment. In conifer stands as a maintenance treatment. In areas that are well fragmented with roads, trails, or ski runs to burn small sections at a time.	In areas sensitive to the smoke from burning. In untreated areas that have heavy fuel loading and ladder fuels.	This is a technical and regulated process and should be managed by professionals. Consult certified prescribed fire managers for further details.
Kiln Burning	Burning cut and staged material in specific areas utilizing metal kilns to produce biochar. Biochar can be a valuable soil amendment for forest,	In areas with good access for equipment and a flat open area for kiln burning. In areas with good biomass options that are an ideal size for kiln burning.	In areas with no good site for biomass processing in kilns. In areas without a water source for quenching kilns.	This is a technical and regulated process and should be managed by professionals. Consult certified prescribed fire managers for further details.

	agriculture lands, compost, or gardens.	In areas where biochar is desired for uses.	In areas with no market or desire for biochar.	This process moves slowly and requires a lot of equipment and planning, thus not typically used as an efficient method to process large amounts of biomass. This procedure must have a good water source close by for the kiln quenching process.

Treatment Prescriptions

Different fuel types and fuel characteristics call for a different methodology and approach to what vegetation is desired to be removed or retained. Guidelines for this are called prescriptions, describing the project specifications, or “specs,” are developed to describe the intended process and outcome. This common understanding is important between everyone associated with a project to be on the same page. Landowners, land managers, project managers and contractors typically agree on the specs and use them to judge the performance and success of the project.

In many areas, tree and shrub species intermingle and coexist. When performing fuel reduction or restoration work under these conditions, a survey of the area during the planning phase can determine what may be a priority species to remove or retain. Included here are five basic treatment specifications for the most common fuel types in CWRA project area. These are intended to be a starting point for project planning, but not comprehensive or site specific. Each work area deserves thorough surveys to align project objectives with site conditions.

- Conifer dominated
- Aspen dominated
- Hardwood shrub
- Sage/grass
- Mixed vegetation

Conifer

Description:

This fuel type is dominated by conifer tree species, and typically found on northwest- southeast slopes at mid to upper elevations. Prominent conifer species include white fir, subalpine fir, Douglas-fir and Engelmann spruce. Less common varieties include junipers, ponderosa pines and limber pines. Some aspen may be present in areas, and an assortment of understory shrubs are common as well. These areas are known to have increased tree mortality from recent surges in pests, particularly in true firs from the fir engraver beetle and balsam wooly adelgid. Having not seen natural fire or management activities in many decades, there is often a heavy load of dead and downed woody material on the forest floor or “jackstrawed” within tree canopies, adding to ladder fuels.

Figure 6-0-17. Conifers are typically found on northwest-southeast slopes.

Adjacent to structures:

- Firewise® Home Ignition Zone concepts should be used with few to no trees within 30 feet, and widely spaced trees (>10 feet) from 30-100 feet from the structure.

Away from structures:

- Remove dead and down woody debris to minimize fuel loading:
    - Prioritize the removal of down logs under 10 inches in diameter to reduce fine fuels. Some of these logs may be left for operational feasibility and other resource needs (e.g. soil cover). Larger logs left in place should be bucked to lay flat on the ground.
- Cut dead standing and other identified hazard trees, prioritizing areas near any trails, roads, or other infrastructure for public safety.
    - Hazard tree cleanup would follow specifications for downed woody debris.
    - Retain large (greater than 10 inches in diameter) dead standing trees away from roads, trails, buildings/houses, and other improvements to provide habitat for wildlife.
- Thin conifer regeneration to increase spacing between stems.
    - Retain species by priority (most to least desirable): healthy aspen, Douglas fir, white fir. As a rule, leave the healthiest trees first as exact spacing is not the desired outcome.
- Remove conifer regeneration <5 inches dbh under drip lines of larger trees adding to ladder fuels.
- Limb up the lower bole of live trees 6 feet, leaving a minimum of 30% of live crown ratio.
- Reduce understory hardwood shrubs by clearing around conifer drip lines and targeting ladder fuels.

Aspen

Description:

This fuel type is dominated primarily by aspen trees, and can be found on almost all slopes from low to mid elevations. While this species likes to grow together in communities, they thrive off of periodic disturbances. This was usually accomplished by fires, wind events, or beaver activity. With fewer disturbances in recent times, many aspen stands have become encroached by conifer trees, which then grow to outcompete the aspens and change the composition and resiliency of the forest. Aspen stands can also see the encroachment effects of brush species, which can dominate the forest floor and reduce the stands' ability to nurture young trees. With recent forest health impacts to aspens, there can be a heavy presence of dead standing and dead fallen trees within the stand.

