Wildfire Ready Action Plan for the North Fork of the South Platte River, Jefferson, Park, and Clear Creek Counties, Colorado (Updated)

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PREPARED FOR

Jefferson Conservation District
Denver Water
Aurora Water
Colorado Water Conservation Board

PREPARED BY

SWCA Environmental Consultants

WILDFIRE READY ACTION PLAN FOR THE NORTH FORK OF THE SOUTH PLATTE, JEFFERSON, PARK, AND CLEAR CREEK COUNTIES, COLORADO

Prepared for

Jefferson Conservation District
Denver Federal Center, Building 56
6th Avenue and Kipling Street
Denver, Colorado 80226

Denver Water
1600 West 12th Avenue
Denver, Colorado 80204

Aurora Water
15151 East Alameda Parkway, Suite 3600
Aurora, Colorado 80012

Colorado Water Conservation Board
1313 Sherman Street, Room 718
Denver, Colorado 80203

Prepared by

SWCA Environmental Consultants
295 Interlocken Boulevard, Suite 300
Broomfield, Colorado 80021
(303) 487-1183
www.swca.com

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EXECUTIVE SUMMARY

The North Fork of the South Platte (North Fork River) is a vital water source for over 2 million residents in the Denver and Aurora metro areas, supplying Strontia Springs Reservoir, which conveys 80% of Denver Water's and 90% of Aurora Water's supply. This watershed faces an extreme wildfire risk, among the highest in Colorado, necessitating strategic interventions despite limitations posed by accessibility and designated wilderness areas. The North Fork River Wildfire Ready Action Plan (North Fork WRAP) project identified partners, needs, and project locations for wildfire mitigation, post-fire recovery planning, and proactive watershed projects to help stakeholders prepare for and mitigate wildfire impacts.

The project used existing data and assessments alongside new hazard and susceptibility analyses and leveraged the collaboration and experience within the watershed to develop a comprehensive plan. The primary objectives of the North Fork WRAP included engaging stakeholders across various sectors, addressing hydrologic and hydraulic hazard assessment gaps, and completing a susceptibility analysis with all existing and new data. This planning phase sets the foundation for future project development and collaboration to enhance wildfire readiness and watershed resilience.

The key take aways from the North Fork WRAP process is that the North Fork of the Upper South Platte watershed in Colorado faces significant environmental concerns due to its geographical and climatic characteristics. Hydrologic and hydraulic risks are prominent due to the area's susceptibility to intense rainfall events that can lead to flash flooding, impacting both natural ecosystems, human infrastructure, and other assets. Debris flow risk is heightened in this region because of steep slopes and loose soil composition, which can result in rapid movement of sediment and debris during heavy rains, posing threats to property and safety. Hillslope erosion is another critical issue, exacerbated by the area's steep topography and wildfires that reduce vegetation cover, leading to increased soil instability and sediment transport into waterways. These factors collectively threaten water quality, aquatic habitats, and the overall health of the watershed, necessitating comprehensive management and mitigation strategies.

Section Overview:

Section 1 provides an overview of the project vision, goals, and objectives for the planning efforts. This section then provides an overview of the current context of the watershed including historic wildfires and past efforts to build resilience and mitigation the impacts of wildfire.

Section 2 discussed collaboration between stakeholders in the planning area. Meetings, workshops, and other collaboration completed during the planning process. Additionally, agreements, partnerships and collaboration that are ongoing, independent of the WRAP planning process are discussed in Section 2.

Section 3 discusses data used for plan development and modeling efforts. The section also discusses identified data gaps and implications for the plan.

Section 4 provides a robust discussion on the hazard analysis phase. The section begins with a description of the watershed characteristics, then overviews the modeling tools and process used for the analysis. This includes information on hydrology, hydraulics, and fluvial hazard zone. Section 4 concludes with analysis results and mapping for each subwatershed and a qualitative discussion about additional watershed hazard considerations.

Section 5 focuses on the susceptibility analysis which relied on results derived from the hazard analysis. This section discusses values at risk in the watershed, the process for completing the susceptibility analysis, and identifies priority areas for resilience and mitigation efforts.

Section 6 includes tables with project opportunities for each priority area. The location, purpose, and project options are outlined in the table for each priority area with reference to additional guidance. Mapping of each priority area is also included.

Section 7 is similar to Section 6 but focused on a post-fire context where mitigating impacts is necessary. The section begins with resources for technical and financial assistance then provides mapping and a project table for each priority area.

Additional resources and information can be found in the Appendices.

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ABBREVIATIONS

AEP	annual exceedance probability
ASC	active stream corridor
ATF	After the Flames
BAER	Burned Area Emergency Response
CFRI	Colorado Forest Restoration Institute
CWCB	Colorado Water Conservation Board
CWPP	Community wildfire protection plan
FHZ	fluvial hazard zone
FtF	Forests to Faucets
GIS	geographic information system
HUC	hydrologic unit code
NRCS	Natural Resource Conservation Service
REM	relative elevation model
RUSLE	Revised Universal Soil Loss Equation
SBS	soil burn severity
SWCA	SWCA Environmental Consultants
USGS	U.S. Geological Survey
USPP	Upper South Platte Partnership
VAR	values at risk
WRAP	Wildfire Ready Action Plan
WRW	Wildfire Ready Watersheds

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1 INTRODUCTION AND BACKGROUND

The North Fork of the Upper South Platte River (North Fork River) is a vital water source for over 2 million customers in the Denver and Aurora metro areas, supplying Strontia Springs Reservoir, which conveys 80% of Denver Water's and 90% of Aurora Water's supply. Denver Water and Aurora Water, with grant funding from the CWCB and grant management through Jefferson Conservation District, committed match funding to support the development of the North Fork Wildfire Ready Action Plan (WRAP) in 2024. Many entities in the watershed have been planning and implementing wildfire risk reduction projects, including USFS, CSFS, water utilities, county agencies, fire protection districts, and others. The WRAP was developed to plan for and implement projects to address future wildfire events in the watershed both proactively pre-fire and to be better prepared for post-fire recovery actions. The development of the WRAP involved the synthesis of previously completed analyses and planning documents; the compilation and review of infrastructure, forest, and watershed data (Section 3); the identification of post-fire and flooding hazards (Section 4); and the development of a susceptibility analysis (Section 5). The information and analyses were used to create the pre- and post-fire preparedness plans (Sections 6 and 7), which identify and describe potential projects. The North Fork WRAP was developed according to the CWCB Wildfire Ready Watersheds (WRW) initiative.[1]

1.1 Goals of the Action Plan

1.1.1 Project Vision

The North Fork River watershed is a highly valued, critical watershed situated in a heavily forested landscape with a fire regime that historically ranged from about 20-300 years depending on location in the watershed and vegetative composition. As wildfires on Colorado landscapes increase in frequency and intensity, water resources, adjacent communities, and infrastructure are increasingly at risk from the impacts of wildfire and post-wildfire hazards, including flood, erosion, and debris flows. This North Fork WRAP outlines resilience and recovery projects that can be implemented in preparation of a wildfire or after a wildfire has occurred to protect life, property, and community values from the effects of post-fire hazards. Partners and stakeholders, such as the Upper South Platte Partnership and From Forest to Faucets Partnership, have invested time, money, and resources to improve forest resilience and mitigate the potential impacts of a wildfire in the watershed. The North Fork WRAP builds upon those efforts by holistically examining opportunities to restore landscapes and foster resilience in the forests and rivers in preparation for future wildfire events. The analysis and planning process focused on efforts to protect the watershed, critical infrastructure, and the life and properties of communities in the watershed.

1.1.2 Goals and Objectives

The mission of CWCB's WRW program is to determine the susceptibility of Colorado's water resources, communities, and critical infrastructure to post-wildfire impacts. The North Fork WRAP expands upon CWCB's statewide mission with the following goals and objectives:

Goal 1: Stakeholder Engagement

- Engage all key watershed stakeholders in the planning effort.

Goal 2: Geographic Information System (GIS) Data Integration

[1] https://www.wildfirereadywatersheds.com/

- Develop or integrate into an existing public facing GIS platform for plan development and project success tracking.

Goal 3: Hazard and Susceptibility Analyses

- Fill existing hydrologic and hydraulic hazard assessment gaps with additional modeling.
- Complete a susceptibility analysis.

Goal 4: Develop Pre-fire and Post-fire Projects and Strategies

- The pre- and post- fire plan will include actions and priority areas for wildfire risk reduction.
- Plan for post-fire flooding and debris flows in areas where risk cannot be reduced and identify appropriate post-fire mitigation action in these areas.
- Proactively identify watershed and stream restoration projects to build watershed resilience for future fires and high-intensity rain events.
- Identify roles and responsibilities for wildfire response.
- Identify opportunities and agencies for post-fire recovery.

1.2 Overview of Planning Area

The North Fork WRAP planning area covers approximately 304,794 acres (476.2 square miles) across three counties: Jefferson, Park, and Clear Creek. The planning area is situated approximately 22 miles southwest of the City of Denver. Land in the planning area is primarily owned by the U.S. Forest Service, but portions are also owned by Denver Water, Colorado Parks and Wildlife, private entities, and some counties. Table 1.1 shows a breakdown of land ownership in the planning area. U.S. Route 285 (U.S. 285) is a highly traveled highway that crosses through the planning area and connects several communities and developments along its corridor (Figure 1.1).

Table 1.1. Land Ownership Acreage and Percentage of Planning Area

Landowner/Agency	Acres in Planning Area	Percentage of Planning Area
U.S. Forest Service	207,007.50	67.967%
Private	82,846.45	27.201%
Denver Water Board	4,704.11	1.544%
Jefferson County	3,834.62	1.259%
Colorado Parks and Wildlife	3,196.17	1.049%
Colorado State Land Board	2,230.43	0.732%
City and County of Denver	446.95	0.147%
Bureau of Land Management	187.42	0.061%
Clear Creek County	109.60	0.036%

The planning area boundary encompasses the nine HUC12 subwatersheds of the North Fork, capturing the entire drainage area of the North Fork from its headwaters to the confluence with the South Platte River (Figure 1). The easternmost boundary point of the planning area aligns with the confluence of the North Fork with the South Platte River and is approximately 1.5 river miles upstream of Strontia Springs Reservoir. Together, the nine subwatersheds of the North Fork are critical for supplying water to over 2 million people in the Denver and Aurora metro areas, as 80% of Denver Water’s and 90% of Aurora Water’s water supply moves through Strontia Springs Reservoir.

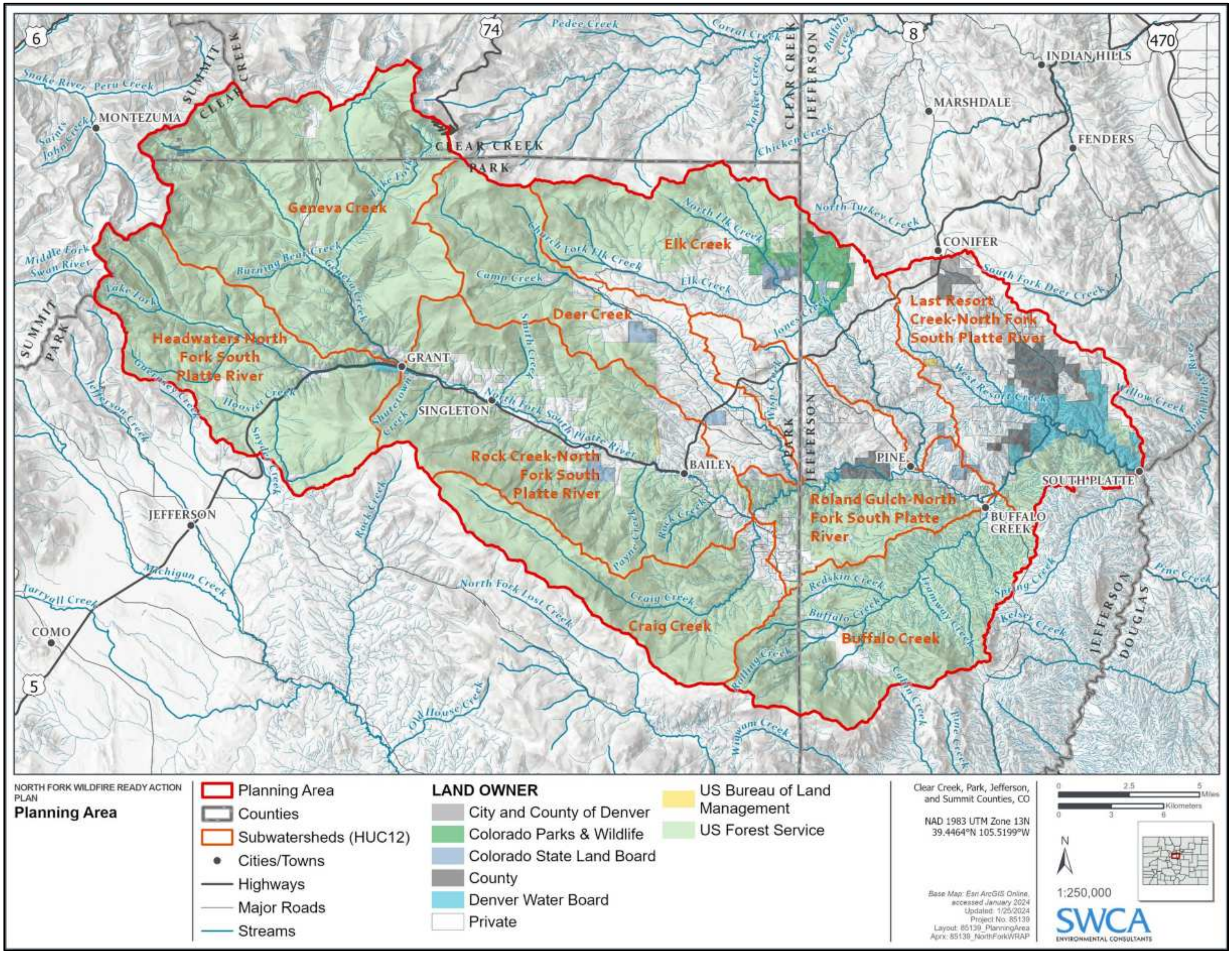

Figure 1.1 Overview of North Fork Wildfire Ready Action Plan planning area.

1.2.1 Historical Wildfires in the Watershed

There have been several historical fires in the North Fork River watershed. Table 1.2 lists each fire and the percentage of the planning area and each HUC12 subwatershed that was impacted by each fire.