Adjacent to structures:

- Live aspens should be evaluated for root rot, heavy leans or growth structures that could make them hazardous and removed if found.
    - Prioritize retaining younger aspens near structures, as these tend to be less hazardous.

Figure 6-0-18. Before and after aspen restoration treatments (Park City, UT)

Away from structures:

- Cut dead standing and other identified hazard trees within 2 times the tree height around trails, roads, or other infrastructure for public safety.
- Remove 80 percent of dead and downed material to increase the suckering potential of aspen.
    - 20 percent of dead and down aspen can be retained for moisture retention and soil stability.
- Remove all conifer trees growing in the understory and mid-story layers of aspen stands under the drip lines.
- Remove 80 percent of the understory consisting of hardwood shrubs, preserving any aspen regeneration.
- Cutting occasional live aspens can be done, as this can serve to stimulate the stand.

Hardwood Shrub

Description:

This fuel type is dominated by a variety of hardwood shrubs, and can be found on most slopes from low to mid elevations. Species can include a mix of Gambel oak, canyon maple, serviceberry, chokecherry, ninebark, mountain mahogany, snowberry and others in fewer quantities. Older stands can be managed to maintain a canopy overstory, while in other areas the brush may be too young and dense with stems. Most of these varieties resprout vigorously after being cut, leading to the need for retreatments in future years to maintain fuel reduction effects. Some areas have benefited from the use of herbicides to control resprouting. Prioritization of species is common in this fuel type, favoring mature maple, oak, and mahogany, as these typically provide more canopy and have proven to be more resilient.

Adjacent to structures:

- Firewise® Home Ignition Zone concepts should be used with limited brush within 30 feet, and small pockets allowed from 30-100 feet from the structure.

Figure 6-0-19. Pre- and post-hardwood shrub fuel reduction adjacent to a structure (Park City, UT).

Away from structures:

- Brush should be thinned allowing for a few older-growth clumps of 5-10 trees to remain, serving as a shaded fuel break.
    - Clumps should be isolated from other clumps to create canopy gaps.
    - Limb brush clumps to a height of 3-4 feet to raise canopy base height.
- Dead and downed material, understory vegetation and branches serving as ladder fuels should be removed.
- Maintenance treatments will need to be applied every 3 to 5 years at a minimum to address sprouting response.

Sage and Grass

Description:

This fuel type is dominated by varieties of sagebrush and grasses, and is typically found on western-southern-eastern facing slopes at lower, middle and upper elevations. It can be a fairly continuous bed of vegetation or broken up significantly by rock, scree and dirt. Some areas can see sagebrush encroachment by other brush species, such as Gambel oak, which can take over and outcompete the sagebrush. Some areas may actually see some juniper trees interspersed. In general, overall fuel loading is much lighter when compared with other forested or brushy areas. Management options in this fuel type are somewhat limited, with mechanical methods like mulching and mowing being the most common. The presence of invasive and noxious weeds in the area could spread rapidly post treatment and must be considered.

Adjacent to structures:

- Firewise® Home Ignition Zone concepts should be used with limited brush within 30 feet, and small pockets allowed from 30-100 feet from the structure.
    - Grass should be mowed within 30 feet of structures.

In other locations:

- Mulching and mowing along roadways or in mosaic patterns can be performed to reduce overall fuel loading.
    - o Reseed disturbed areas with native grass and forbs to reduce undesired weed invasions.
- Thinning of brush is possible in some areas to reduce overall fuel loading, prioritizing to retain healthy sagebrush of all age classes.

Mixed Vegetation

Description:

Some forested areas present as a mixture of the previously mentioned fuel types, in which case guiding principles from the specifications above can be implemented. Through the study of forests, wildfires and the ecological processes of the local area we can begin to understand fire behavior, health trends, drought tolerance and other factors. These concepts serve to drive the prioritization of species to remove or retain when conducting fuel treatments. Listed below are some prioritization strategies that could be used.


Figure 6-0-20. Fuel reduction treatments applied to mixed vegetation fuel types containing aspen, other hardwood shrub, and conifer (Park City, UT).

In all areas:

- Retain healthy aspens and create room for them within the stand overstory and understory.
    - o Reduce encroachment in and around pockets of aspens, over individual aspen trees that are spread out.

In all conifer areas:

- Retain Douglas-fir over every other conifer. Retain white fir or Engelmann spruce over subalpine fir.
- In general, retain larger and healthier conifers over smaller and suppressed.

In areas of hardwoods and brush:

- Retain canyon maple, sagebrush and mountain mahogany over other species.

- o In general, retain taller overstory vegetation that is providing shade in clumps, and thinning by removing understory and ladder fuels.

Resources

Utah Department of Natural Resources, Forestry, Fire, and State Lands: The Utah Department of Natural Resources is one of the state's largest agencies. It helps ensure the quality of life of Utah residents by managing and protecting the state's natural resources. This site has extensive links to aspects of forestry, wildfire, and key contacts. (ffsl.utah.gov)

Utah State University Forestry Extension: Utah State University Extension provides research-based programs and resources with the goal of improving the lives of individuals, families and communities throughout Utah. USU Extension operates through a cooperative agreement between the United States Department of Agriculture, Utah State University, and county governments. (extension.usu.edu/forestry)

Utah Biomass Resources Group: The mission of the Utah Biomass Resources Group (UBRG) is to assist in building a sustainable biomass utilization industry in Utah. Sustainable biomass industries aid in promoting forest health, watershed protection, renewable resource utilization, and rural job development. (www.usu.edu/ubrg)

Utah Prescribed Fire Council: The mission of the Utah Prescribed Fire Council is to serve as a forum for prescribed fire practitioners at all levels of government, academic institutions, tribes, coalitions, and interested individuals. This Council will work collaboratively to promote, protect, conserve, and expand the responsible use of fire across Utah's landscape to meet both private and public land management objectives. (extension.usu.edu/forestry/utah-prescribed-fire-council/who-we-are)

Utah Smoke Management: This is a portal for Federal and state land managers conducting prescribed fire in Utah to enter the details of their planned burns. Other landowners/managers not covered under agricultural or general burning may also participate. (smokemgt.utah.gov)

Utah State Historic Preservation Office: SHPO is a state agency that is tasked with preserving Utah's archaeological past. They maintain archeological records, ensure compliance with a number of federal and state laws, and oversee historic preservation of structures and sites. (ushpo.utah.gov)

Rocky Mountain Research Station: The Rocky Mountain Research Station (RMRS) is an integral component of USDA Forest Service Research and Development (R&D). RMRS researchers work in a range of biological, physical and social science fields to promote sustainable management of the Nation's diverse forests and rangelands. (www.fs.usda.gov/research/rmrs)

National Fire Protection Association Firewise® USA program: The national Firewise USA® recognition program provides a collaborative framework to help neighbors in a geographic area get organized, find direction, and take action to increase the ignition resistance of their homes and community and to reduce wildfire risks at the local level. (www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Firewise-USA)

Fire Adapted Learning Network: This organization exists to support and connect people and communities working on wildfire resilience. It offers community-based leaders resources, tools and connections to reduce their wildfire risk and increase community resilience. (fireadaptednetwork.org)

Glossary of Terminology

Canopy cover - The proportion of ground or water covered by a vertical projection of the outermost perimeter of the natural spread of foliage or plants, including small openings within the canopy. Total canopy cover can exceed 100 percent because of layering of different vegetation layers or strata.

Canopy gaps - The space occurring in forest stands. Can be created by tree mortality, blowdown or fuel treatment activities.

Clumps - A group of generally dense trees.

Communities (vegetation) - An assemblage of plants living together and occupying a given area.

Diameter - The diameter (circumference usually expressed in inches) of the stem of a tree measured at 4.5 feet from the ground.

Disturbance (fire, insects, pathogens, wind, etc.) - Any relatively discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability or the physical environment.

Dripline - The line extending vertically from the exterior edge of a tree's live crown to the ground.

Encroachment (e.g., by conifers) - Commonly refers to the gradual ingrowth of conifer (evergreen) trees that are able to grow in aspen stands, meadows or other areas without conifers due to the lack of disturbance such as fire.

Entry - A specific time period in which vegetation treatment activities take place by manual or mechanical methods. There may be multiple, separate periods in which treatment activities are initiated.

Forest density - The size of a population in relation to some unit of space, e.g., the number of trees per acre.

Forest health - The perceived condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease and resilience to disturbance. These perceptions are influenced by individual and cultural viewpoints, land management objectives, spatial and temporal scales, and the relative health of the forest at a certain point in time.

Fuels reduction - The removal of wildland fuels to reduce the likelihood of ignition and spread, potential resource damage and/or resistance to control. Includes terms such as thinning, pruning or limbing, lopping, chipping, crushing, piling and burning.

Forest restoration - The process of returning ecosystems or habitats to their original structure and species composition.

Forest structure - The horizontal and vertical distribution of components of a forest stand including the height, diameter, crown layers and stems of trees, shrubs, herbaceous understory, songs and down woody debris.

Fuel type - An identifiable association of wildland fuel elements of distinctive species, form, size, arrangement or other characteristics that lead to a projected rate of spread and/or resistance to control under specified weather conditions; can be divided into activity levels generated by management versus natural fuels, fine versus heavy (coarse) fuels and whether they are aerial, ground, ladder or surface fuels.

Live crown ratio - The ratio of crown length to total tree height.