Table 1.2. Historical Wildfires in the North Fork River Watershed

Fire Name	Fire Year	Acreage	Percentage of Planning Area Burned (%)	Percentage of HUC12 Subwatershed Burned (%)
Tyler Gulch	1903	2,256	0.740%	Rock Creek: 0.13% Rock Creek-North Fork South Platte River: 4.79%
Buffalo Creek	1996	11,852	3.890%	Buffalo Creek: 20.58% Last Resort Creek-North Fork South Platte River: 1.01% Pine Creek-South Platte River: 18.85%
High Meadows	2000	10,718	3.520%	Deer Creek: 0.33% Elk Creek: 0.25% Buffalo Creek: 0.65% Roland Gulch-North Fork South Platte River: 38.07%
Snaking	2002	2,312	0.760%	Rock Creek-North Fork South Platte River: 4.99%
Black Mountain	2002	200	0.070%	Elk Creek: 0.38% Evergreen Lake-Bear Creek: 0.03%
Hayman	2002	138,287	Did not burn within the WRAP planning area	Cheesman Lake-South Platte River: 99.53% Elevenmile Canyon-South Platte River: 2.20% Fourmile Creek-South Platte River: 72.67% Goose Creek: 69.29% Gunbarrel Creek-South Platte River: 22.51% Horse Creek-Trout Creek: 25.88% Long Gulch-Trout Creek: 7.06% Outlet Lost Creek: 0.82% Outlet Tarryall Creek: 31.64% Twin Creek: 0.75% Vermillion Creek-South Platte River: 67.24% Webber Park-Tarryall Creek: 0.30% West Creek: 58.09% Wigwam Creek: 53.71%
Lime Gulch	2013	511	0.170%	Last Resort Creek-North Fork South Platte River: 1.71
Lower North Fork	2013	3,217	0.780%	Last Resort Creek-North Fork South Platte River: 7.97% Platte Canyon-South Platte River: 3.45
Shooting Range	2018	14	0.005%	Elk Creek: 0.04%
64-A	2019	12	0.004%	Rock Creek-North Fork South Platte River: 0.03%
Shawnee Peak	2019	69	0.020%	Craig Creek: 0.32%
Whiteside	2019	215	0.070%	Geneva Creek: 0.43%
North Fork	2020	3	0.001%	Last Resort Creek-North Fork South Platte River: 0.01%
Platte River	2021	35	0.010%	Last Resort Creek-North Fork South Platte River: 0.12%

The High Meadow Fire (2000) and the Buffalo Creek Fire (1996) are the largest historic fires to have impacted the watershed. Both burned over 10,000 acres across multiple HUCs on the southeast border of the watershed. Although the Hayman Fire did not directly burn any area within the North Fork River watershed, it is included in this list due to its size, proximity to the planning area, lasting impact on the landscape, and connection to downstream resources discussed in this plan. Figure 1.2 shows the geographic extent of previous fires in the planning area.

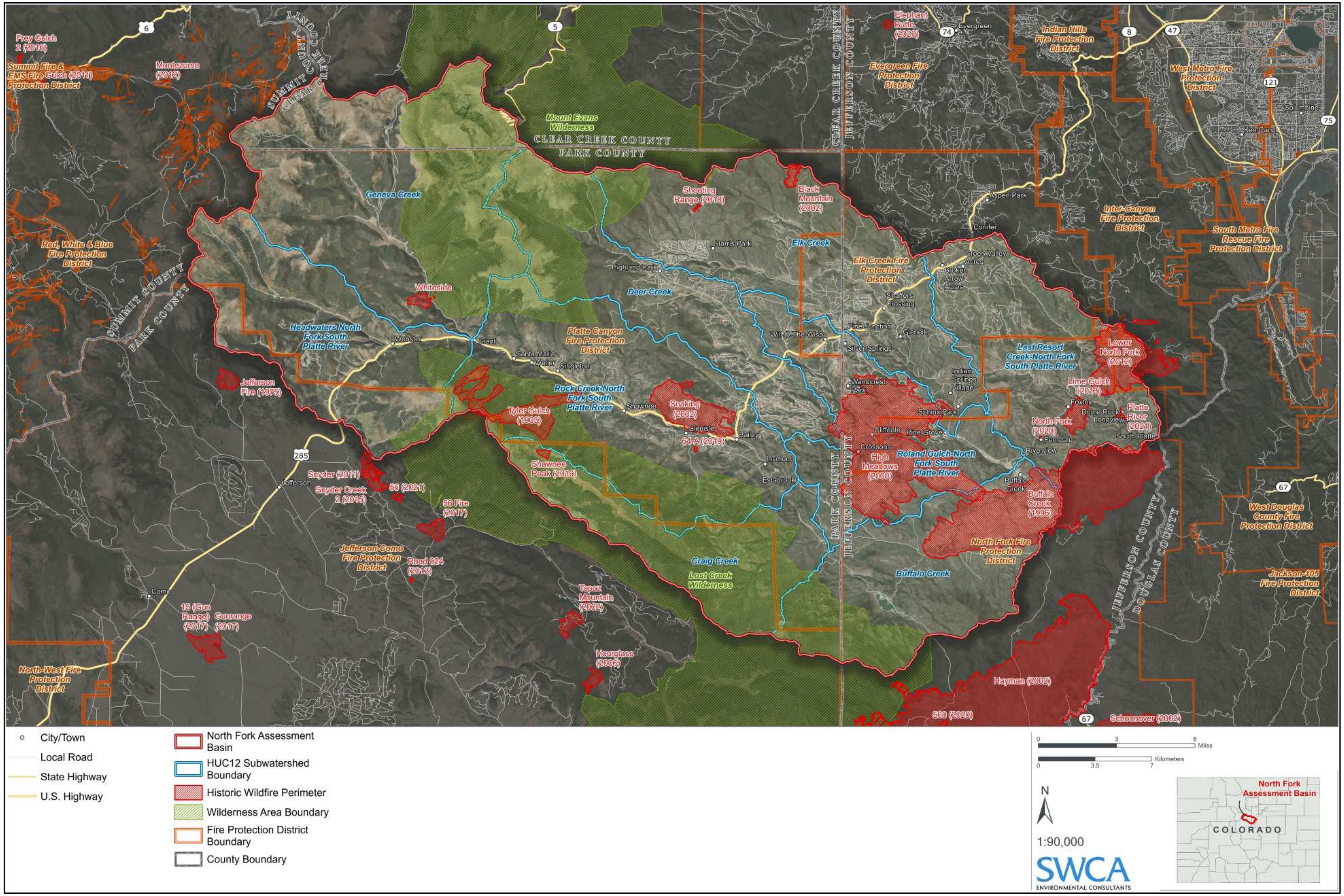

Figure 1.2. Historical fires in the North Fork of the South Platte Wildfire Ready Action Plan planning area.

1.2.2 Fuel Treatments

Fuel treatments are an important component of any wildfire risk reduction planning and action. Treatments are often used to lessen fire hazard to nearby communities by reducing the amount of fuel in strategic locations and creating tactical opportunities for firefighters to more safely engage with wildland fires. Methods vary based on budget and goals, but effective fuel reduction can be achieved through stand thinning, patch cutting, small tree and brush mastication, pile burning, grazing, and the use of prescribed fire. See the treatment table in Appendix E.3 or refer to your local community wildfire protection plan (CWPP) for additional details and considerations regarding fuel treatments. Fuel treatments frequently overlap with forest restoration objectives to improve forest health and enhance wildlife habitat while simultaneously reducing the risk of high-severity wildfire.

It is imperative that long-term monitoring and maintenance of all treatments is implemented. Post-treatment rehabilitation, such as seeding native plants, noxious weed management, and erosion control, may also be necessary, depending on site conditions and desired outcomes. In addition, post-treatment fuel clean-up (e.g., slash disposal, pile burning) is necessary to ensure treatment goals are met and fuels are actually removed from the landscape and not just redistributed.

1.2.3 Sediment Management

A sediment management plan was developed by Denver Water in response to natural sediment transport exacerbated by wildfires and a lack of post-fire recovery in the area upstream of Strontia Springs Reservoir (SWCA Environmental Consultants [SWCA] 2021). The naturally erosive Pikes Peak Granite soils in the North Fork and the mainstem downstream of Cheesman Reservoir are addressed in the 2021 Strontia Springs Watershed Sediment Management Plan. Strategies to reduce both sediment supply and downstream transport are needed to reduce threats to hydroelectric power generation, dam safety, water quality, and storage capacity at Strontia Springs Reservoir. On average, 50,000 cubic yards of sediment is deposited into the Reservoir each year, with a majority of high erosion risk areas found in the North Fork River watershed (SWCA 2021). Post-wildfire conditions are likely to increase sediment transport. Therefore, this WRAP incorporates information from the Strontia Watershed Sediment Plan along with project identified or in-progress.

Adopting an adaptive strategy is essential to any natural resource plan and especially for managing sediment in a dynamic watershed. An adaptive approach is recommended to implement this plan, which includes a structured, iterative process to evaluate and reevaluate the subwatersheds, priority areas, projects, and/or other considerations and resources. Adaptive management provides flexibility to adjust the approach or activities based on new information or changing conditions such as watershed characteristics, landowners, budget, or funding, and creates a more efficient and effective sediment management plan over time. Pre- and post-project monitoring will inform and support the overall adaptive management strategy.

2 PROJECT PARTNERS, CORE TEAM, AND STAKEHOLDERS

The successful completion of the hazard risk analysis, susceptibility analysis, the identification of potential projects, and the development of the pre- and post-fire preparedness plan was driven by a robust engagement process. The process included monthly facilitated meetings with an established project core team, four facilitated workshops with a broader stakeholder group, and additional meetings and review periods with the project partners, as necessary. Engagement occurred for the duration of North Fork

WRAP development and was a key element of the project's success. The project partners, core team, and stakeholders consist of the following key organizations:

- Project partners
    - Jefferson Conservation District
    - Denver Water
    - Aurora Water
- Core team
    - All project partners
    - CWCB
    - Colorado State Forest Service
    - U.S. Forest Service
    - Jefferson County
    - Park County
- Stakeholders
    - The project partners and core team
    - Colorado Rural Water Association
    - Denver Mountain Parks
    - Division of Fire Prevention and Control
    - Ember Alliance
    - Natural Resources Conservation Service
    - Stewardship West
    - Upper South Platte Partnership
    - Other entities were invited but declined to participate.

2.1 Core Team Meetings

Core team meetings were held monthly and provided an opportunity for the technical consultant team to connect with core team members on any data needs and questions and to review and discuss the model outputs as relevant. This process was crucial to ensure the integrity of the hazard and susceptibility analysis, because core team members helped identify and provide key datasets, provided feedback based on their detailed understanding of the watershed, informed the location and distribution of values at risk, and reviewed outputs to identify issues or discrepancies.

2.2 Stakeholder Workshops

Stakeholder workshops were held at four key project milestones. These workshops were facilitated by a representative from PEAK Facilitation with support from SWCA and Ayres Technical Team members. The workshop summaries are provided in Appendix A. Two of the workshops were held in person, and two were held virtually. Each workshop covered a unique topic and provided an opportunity for stakeholders to provide input and feedback to the project team. The workshop topics, format, and content were as follows:

- **Workshop 1: Project Overview and Introduction (in-person)**
    - Review of data gaps

  - Request stakeholder coordination on data to fill gaps
  - Define and identify values at risk on the landscape (roads, culverts, etc.) or datasets that may include them
  - Discuss timelines and next steps
- **Workshop 2: Hazard and Susceptibility Analysis (virtual)**
  - Review hazard risk analysis results
  - Obtain feedback from stakeholders
  - Discuss how these data can be used by stakeholders
  - Discuss methods/approach for susceptibility analysis, timelines, and next steps
- **Workshop 3: Susceptibility Analysis and Project Identification (in person)**
  - Review susceptibility analysis methodology and results
  - Discuss how these data can be used by stakeholders
  - Discuss hazard types and which project/treatment types can effectively address each hazard type
  - Workshop potential project types and locations based on highly susceptible areas and associated risk.
- **Workshop 4: Draft Plan (virtual)**
  - Inform stakeholders about the plan, findings, next steps, and how stakeholders can use the plan.
  - Solicit feedback on the draft plan.

2.3 Agreements and Partnerships

The North Fork River watershed has a number of local governments, state and federal agencies, and private landowners with vested interest in the health and resilience of the watershed and a desire to collaboratively manage water and land resources. As such, multiple partnerships, agreements, and working groups have been established to concisely address management concerns across jurisdictional boundaries. These partnerships and agreements are discussed in the following subsections.

2.3.1 Upper South Platte Partnership

The Upper South Platte Partnership (USPP) is a voluntary partnership program consisting of over 15 agencies that actively provide input on decisions in the Upper South Platte watershed and provide their specific subject matter expertise. The vision of the partnership is to foster a sustainable and resilient landscape, ensure healthy forests, work with residents to develop fire-adapted communities, and effectively manage wildfire across the Upper South Platte watershed. Agencies involved in the partnership include water districts; conservation, open space, and forest service organizations; fire protection districts; and non-profit organizations. The USPP consists of three decision-making teams: the goals, strategies, and funding team; the management and science team; and the engagement, communication, and outreach team. These teams work in the Upper South Platte watershed on a variety of projects and objectives, which include planning, monitoring, report creation, developing management methodology, improving collaboration in project implementation, public messaging, funding identification, and providing resources to ensure completion of projects and coordinated efforts in the watershed.

For a full list of involved agencies and to learn more about the work of the USPP, visit their website at: https://uppersouthplattepartnership.org/

2.3.2 From Forests to Faucets Faucets

Forests to Faucets is a collaborative partnership established in coordination with USFS, Denver Water, CSFS, NRCS, and CFRI following the Buffalo Creek and Hayman wildfires in the South Platte Watershed. The partnership began in 2010 and to date, has invested over 144 million dollars in forest management and fuel reductions on more than 120,000 forested acres. The partnership has included multiple watershed and forest assessments to identify concern areas for wildfire hazard, flooding, debris flow, and erosion. The purpose of the Forest to Faucets assessments is to provide water and land managers with a planning mechanism for identifying priority reaches and tributaries in need of conservation, forest management, additional analysis, and stream restoration. These efforts channel in to on the groundwork to reduce fuel loads and strategically address wildfire risk across a landscape with diverse land ownership. Data from the 2024 Forest to Faucets Wildfire Risk Assessment were used at multiple stages of this planning process. The effort is also a useful tool for communicating forest-watershed interconnection with community members. Additional information about the Forests to Faucets partnership can be found on Denver Water's website here: https://storymaps.arcgis.com/stories/6ef2af96207046baa8451cf20def46cb

3 DATA COLLECTION AND GAP ANALYSIS

Data collection and data gap analysis was completed by SWCA and the Ayres Technical Team, who worked to obtain relevant publicly available data in alignment with Colorado WRW Program Guidance (CWCB 2022a).[2] The Technical Team collaborated with the core team to identify data gaps and worked directly with stakeholders to resolve any data gaps. The Data Gap Analysis Technical Memorandum (Appendix B) includes a full discussion of the methodology and identifies data gaps related to fire behavior, debris flow, erosion and sediment, flooding, and values at risk.

4 HAZARD ANALYSIS

A hazard analysis was completed to assess the potential impacts of erosion, flooding, and debris flow in the planning area under modeled wildfire conditions and identify areas at elevated risk from post-fire hazards. The hazard analysis informed the susceptibility analysis by ranking watershed areas based on risk.

This section provides an overview of the methods (Section 4.2 and 4.3) and results (Section 4.4) of the hazard analysis and an interpretation of those results. Additional information regarding the post-fire hazard risk analysis is provided in Appendix C.

Post-fire hazards identified in the North Fork of the Upper South Platte watershed include increased runoff and flooding, erosion and deposition along stream corridors, alluvial fan deposition, hillslope and gully erosion, debris flows and mudslides, and water quality degradation. Five primary models were selected for the post-fire hazard analysis to identify, quantify, and map these hazards based on the existing data gathered and cataloged during the data collection and gap analysis phase (Section 3) and guidance from CWCB (CWCB 2022a, 2022b, 2022c, 2022d, 2022e, 2022f). The selected models, their focus, advantage, and limitations are shown below in Table 4.1. Appendix C includes a full discussion on the use and limitation of each of these models.

[2] https://www.wildfirereadywatersheds.com/resources

Table 4.1. Models and Analyses Included in the North Fork Wildfire Ready Action Plan Hazard Analysis

Model Name	Focus, Advantages, Limitations
USGS Debris Flow Probability Model (Regression Equations)	Focus: Debris flow prediction. Smaller channel and gulley systems and the probability of debris flow occurrence during high-intensity rainfall. Advantage: Good communication of post-fire and post-flood debris flow risk and prioritization. Great for smaller clusters of VARs located at the outlet of tributaries on alluvial fans. Limitations: Difficult to use for infrastructure and mitigation design. Large uncertainty on sediment yield predictions. Academic focus with a limited user base.
Revised Universal Soil Loss Equation (RUSLE) Model	Focus: Sediment yields. High resolution data across a large area. Calculated post-fire impacts continuously across the landscape. Advantage: Provides the best estimate of pre- and post-fire sediment yields. Data can be pulled at many different scales. Limitations: Difficult to use for infrastructure and mitigation design. Academic focus with a limited user base.
Watershed-Wide Hydrologic Model using HEC-HMS	Focus: Converts rainfall to flow volumes and accounts for timing. A calibrated HMS model will focus on quantifying accurate flows within the North Fork River. These data can drive flood prediction estimates and order of magnitude increase estimates along the mainstem of the North Fork. Advantage: Modeling can be used for mitigation design. Large user base in post-fire settings. Limitations: Not focused on storm events that drive post-fire risk, like high intensity-short rainfall in smaller tributary channels. Calibration is important but is usually costly and difficult.
2D HEC-RAS Modeling	Focus: Works to convert the discharge estimates from HEC-HMS to flow on the landscape, including velocity, depth, and stream power. Advantage: Critical for site-level design for many project types, including infrastructure protection, stream enhancement, and community planning. Limitations: Does not incorporate erosion and deposition of sediment or wood debris dynamics (Although sediment transport and non-Newtonian flow modules are available, they will not be used for this effort). The detailed outputs can provide false confidence in a highly uncertain post-fire flood environment.
Fluvial Hazard Zone Delineation	Focus: Provides a long-term planning boundary that estimates and predicts potential fluvial hazards. Advantage: Appropriate for engineering and geologic timescales. Reorients risk in fluvial environments to “when” not “if.” Limitations: Not as detailed as other products. Estimates processes that occur over engineering timescales (life span/design life of large infrastructure approximately 50–100 years old) and can be difficult to plan around.

4.1 Watershed Characteristics and Description

The North Fork is a key river system that provides water to many front range communities . The mainstem of the river is approximately 43 miles across the Southern Rocky Mountain ecoregion beginning in Hall Valley, east of the continental divide near Handcart Peak. From its origin, the river travels southeast until its confluence with the Upper South Platte River. The North Fork includes nine HUC12 subwatershed basins and is approximately 476.2 square miles. Ecology in the watershed planning area is almost entirely mixed conifer forests, ranging from sub-alpine forests at the headwaters (composed of spruce, fir, and intermixed aspen) to mid-elevation forests (composed of ponderosa pine, Douglas-fir, lodgepole pine, and aspen). The watershed begins in the alpine zone where vegetation is primarily grass and sedge, with some dwarf conifer species found. The mid and low elevation portions of the planning area also contain grasslands and wet meadow habitats defined by sparce trees, grasses, sedges, willows, and shrubs. Fluvial processes in the river system are heavily influenced by large wood, which aids in attenuating sediment and stream flow while also influencing flooding. In some tributaries that are steeper and more confined, wood has a less significant influence as spring flows often flush materials and the natural geomorphology plays a more defining role.

Bedrock in the watershed is primarily igneous and metamorphic rock with some glacial drift; alluvial deposits are also common in the watershed. The North Fork has its origin along the Continental Divide, beginning at an elevation around 13,000 feet above sea level. From there, the river travels east where it converges with the main stem of the Upper South Platte River before it reaches the high plains portion of its journey at an elevation of 6,ooo feet above sea level. The watershed features steep tributary channels and hillslopes that channel sediment into the North Fork and its valley system. A majority of sediment transported into the river and valley continues downstream settling in reservoirs and natural depositional areas, whereas a smaller portion of materials is retained in-channel.

Along its path, the North Fork is frequently confined by erosion resistant bedrock, which often constrains fluvial process and limits geomorphic change. Because of this, energy from large flood events is often preserved and channeled to less constrained portions of the systems where this energy can be released in more open flood plains, causing dramatic change at times. The hydrologic regime of the river is primarily driven by alpine snowmelt and thunderstorms. Most flood events are triggered by high-intensity thunderstorms, which are most likely to cause hazards. Additionally, water is imported for conveyance in the North Fork River, which has drastically increased the normal flow regime of the river, creating an oversized bankfull channel.

4.2 Hydrology and Hydraulics

4.2.1 Hydrology

The purpose of the hydrologic model is to estimate pre- and post-fire flow conditions for the North Fork River. More precisely, the change in anticipated flow between the two watershed conditions was calculated to determine where flooding impacts are likely to be highest after a fire. Large differences between pre- and post-fire flow rates indicate an area is likely to be more susceptible to flooding. The subsections below briefly describe the model inputs, process, and results. For a more detailed description of the hydrologic model, please refer to Appendix C.

4.2.1.1 INPUTS

Watershed Subbasins: The nine HUC12 subwatersheds were further divided into subbasins based on U.S. Geological Survey (USGS) Debris Flow basin delineations, stakeholder values input, road crossings, large tributary basins, and reservoir locations. Multiple rounds of subdivision were completed—first based on known large tributaries, then matching debris flow basins with downstream assets and values, then merging subbasins with shared downstream values. In total, the watershed planning area was divided into 50 subbasins.

Excess precipitation: Soil Conservation Service modeling was used to calculate excess precipitation for each subwatershed basin. Multiple data sources were used to calculate the curve number; precipitation that is not absorbed into the landscape and lag time; and the time needed for that water to reach the outlet of the watershed. These calculations incorporated land use, soil, terrain, land cover, and precipitation data.

Rainfall: Rainfall was modeled using a Soil Conservation Service Type 2 storm distribution, which was determined to be the best representation of the storms typically experienced in the planning area. Different National Oceanic and Atmospheric Administration atlas 14-point precipitation depth rainfall zones were determined for each subbasin based on the centroid of the basin. A National Oceanic and Atmospheric Administration TP40 area reduction curve was applied to the meteorological model to account for large storm occurrences. The 10-year post-fire flow was chosen for the model based on the likelihood of occurrence, general use of this flow rate by agencies, and the usefulness of this rate in practical design.

4.2.1.2 MODEL COMPONENTS AND CALIBRATION

HEC-HMS Version 4.11 was used to model hydrology. One hundred and twenty-three total components were incorporated into the model, including 50 subbasins, 39 stream reaches, and 34 junctions. The model applies methodology and accounts for routine flow, index flow, stream roughness, and side slopes. Physical parameters for the reaches were generated using WMS Version 11.1, and index flow was generated within the model iteratively. Mannings n values were applied to the model to account for friction losses and ranged from 0.06 to 0.12. Three gaging stations in the watershed were applied to the model, integrating over 30 years of stream flow records. Table 4.2 shows information on the gage data that was used. This data was used to calibrate the modeled flow for all HUC 12 junction points. Figure 4.1 below shows results for 10- and 100-year flood events with Junctions 3, 4, and 5 modeled based on recorded flow data.

Table 4.2. Gage Data Used for the Calibration Effort

HUC12/Junction Point	Gage Number	Gage Name	Source	Years of Record	Analysis Method	10-Year Flow Value (cubic feet per second)
Geneva Creek and Headwaters (Junction 1)	06706000	North Fork South Platte River below Geneva Creek, at Grant, Colo.	USGS (Vaill 2000)	31	(Vaill 2000)	780
North Fork River and Craig Creek (Junction 2)	Not available	CWCB – North Fork South Platte River at Bailey (PLABAICO).	(CWCB 2024; DWR 2024)	31	PeakFQ without regional skew	1,027
North Fork River Outlet (Junction 6)	06707000	North Fork South Platte River at South Platte, Colo.	USGS (Vaill 2000)	60	(Vaill 2000)	1,600

* 1996 outlier removed

To predict burn severity, Crown Fire Activity was determined to be the best proxy for the planning area. The 2024 Colorado Forest Restoration Institute's (CFRI's) Wildfire Risk Assessment included Crown Fire Activity for the 97th percentile weather condition which was applied for burn severity with each crown fire activity level (non-burnable, surface fire, passive crown fire, and active crown fire) converted to a burn severity level (no burn, low, moderate, high), respective to each category level. Areas for each burn severity level were calculated, and the model was rerun to calculate post-fire flows for 10 and 100-year flood events. For more detailed information on the hydrologic model, refer to Appendix C.

4.2.1.3 RESULTS

The intent of the hydrologic model was to determine the magnitude of change in each subbasin from pre-fire to post-fire conditions. Areas with a high percent change in flow conditions are likely to have the most severe impacts following a wildfire. Figure 4.1 shows the summarized results of the 10-year (A) and 100-year (B) flood events under existing and post-fire conditions.

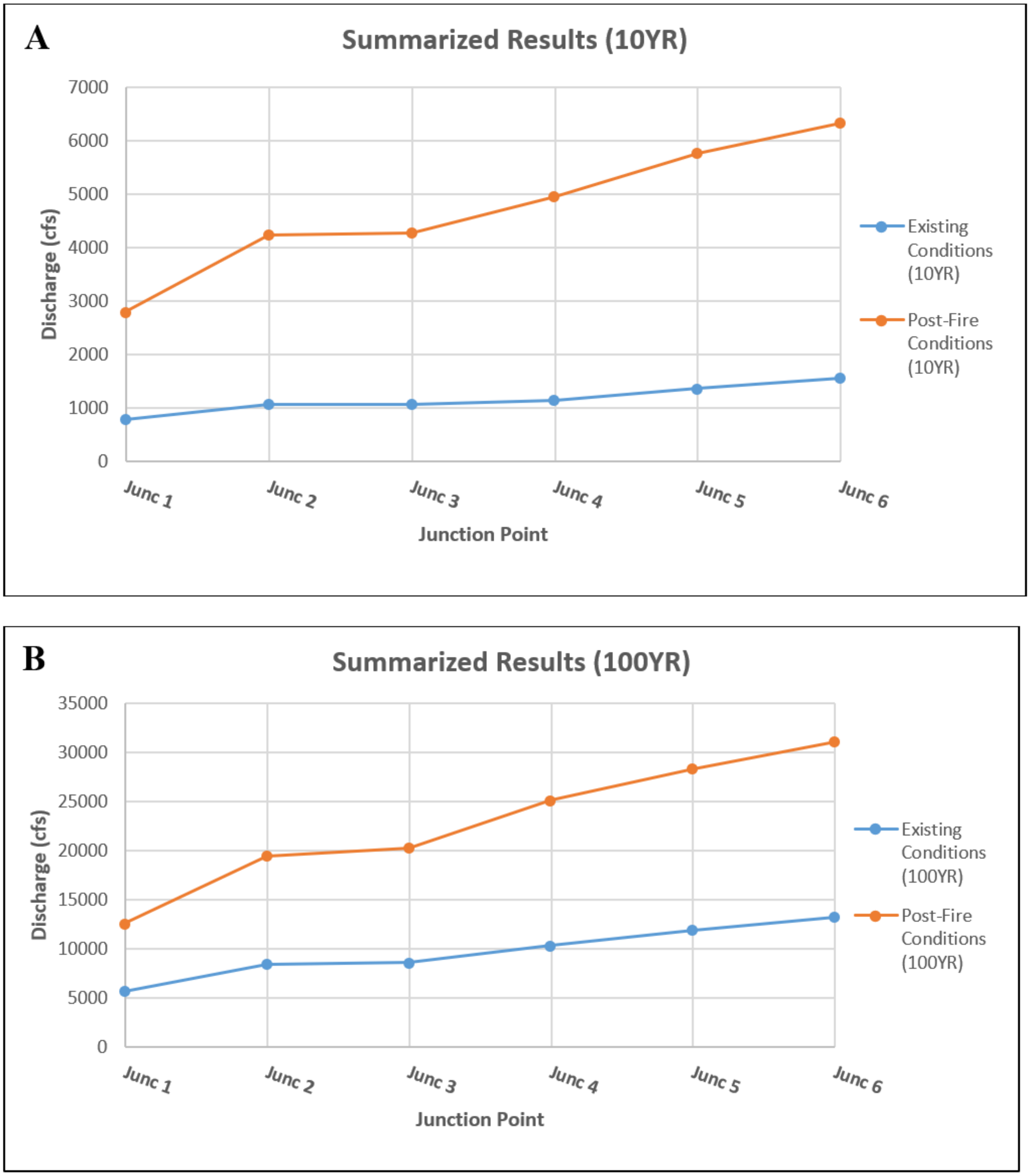

Figure 4.1. Results of pre- and post-fire impacts on the North Fork hydrology for the 10-year (A) and 100-year (B) events.