Ladder fuel - Combustible materials that provide vertical continuity between surface fuels and vegetation above. This allows fire to climb into the crowns of trees or shrubs with relative ease.

Limbing - The removal of live or dead branches on the lower stem of the tree.

Georeferenced images - When an image is tied to a known coordinate, allowing for spatial calculations to determine geo-locations of objects within the image to known points on Earth.

Ground roughness - A measure of ruggedness, or surface irregularity, across a digital surface model representing real world conditions; often increased by the rocky terrain or robust ground vegetation.

Hazard tree - Trees that are identified as a potential risk, for failure that would cause injury to a person or damage property.

Interacting hazards - When the possibility of multiple natural hazards exists and the occurrence of a primary natural hazard may trigger and/or affect the frequency or magnitude of another secondary hazard.

Land use/landowner/land manager (management) objectives - A concise, time-specific statement of measurable planned results that correspond to pre-established goals in achieving a desired outcome. It commonly includes information on resources to be used, forms the basis for further planning to define the precise steps to be taken and the resources to be used and assigned responsibility in achieving the identified goals.

Maintenance treatment (related to “entry”) - Treatments that are planned after initial treatments are completed in order to maintain some desired vegetation condition.

Potential release areas (PRAs) - Spatially continuous areas of a slope where terrain characteristics, vegetation and snow supply all combine to allow for the release of snow avalanches (i.e., the full possible spatial extent of an avalanche path “start zone”).

Prescription - A document that describes how vegetation will be changed to meet resource or fuels management objectives. This includes specifications on what will be removed or retained.

Project activities - The description of management objectives, actions and projects to implement decisions of the resource management plan or other planning documents. An activity plan is usually prepared for one or more resources in a specific area.

Regeneration - The established progeny (offspring) from a parent plant e.g., seedlings and saplings.

Runout zones - The area of an avalanche path where debris from large (relative) avalanches will begin to decelerate and be deposited.

Snag - A standing dead tree.

Sprouting response - Generally, when shoots arise from the base of a woody plant.

Thinning - A treatment that reduces the density of trees.

Treatment type or method - How fuel treatment objectives are achieved by activities such as, but not limited to: thinning, burning, mowing or brush cutting, among others.

UAV orthomosaic imagery - Aerial imagery derived from the use of unmanned aerial vehicles (UAV) by assembling a number of georeferenced photographs into a single, composite orthoimage.

Vegetation distribution - The patterns of where plant species grow.

Vegetation type - A category of forest and non-forest (e.g., grasses, shrubs) areas usually defined by its vegetation, particularly its dominant vegetation. It is based on the percentage of cover of trees, shrubs or grasses.

Project Planning Template

See sample project planning template below.

Example Work Plan for Fuel Treatments

Project Name:

Year:

General Information	
Include relevant information about who is involved in planning and implementation and who needs to know about it.	
Project Manager:	
Project Manager Contact:	
Land Ownership(s):	
Landowner(s) Contact:	
Project Partners:	
Public Outreach:	
Project Information	
Provide an overview of the project. Describe when and where work will take place.	
Project Summary:	
Location(s):	
Objective(s):	
Total Acres:	
Project Timeline:	
Resource Considerations	
Determine the animal, plant, and other natural resources that need protection and require mitigation activities.	
Endangered, Threatened, or Sensitive Animal or Plant Species:	

Limited Operating Periods:	
Water Resources:	
Soils:	
Avalanche Potential Release Areas:	
Cultural / Historical:	
Scenery/Aesthetics	
Noxious Weeds:	
Other	
Vegetation Describe the types of vegetation within the project area, and how they will be treated to meet landowner objectives.	
Vegetation Type(s):	
Elevation:	
Aspect:	
Slope:	
Treatment Method(s):	
Equipment and Labor Needs:	
Treatment Specifications:	
Other	
Operational Plan Strategize how the work will be completed following laws, property lines, and safety considerations.	
Operation Summary:	

<table>
<tr><td>Boundary Marking:</td><td></td></tr>
<tr><td>Road or Trail Closures:</td><td></td></tr>
<tr><td>Notifications:</td><td></td></tr>
<tr><td>Permitting:</td><td></td></tr>
<tr><td>Laws/Ordinances:</td><td></td></tr>
<tr><td>Wildfire Response:</td><td></td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="2">Project Maps
Visual representations of where work will be done, the resources to be protected, and logistics for equipment.</td></tr>
<tr><td>Vegetation</td><td></td></tr>
<tr><td>Resources</td><td></td></tr>
<tr><td>Treatment Areas</td><td></td></tr>
<tr><td>Operations</td><td></td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="2">Author / Contributor / Reviewer</td></tr>
<tr><td>Completed By:</td><td></td></tr>
<tr><td>Reviewed By:</td><td></td></tr>
</table>

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