4.2.2 Hydraulics

4.2.2.1 INPUTS

HEC-RAS 2D Version 6.5 was used to model the hydraulics of two stretches along the North Fork River (Hydraulic Engineering Center 2024). The model estimates how stream flow will impact the channel system, including stream power, velocity, depth, and sediment transport potential. The model also establishes inundation boundaries, which helps identify high-risk areas. Two stream stretches were selected for the model: the first from Grant to Bailey, spanning the entire Rock Creek HUC12 and paralleling U.S. 285, and Pine to just past the confluence of the North Fork with Buffalo Creek. These reaches were selected because they are not bedrock confined and therefore have more channel movement potential, are in more populated areas of the planning area, are higher priority for stakeholders, and have higher feasibility for mitigation projects.

Inputs to the model included terrain, land use, and 10-year post-fire flows from the hydrology model. A bulking model was incorporated into the flows to capture higher sediment loads post-fire. Modifications were made to the model to account for debris impacts. It was assumed that culverts were blocked by debris, which resulted in water backups and road overtopping. It was assumed that bridges with few to no piers would provide little resistance to flow, so these were modeled as unblocked. Mannings' n zones were established, along with land use, in the terrain model to account for surface roughness.

The naming convention in Figures 4.2 and 4.3 attempts to reference the hydrologic model and overlay additional elements in the hydraulic model. For example, "RG6R", the "RG" references the HUC-12 watershed Roland Gulch. The first letter or two will always reference the HUC-12 watershed. The next number, "6", is a simple numerical ID that is given in order, generally, from upstream to downstream. The last letter, "R", references the hydraulic feature type. "R" for reaches which convey flow. "C" for confluence which combines from multiple reaches. No letter after the numerical element indicates that the feature is a subbasin from the hydrologic model.

4.2.2.1.1 Grant to Bailey

This modeled stretch covers approximately 17 miles of the main stem of the North Fork River. The stretch had 16 input flow boundary areas that corresponded to the subbasins along the reach. Figure 4.2 shows the Grant to Bailey model reach and inflow points.

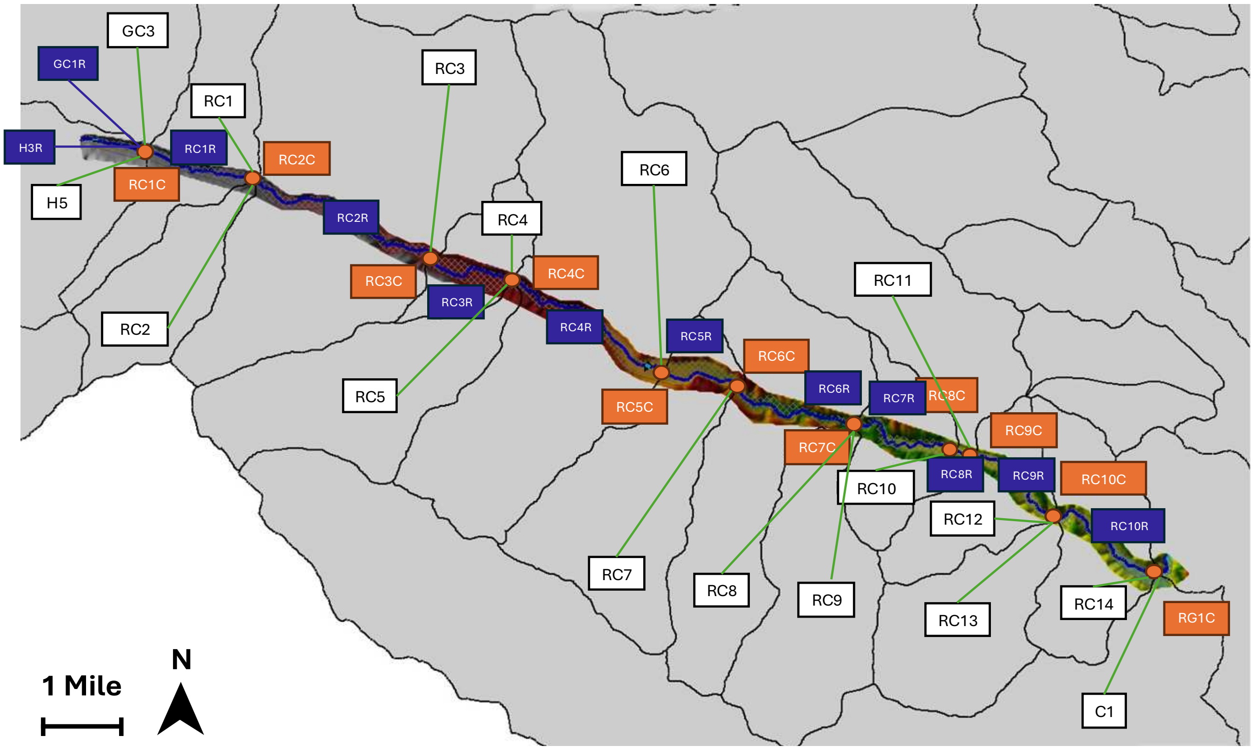

Figure 4.2. Grant to Bailey hydraulic model and inflows. The blue labels show the reach elements, the white labels show basin elements, and the orange label show junction elements. Additional information on these elements can be found in the Grant to Bailey HEC RAS Model (NFork_Grant_Bailey_BC_Flows.xls).

4.2.2.1.2 Pine

The Pine to Buffalo Creek stream reach covers approximately 6.5 miles of the main stem of the North Fork River. The reach had three main input flow boundary areas. Figure 4.3 shows the model reach and input areas.

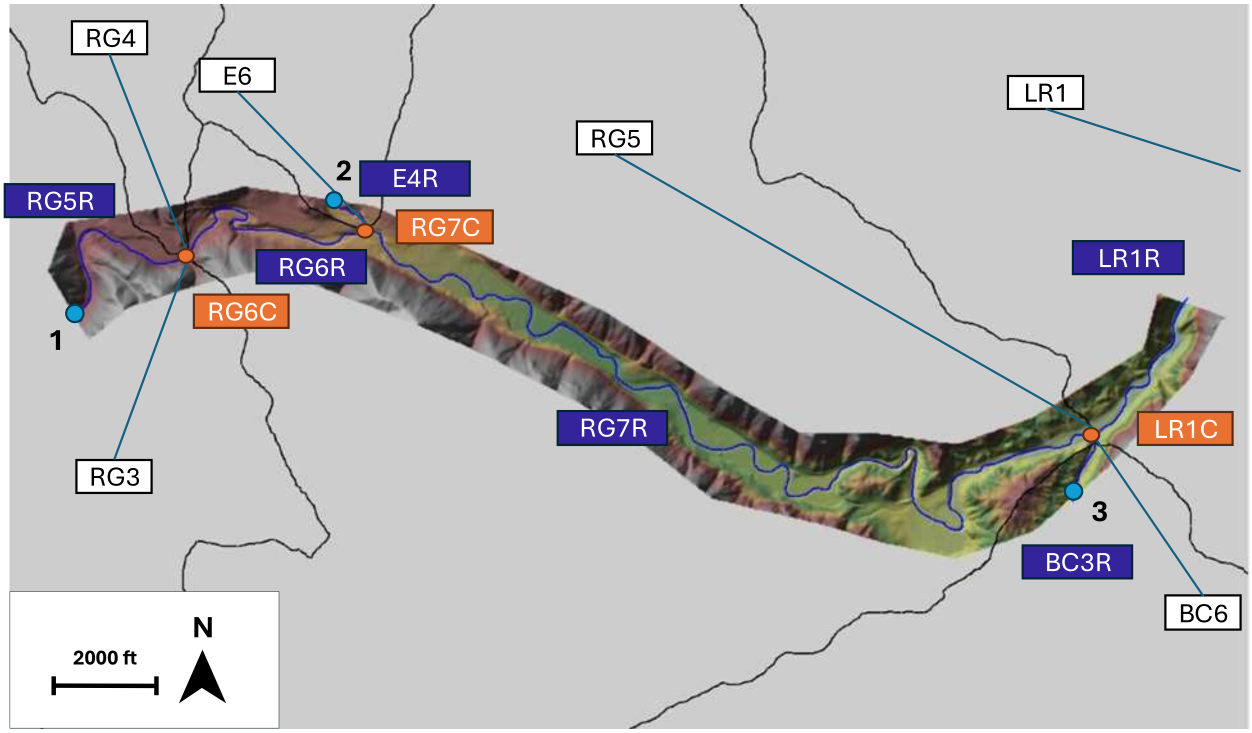

Figure 4.3. Pine hydraulic model and inflows. The blue labels show the reach elements, the white labels show basin elements, and the orange label show junction elements. Additional information on these elements can be found in the Pine HEC RAS Model (NFork_Pine_BC_Flows.xls).

4.3 Fluvial Hazard Zone

4.3.1 Channel Morphology

Channel morphology for the North Fork River was assessed using aerial imagery and terrain data (USACE 2024). It was determined that the North Fork is a meandering river with a sinuosity estimate of 1.45, which was calculated by dividing the length of the channel by the straight-line distance from start to end. Slope in the channel was determined to range from 0.0054 to 0.0251 feet. Channel confinement was primarily confined and partially confined with some unconfined reaches.

4.3.1.1 GEOMORPHIC REACHES AND CHARACTERISTICS

To better describe the geomorphic conditions in the area, the channel was divided into 12 geomorphic reaches based on confinement and morphology. Reaches range from 0.4 mile to 11 miles long with channel widths ranging from 25 to 83 feet. Sinuosity was also calculated for each reach and ranged from 1.1 (straight) to 3.3 (highly meandering) among the reaches in the North Fork Watershed. Each reach was also defined using the Montgomery and Buffington classification scheme (Montgomery and Buffington 1997). Table 4.3 provides a breakdown of the reaches and characteristics. Geomorphic reaches can be viewed in the project webmap.

Table 4.3. Geomorphic Reaches and Their Characteristics

Reach ID	Length (miles)	Average Channel Width (feet)	Sinuosity	Average Slope (%)	Confinement	Channel Type
1	11.5	30	1.1	1.86%	Unconfined	Pool-riffle
2	1.8	32	1.2	2.51%	Unconfined	Pool-riffle, with large plane-bed stretches and engineered steps/diversions
3	4.0	39	1.2	1.22%	Partially confined	Pool-riffle
4	1.8	39	1.2	1.12%	Partially confined	Pool-riffle
5	5.2	25	1.6	2.24%	Partially confined	Pool-riffle
6	2.3	53	1.6	0.85%	Partially confined	Pool-riffle
7	0.8	66	1.8	1.49%	Confined	Forced pool-riffles
8	1.1	60	1.6	0.68%	Partially confined	Pool-riffle
9	3.4	61	1.3	0.58%	Partially confined	Pool-riffle
10	0.5	65	3.3	0.54%	Unconfined	Pool-riffle
11	10.2	66	1.9	0.96%	Confined	Pool-riffle
12	0.4	83	1.4	0.55%	Partially confined	Pool-riffle

4.3.2 Fluvial Hazard Zone Delineation

The fluvial hazard zone (FHZ) for this planning effort was developed using the Colorado Fluvial Hazard Zone Delineation Protocol. Additional information on the protocol is available from the CWCB at: https://www.coloradofhz.com/resources.

First, the active stream corridor (ASC) was determined based on elevation modeling derived from lidar data. This is the area where the channel has the potential to widen or migrate. Next, the fluvial hazard buffer was calculated based on channel confinement ratios. This buffer shows where the stream channel may cause erosion and mass wasting of adjacent hillslopes.

A relative elevation model was created using an inverse distance weighting tool. A relative elevation model was used to identify fluvial patterns and local elevation fluctuations. Alluvial fans were manually identified as marked on mapping. Three types of fans were delineated: persistent, erodible, and ephemeral. The type of fan impacts how the stream channel is delineated around it. Alluvial fans are likely at risk in a post-fire environment. Notable fans include Ben Tyler Creek, McArther Creek, Buck Gulch, and Slaughterhouse Gulch.

The FHZ is useful for assessing risk from fluvial processes. Areas within the ASC have the highest risk of impact from flooding and channel movement. Areas in the FHZ have the second highest risk and may be impacted by slope failure and mass wasting. Areas outside of the FHZ and ASC have the lowest risk. Please note that the main stem of the North Fork River was the only channel for which an FHZ was delineated for this plan.

4.4 Hazard Analysis Results and Mapping

Below is a summary of the hazard analysis results for each HUC12 subwatershed in the planning area. Appendix C contains the full hazard analysis report with complete results for each HUC12 subwatershed.

4.4.1 Geneva Creek

Hydrologic Response. The change in flow rate in the Geneva Creek subwatershed is anticipated to increase by an average magnitude of five throughout the basin. Combined with anticipated post-fire sedimentation, culverts and crossings are likely to be overwhelmed. Lower in the subbasin, County Road (CR) 62 and other infrastructure are vulnerable to fluvial hazard. In particular, erosion, widening, and channel realignment are likely to cause damage. The percent increase in flow rates for subbasins in Geneva Creek is shown below in Figure 4.4

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations (see Section 4.1). For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. The upper portions of Geneva Creek appear to be resilient to post-fire impacts given the wide valley bottom geometry, which is a product of past glaciation (Madole et al. 1998). However, degradation is evident in the middle basin and may limit the stream function and resilience to post-fire.

Debris Flow. Overall risk in the subwatershed ranges from low to moderate. The highest risk exists in the lower portion of the subwastershed where the channel is confined. The headwaters portion of the subwatershed is at a low risk of debris flow.

Riverine and Hillslope Erosion. Following a wildfire, hillslope erosion is most likely to impact forested tributary channels in the lower basins. Threemile Creek and Scott Gomer Creek are likely to see an increase in erosion.

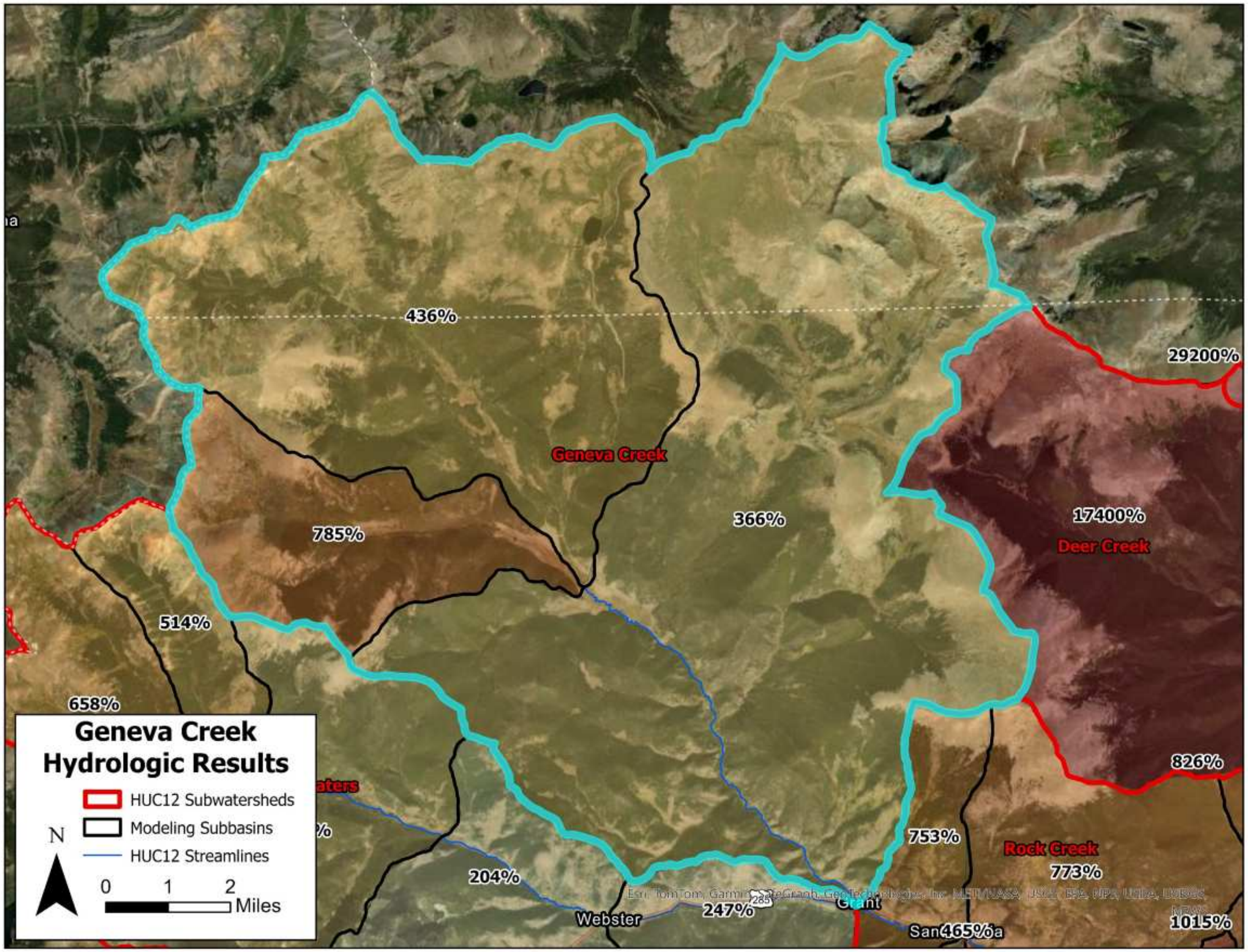

Figure 4.4. Percent change in 10-year flows for each subbasin in the Geneva Creek HUC12 watershed.

4.4.2 Headwaters of North Fork

Hydrologic Response. Stream flows in the headwaters of the North Fork are anticipated to increase roughly four times throughout the subwatershed (shown below in figure 4.5). Along with predicted sediment changes, culverts crossings are projected to be overwhelmed in a post-fire environment. Infrastructure near the stream channel is at an elevated risk from flooding, erosion, and channel realignment. This is particularly true in the lower basin above U.S. 285.

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. The model results indicate that the upper portion of the headwaters are resilient to post-fire impacts due to the wide valley bottom geometry. There are active beaver complexes along CR 60, which will be useful in attenuating flooding and additional sediment. The lower portion of the subwatershed along U.S. 285 has less attenuation potential, because the ASC is confined by the highway.

Debris Flow. Debris flow risk in the Headwaters of North Fork is relatively low. The highest risk areas in the subwatershed are primarily in remote areas where little to no risk to infrastructure is posed.

Riverine and Hillslope Erosion. Hillslope erosion is most likely to impact forested tributary channels, including Beaver Creek and the steep south slopes along CR 60.

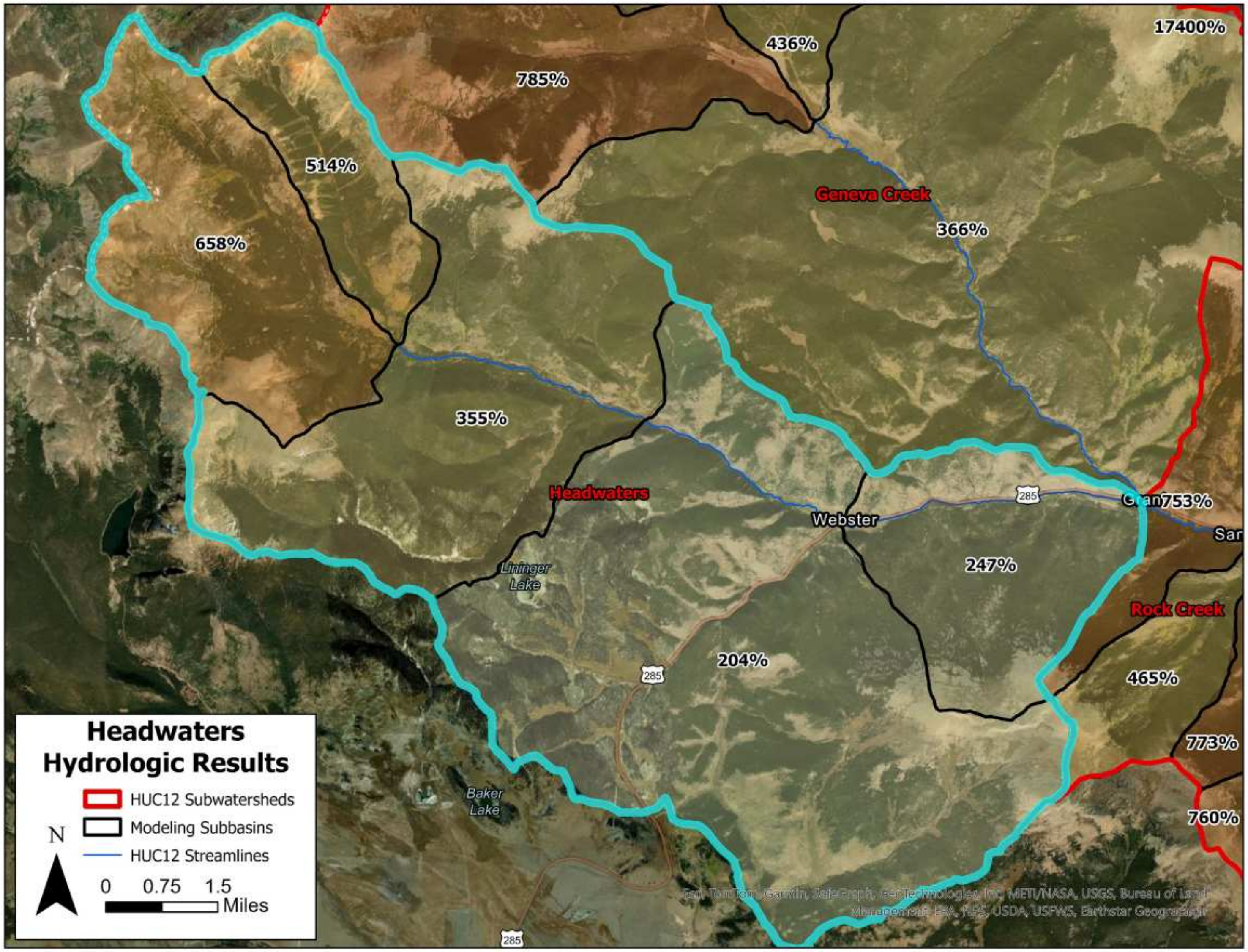

Figure 4.5. Percent change in 10-year flows for each subbasin in the Headwaters of the North Fork HUC12 watershed.

4.4.3 Rock Creek

Hydrologic Response. Rock Creek is anticipated to experience a large increase in flow rate, with an average 10-time order of magnitude increase across the subbasins. The expected increase is fairly consistent across the basin, and the slopes are relatively steep at greater than 30% grade on average. These combined factors will make natural attenuation very difficult and give the subbasin an elevated overall risk. The percent increase in flow rates for Rock Creek is shown below in Figure 4.6

Floods After Fire. Rock Creek is anticipated to see an elevated flood risk throughout the subbasin following a wildfire. U.S. 285 is the highest value resource that will be impacted at crossings. Figure 4.7 below illustrates the modeled hydraulic response for Santa Maria reach of the North Fork River along U.S. 285. This figure shows the likelihood of the road being inundated by flooding and the high velocity of the stream beginning at its crossing with U.S. 285.

Fluvial Hazard and Function. Flooding and debris flow risk are likely to increase in the subwatershed following a fire. U.S. 285 is vulnerable to these impacts, along with other properties and infrastructure near the stream corridor. Sediment deposition is likely to increase in the subwatershed, potentially resulting in lateral channel movement. Off-channel ponds are vulnerable to channel realignment as well.

Debris Flow. The subwatershed's topography and anticipated burn severity make Rock Creek the highest risk watershed in the planning area. Figure 4.8 below shows the subbasin debris flow risk rankings for the Rock Creek watershed. Impacts to communities are likely following a fire, specifically on alluvial fans where sediment movement and deposition is most likely. Specific tributaries at risk according to the debris flow modeling include Crow Gulch, Corbin Gulch, Quiner Gulch, Payne Gulch, Brookside Gulch, and McArthur Gulch. The lower portion of Crow Gulch parallels U.S. 285 and flows through Bailey, threatening this community. Payne and Brookside Gulch flow through several communities and pose a direct threat to private property and structures in the area. Additional basins that could pose a risk to adjacent infrastructure include Ben Tyler Gulch, Bill Tyler Gulch, Foster Gulch, and Shutetown Gulch. Additionally, the 2024 CFRI Wildfire Risk Assessment identified the lower mainstem of the subwatershed, below Bailey, as a zone of concern for its high risk of sediment delivery to Strontia Reservoir post-wildfire (CFRI 2024).

Riverine and Hillslope Erosion. Hillslope erosion in the subwatershed is likely to align with high burn severity areas and debris flow high-risk areas. These risk areas are mostly concentrated in tributaries to the south of U.S. 285. Most high sediment yield areas are in roadless and wilderness areas, which will limit treatment options.

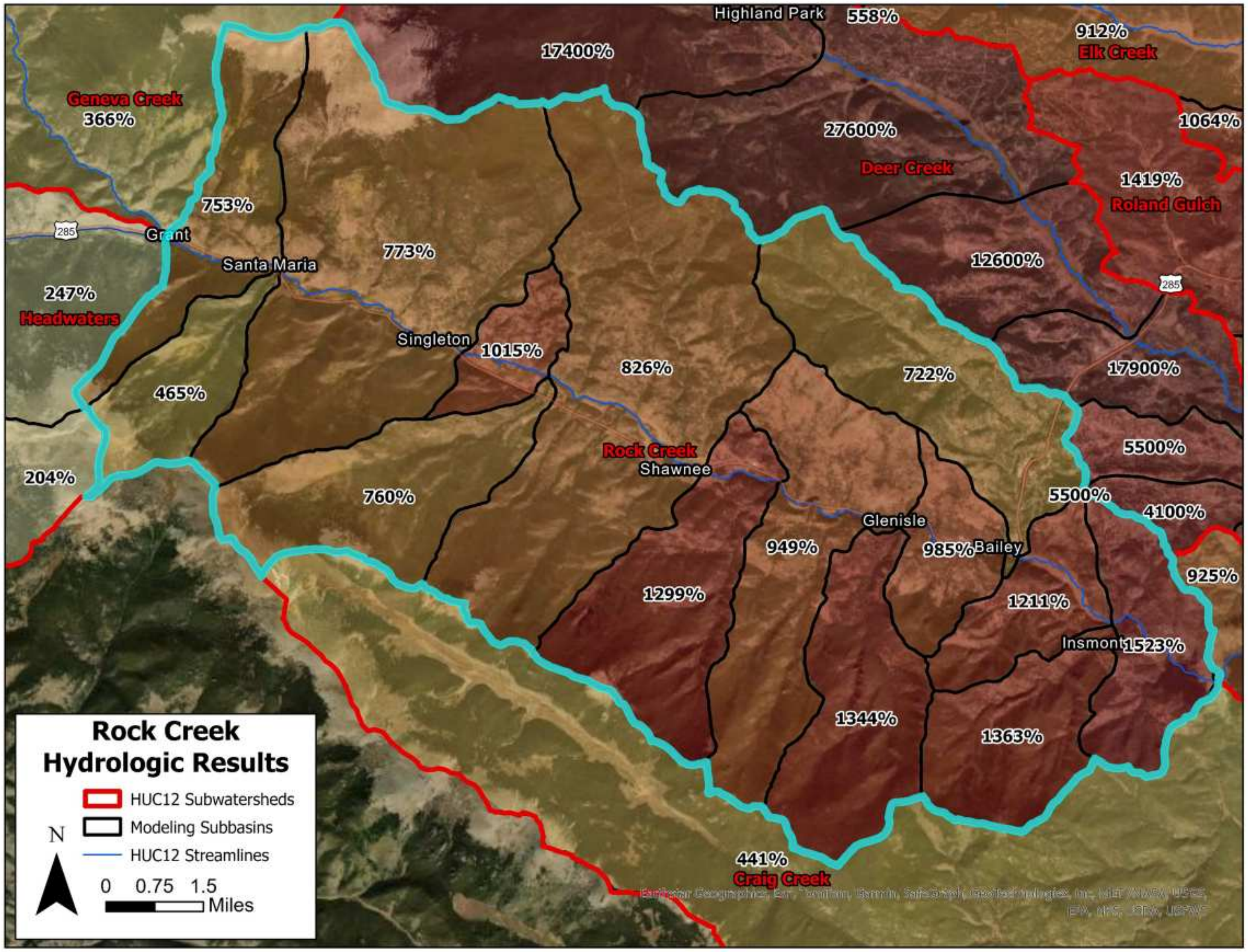

Figure 4.6. Percent change in 10-year flows for each subbasin in the Rock Creek HUC12 watershed.

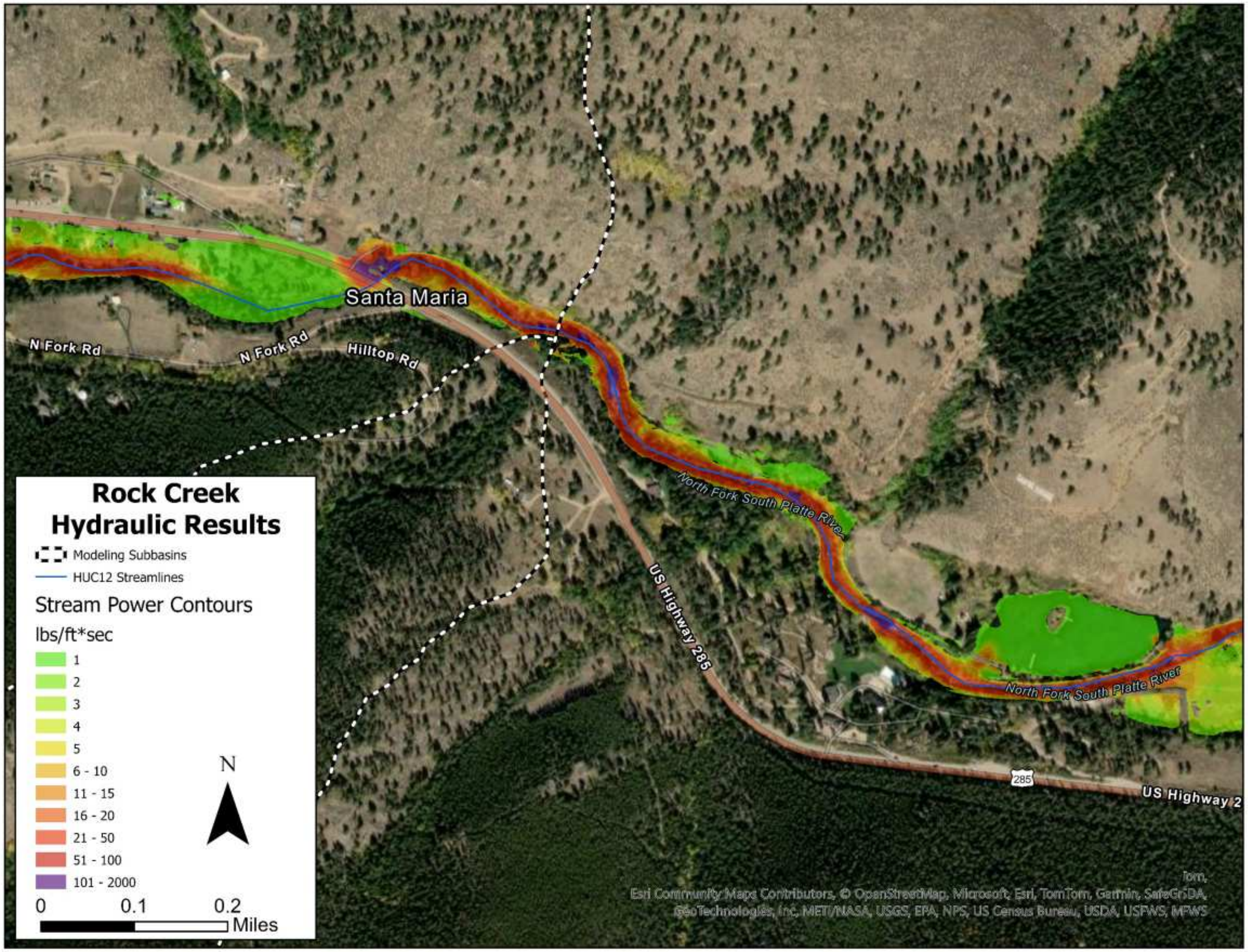

Figure 4.7. Hydraulic response results for the Santa Maria reach of the Rock Creek HUC12 watershed.

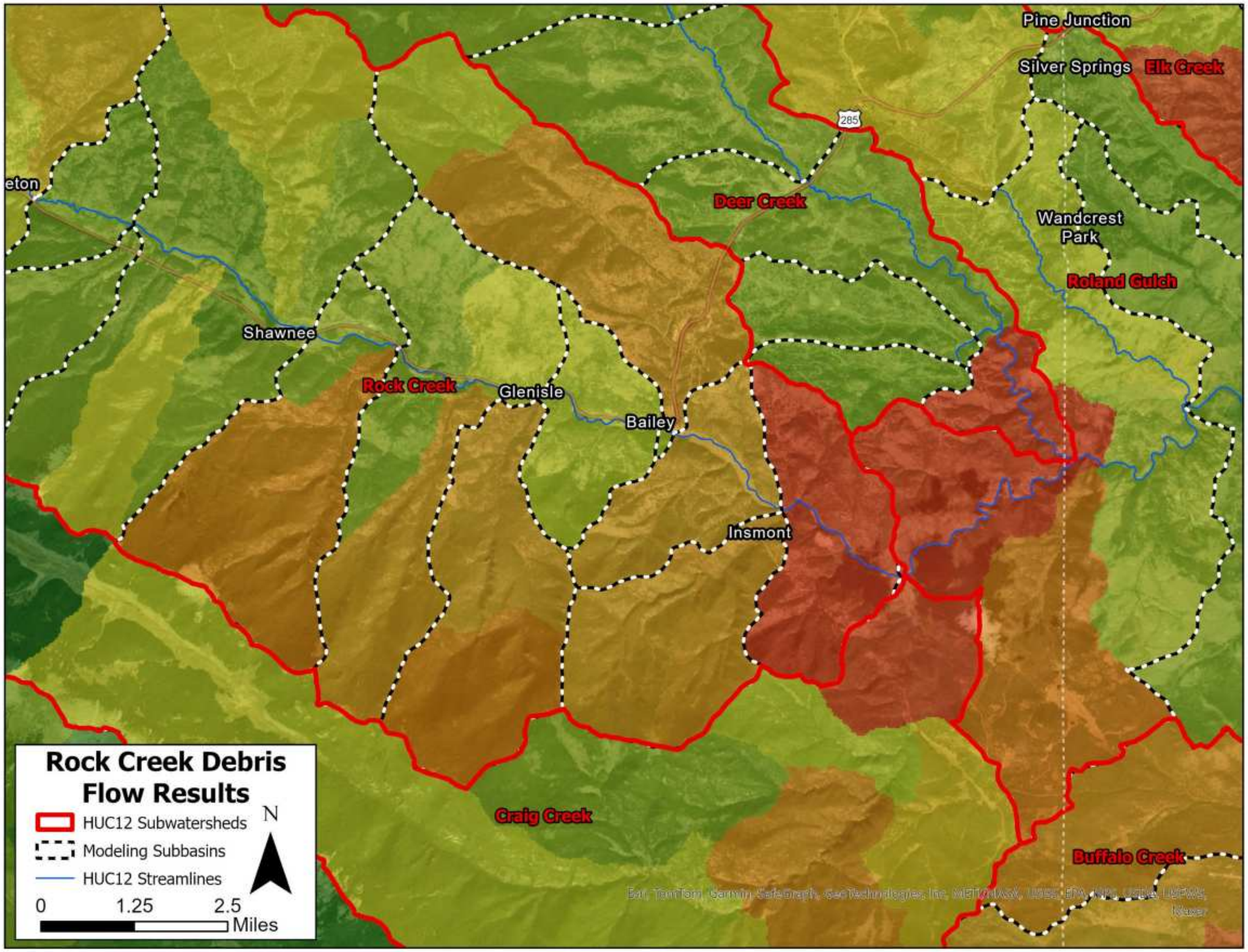

Figure 4.8. Debris flow hazard ranking results for each subbasin in the Rock Creek HUC12 watershed.

4.4.4 Craig Creek

Hydrologic Response. The subwatershed is anticipated to experience a moderate increase in flow rate, averaging a four-time increase across the watershed (shown in figure 4.9 below). Craig Creek is primarily designated as wilderness. The upper basin is primarily an unconfined alpine meadow that leads into a confined canyon before entering a partially confined canyon prior to the stream reaching the North Fork. Flood protection is likely the most effective means of addressing hydrologic response in the lower basin.

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5.

Fluvial Hazard and Function. The middle reach of the subwatershed is mostly confined and unable to support beaver complexes like those in the upper basin. The middle reach also has steep tributary channels that, together with the confined morphology of the reach, makes it a source and transport segment of the watershed. The lower basin has a potential depositional meadow near the intersection of CR 858 and CR 827, which could be a potential project site. There is also an alluvial fan along CR 68 lower in the basin, although imagery appears to show structures on the fan that may limit project opportunities.

Debris Flow. Debris flow risk is relatively low in the subwatershed given a lack of critical infrastructure; however, there are multiple drainages in the middle canyon and an alluvial fan in the lower canyon, which pose a high risk of debris flow events. These areas could pose a water quality hazard if a debris flow were to occur. Pre and post-fire mitigation options are limited due to wilderness designations and the short travel distance to the confluence with the North Fork.

Riverine and Hillslope Erosion. The upper basin is anticipated to experience high erosion yields from the hillslope adjacent to the lower meadow area. Similarly, southern tributaries in the middle canyon portion of the subwatershed were shown to have high yield. Mitigation in the basin is difficult given the high amount of wilderness area. Stream enhancement downstream of the main source tributaries will be necessary to mitigate impacts.

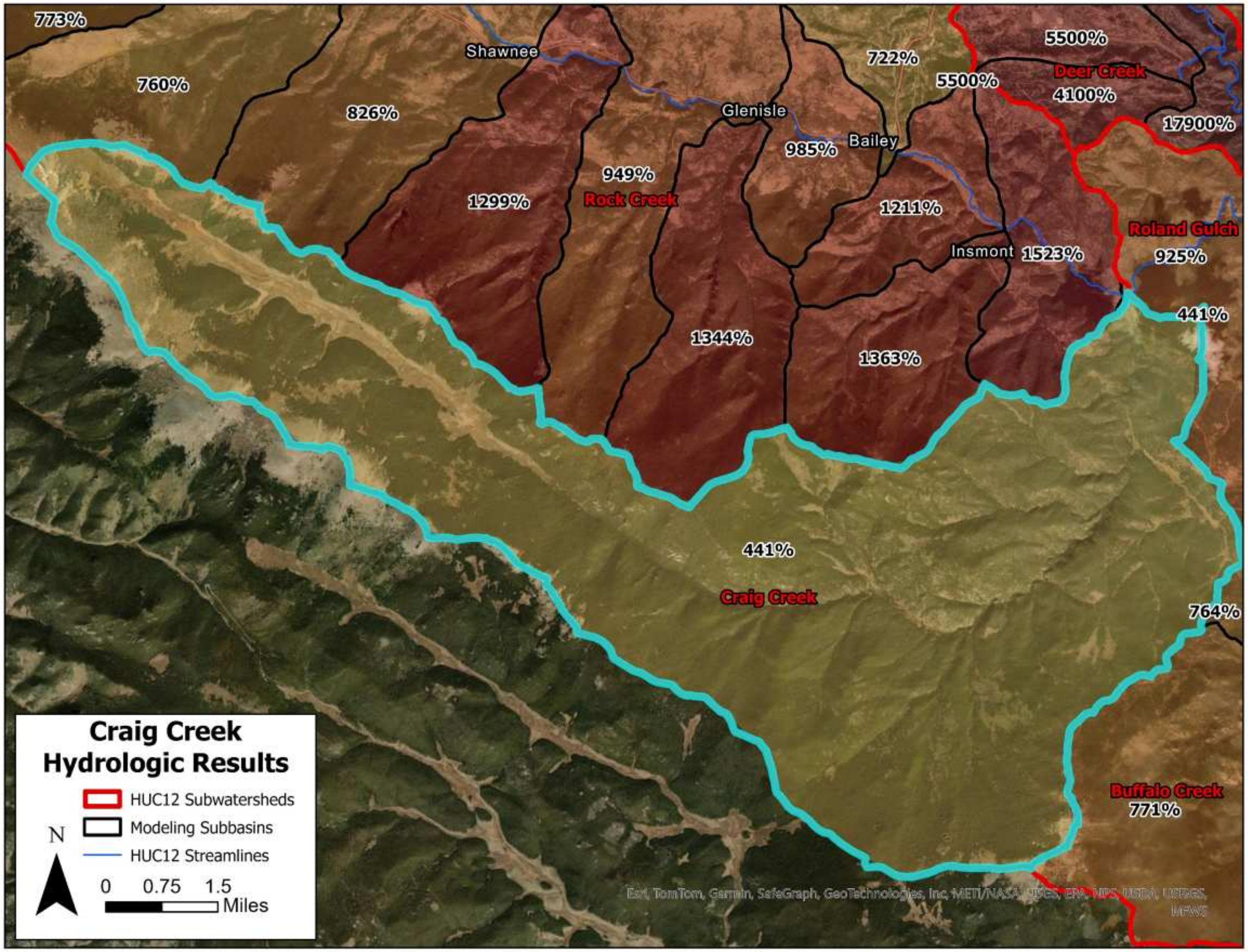

Figure 4.9. Percent change in 10-year flows for each subbasin in the Craig Creek HUC12 watershed.

4.4.5 Buffalo Creek

Hydrologic Response. The upper portion of the subwatershed—consisting of mainly Wellington Lake and Freeman Creek—is characterized by steep slopes, which increases the likelihood of post-fire impacts. However, the intensity of impacts that reach the North Fork are likely to be low due to the long travel distance from these areas. Wellington Lake is likely to attenuate much of the post-fire flow increase and sedimentation higher in the watershed. The percent increase in flow rates for Buffalo Creek is shown below in Figure 4.10

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. The Buffalo Creek subwatershed is fairly homogonous through the basin and is mainly confined to partially confined. There are a number of depositional meadows scattered through the subwatershed that provide an opportunity for enhancement to increase sediment and flow attenuation. Some of the creeks include Rolling Creek, Freeman Creek, inflows to Wellington Lake, South Fork Buffalo Creek, upper portions of Redskin Creek, Morrison Creek, and Buffalo Creek just upstream of the Town. Many of the roads share corridors with the fluvial system, exposing them to increased risk during flood events. The Redskin Creek Road should be improved, when possible, to improve ingress/egress and year round access to the watershed.

Debris Flow. The subwatershed is anticipated to experience moderate to high debris flow risk following a wildfire. Risk is focused in the upper watershed above Redskin Creek and South Fork Buffalo Creek. The upper one-fifth of the watershed is designated a wilderness area, which limits the risk to VARs in this subwatershed. However, the subwatershed demonstrates highly erodible soil, which elevates the risk of indirect impacts to downstream resources despite the highest debris flow risk areas being in the upper portion of the watershed. The 2024 CFRI Wildfire Risk Assessment also identified this watershed as a “zone of concern” given the high burn probability of the basins headwater and connection of Buffalo Creek to Strontia Springs Reservoir, a critical water resource east of the planning area (CFRI 2024).

Riverine and Hillslope Erosion. High yield areas are limited to the upper watershed within the roadless and wilderness areas. Because of the location and erodibility of the source material, mitigation at the source will be limited and impractical.

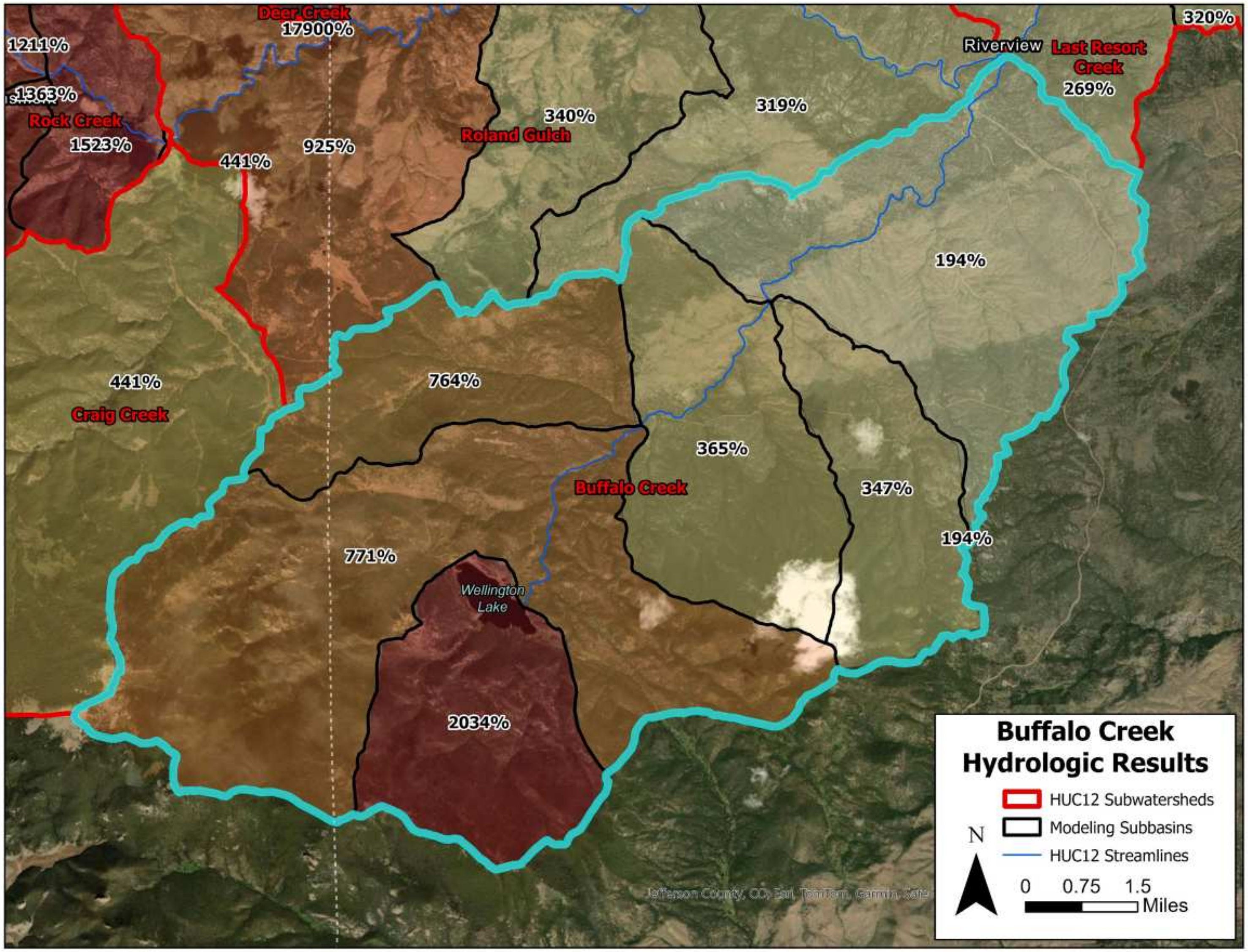

Figure 4.10. Percent change in 10-year flows for each subbasin in the Buffalo Creek HUC12 watershed.

4.4.6 Deer Creek

Hydrologic Response. Deer Creek basin demonstrates low slopes and unconfined valley structures, which limits excess runoff. Because of low base runoff, assessing the basin showed a large percent increase in post-fire flow but the absolute change in the subwatershed is minimal. Absolute change in 10-year flows for each subbasin in Deer Creek is illustrated below in Figure 4.11 Given the low base flow in the basins, any increase could cause hydrologic hazards following a fire and reduce the basins' natural resilience. Additionally, agricultural practices in the mainstem valley have modified portions of the floodplain and channel, which could increase vulnerability to post-fire degradation.

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. For much of its path in the subwatershed, Deer Creek parallels CR 43 in a large valley that was likely a beaver meadow complex in the past. Some ponds are still present, but the valley and channel have been modified for agricultural use. The remaining ponds and wetlands in the valley should be conserved to maintain beaver populations. Below the Rising Sun Road crossing, irrigation divisions, off-channel ponds, and simplification of the channel to a single thread has greatly reduced the function and resilience of this stream reach. This reach has about 14 road crossings that are at an elevated risk from post-fire impacts. Culverts are likely to be overwhelmed and limit the streams connection to the riparian extent of the valley. The lower basin flows through a steep canyon where flows and sediment will not be able to be attenuated or stored. Mitigation options are limited in this reach. Infrastructure is also limited aside from a community adjacent to the CR 72 crossing. This area is vulnerable to any post-fire flooding event given the potential for rapid valley change.

Debris Flow. Except for the lower canyon confined reach, the Deer Creek subwatershed has a low debris flow risk. The subwatershed does have the potential to influence the North Fork given its proximity; however, the lower reaches are confined and have low susceptibility to geomorphic change. The main influence on the North Fork would likely be sediment transport, which could impact downstream VARs.

Riverine and Hillslope Erosion. High yield erosion areas are primarily in the upper subwatershed within a wilderness area. Erosion in the upper basins is not likely to impact the downstream watershed or VARs, as much of the sediment will likely be attenuated in the lower valley reach. Efforts should be made to limit further degradation in the valley reach and rehabilitate the stream system to maintain sediment and flood water capture ability.

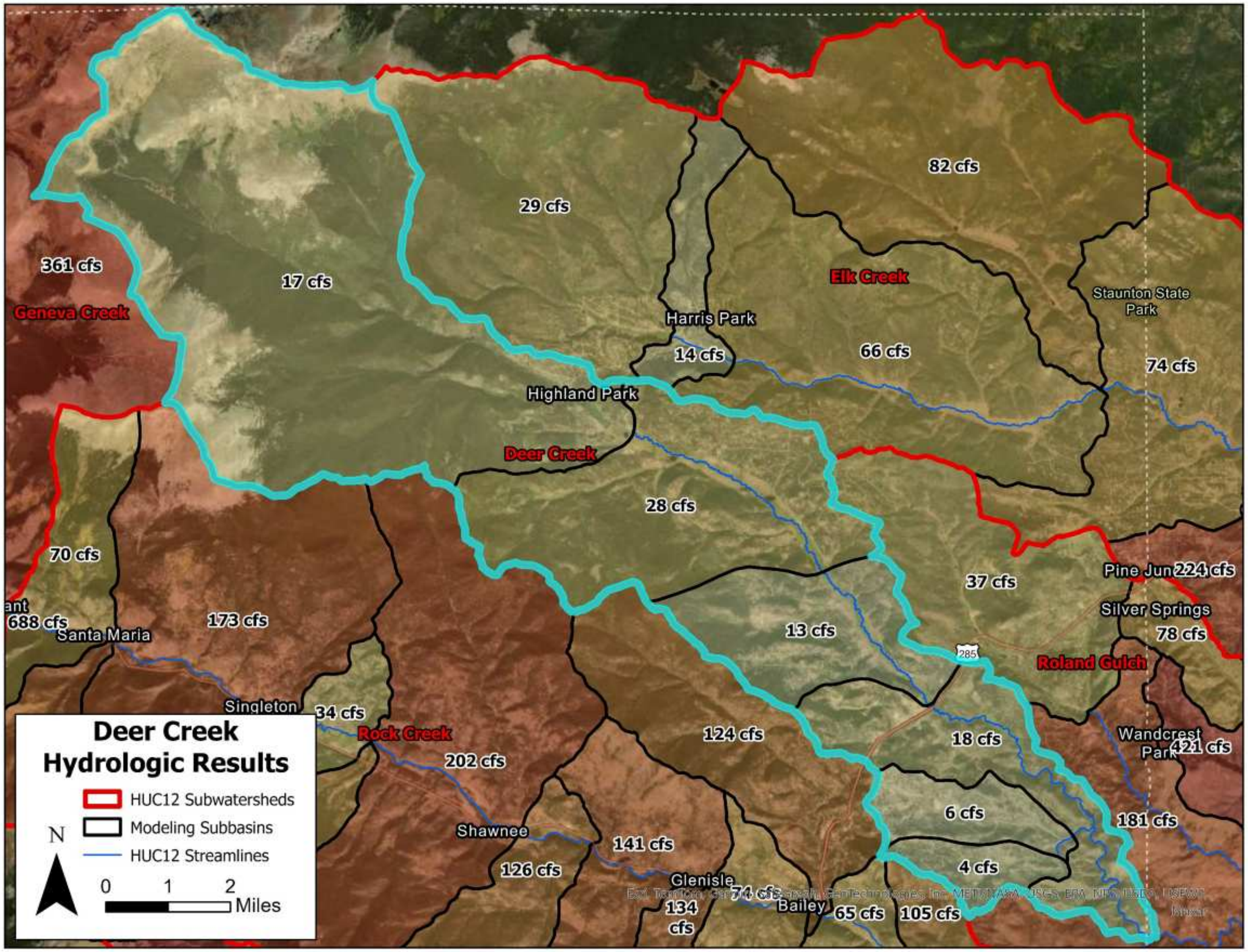

Figure 4.11. Absolute change in 10-year flows for each subbasin in the Deer Creek HUC12 watershed.

4.4.7 Elk Creek

Hydrologic Response. Similar to the Deer Creek subwatershed, Elk Creek has relatively low basin slopes and unconfined valleys that allow it to capture flood waters and sediment effectively. Base flow in the subwatershed is low, because most water is captured in the upper basins, but post-fire conditions could reduce this resilience in the upper basins, increasing flows and downstream impacts. Additionally, the lower basins have experienced degradation from agricultural activities that have increased vulnerability to post-fire hazards. Absolute change in 10-year flows for each subbasin in Elk Creek is illustrated below in Figure 4.12. The figure shows the compounding effects of hydrological change in this subwatershed with the lowest basin showing a substantial increase in flow. This is likely because many of the tributaries in the subwateshed are confined and water would likely move quickly into the main channel in a post-fire environment.

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. The subwatershed has large depositional meadows in the upper half of Elk Creek and middle stretch of North Elk Creek. There are opportunity sites for beaver dam analogues along Forest Drive in Elk Creek and Ridge Road along North Elk Creek where degradation has occurred. Flood and sediment resilience efforts, such as implementing beaver dam analogues, is necessary in these areas, as the stream has been heavily impacted by irrigation diversions, offline ponds, and channel simplification, which has reduced functionality. About four crossings are present in this area as well and would be highly susceptible to flood and sedimentation following a fire. The lower half of the subwatershed below Glenelk and along South Elk Creek Road flows through a steep canyon with little storage and deposition capacity. The canyon has many homes and private infrastructure that are at high risk from fluvial hazards. Indian Springs Village will be at high risk during any post-fire flood events due to the rapid change in valley width and density of structures and crossings.

Debris Flow. Debris flow risk in this subwatershed is low to moderate except for the lower canyon reach. This reach is characterized by tributary channels that are all very prone to debris flows in the event of a high-severity burn. Indian Springs Village and Sphinx Park are at acute risk in a post-fire environment.

Riverine and Hillslope Erosion. High yield areas in the subwatershed are primarily in the forested areas adjacent to the watershed divide. Erosion will likely be attenuated in the middle valley, provided degradation to the channel and floodplain are limited moving forward and, ideally, rehabilitated. Some portions of the lower canyon are showing as high yield, but the risk is less pronounced than in other reaches.

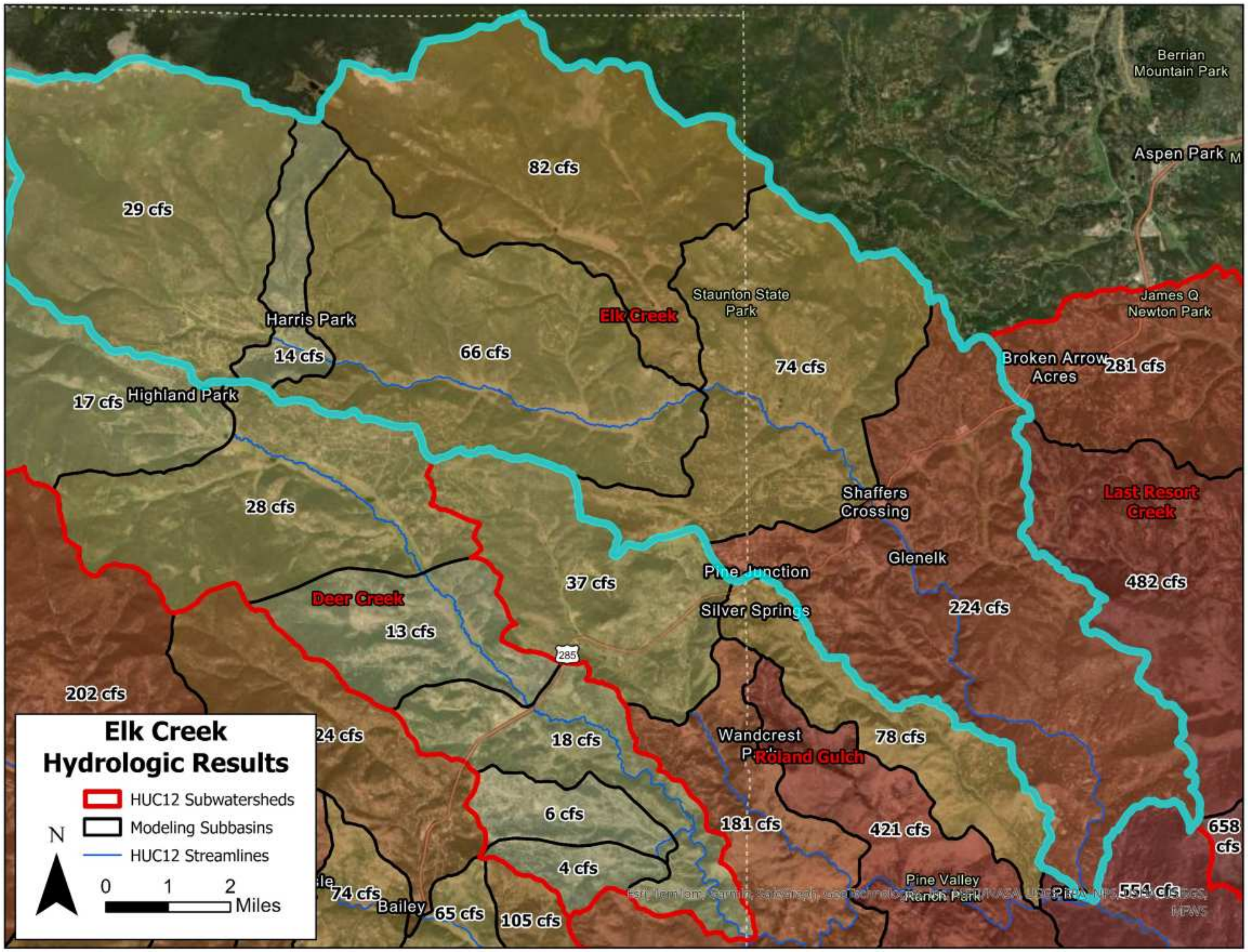

Figure 4.12. Absolute change in 10-year flows for each subbasin in the Elk Creek HUC12 watershed.

4.4.8 Roland Gulch

Hydrologic Response. Roland Gulch was partially burned during the High Meadow Fire and shows variability in flow increases between these areas and unburned areas. Overall, the subwatershed has an average anticipated flow increase of five times pre-fire flow rates (shown in figure 4.13 below). The upper watershed near Pine Gulch has low slopes, which may reduce post-fire impacts downstream. Upstream of Pine, many small tributaries feed directly into the North Fork and may pose a high risk to the mainstem if they were not impacted by the High Meadow Fire.

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. The three main tributaries in the subwatershed —Pine Gulch, Millers Gulch, and Buck Gulch—are confined prior to their confluence with the North Fork, which limits the opportunity for enhancement. One tributary in the upper watershed along CR-70 contains depositional reaches that could be enhanced for resilience. Along the mainstem of the North Fork, Pine Valley Ranch Park may have opportunities to attenuate flood water and sediment; however, the site has multiple uses, which may make it difficult to implement projects. Any roads adjacent to the confined tributaries are at risk of fluvial hazards, but the small drainage area will limit overall stream power and flood potential. CR-126, in particular, is at high risk given the proximity to the channel along a confined reach.

Debris Flow. The subwatershed is characterized by small tributaries in dense forests, which have been identified as high debris flow risk following a fire. The most pronounced risk is downstream of Pine in the confined valley reach of the North Fork. The mainstem of The North Fork is also identified as a concern zone in the 2024 Wildfire Risk Assessment due to the high risk of sediment delivery from this reach impacting downstream water resources.

Riverine and Hillslope Erosion. High erosion yield is predicted in areas with projected high burn severity. Erosion in the subwatershed would be expected to directly impact the North Fork and the broader stream system due to the limited resilience of the subwatershed.

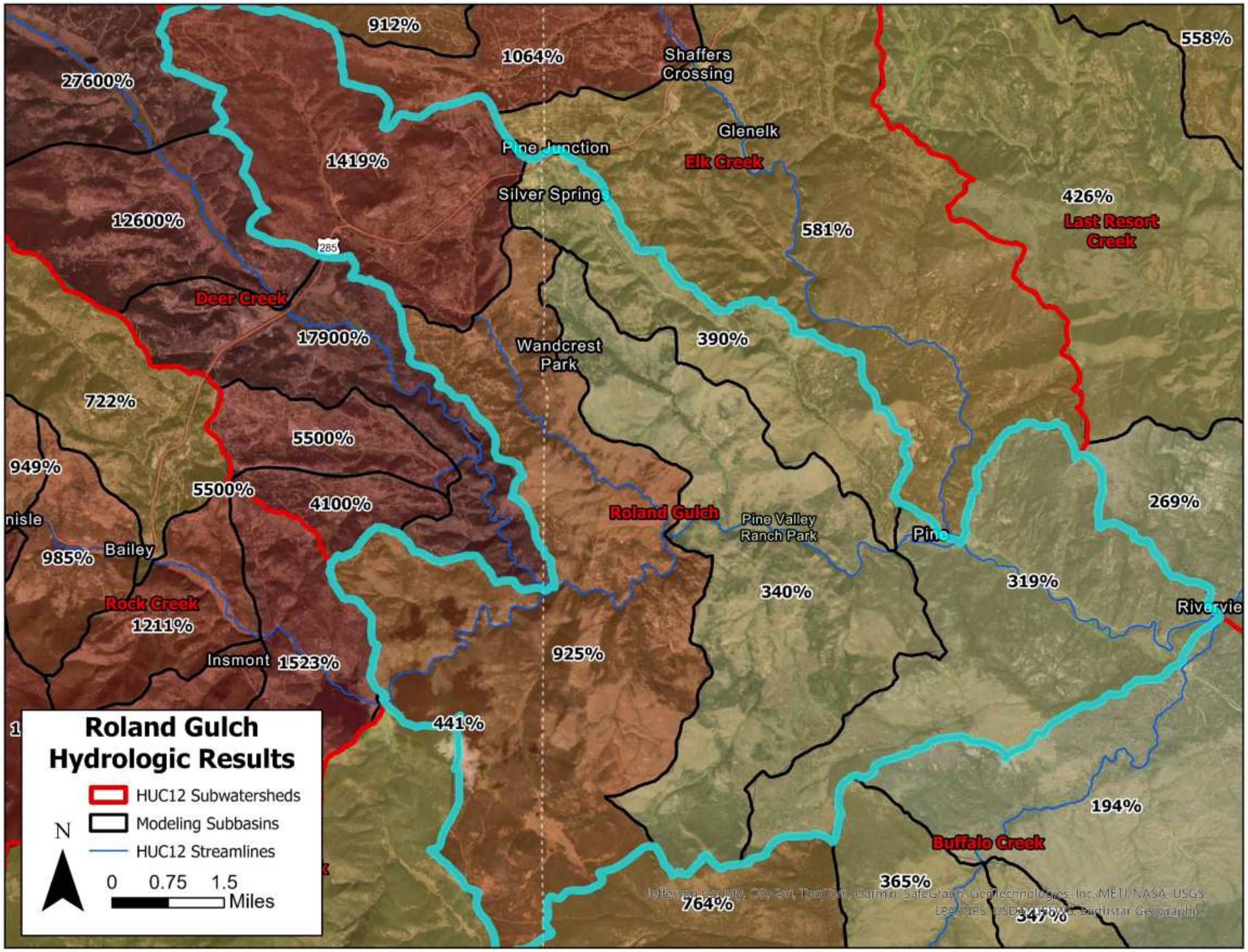

Figure 4.13. Percent change in 10-year flows for each subbasin in the Roland Gulch HUC12 watershed.

4.4.9 Last Resort Creek

Hydrologic Response. Flow increases in the subwatershed are anticipated to be moderate at an average of four times pre-fire flows. The percent change in 10-year flows for each subbasin in Last Resort Creek is illustrated below in Figure 4.14. The subwatershed was shown to have limited high burn severity areas, but overall, the system has limited resilience to post-fire hydrologic hazards. The channel is relatively confined through much of the basin, soils are erodible, and tributary channels are generally short in length. Attenuation in the tributaries will be limited, and impacts will likely reach the main stem.

Floods After Fire. Post-fire flooding was not analyzed for this subwatershed due to modeling limitations. For broadly applicable information on flood-related impacts, refer to Section 4.5

Fluvial Hazard and Function. Depositional zones are extremely limited in the subwatershed. Last Resort Creek and Kennedy Creek, the largest tributaries, are confined in granite canyons and will transport sediment and flow. Lower in the basin where confinement is not as drastic, the riparian corridor is limited by road encroachment and terracing. Roads along confined reaches of the subwatershed are at an elevated risk, particularly CR 69; however, Last Resort Creek is a smaller watershed, so overall stream power and flood potential is limited.

Debris Flow. The subwatershed has the highest modeled debris flow risk in the planning area. Risk ranking for each subbasin in the Last Resort Creek watershed is shown below in Figure 4.15. This is primarily due to the steep, confined nature of the tributaries, soil erodibility, and potential for intense rainfall. Impacts to the North Fork River are anticipated and would likely be drastic with limited mitigation potential.

Riverine and Hillslope Erosion. High yield areas follow high-severity burn predictions. Hillslope erosion is likely to directly impact larger stream systems due to the system's limited resiliency.

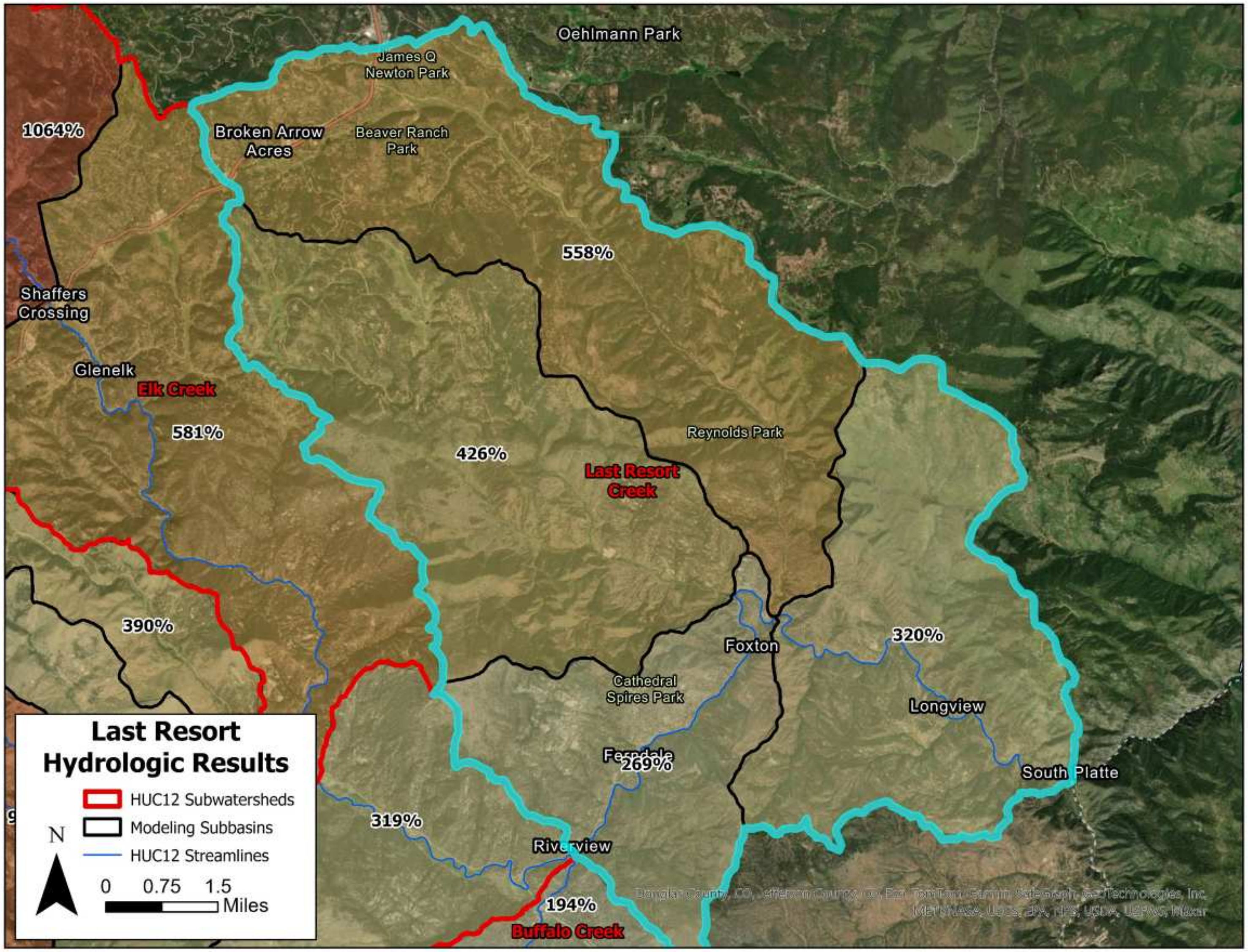

Figure 4.14. Percent change in 10-year flows for each subbasin in the Last Resort HUC12 subwatershed.

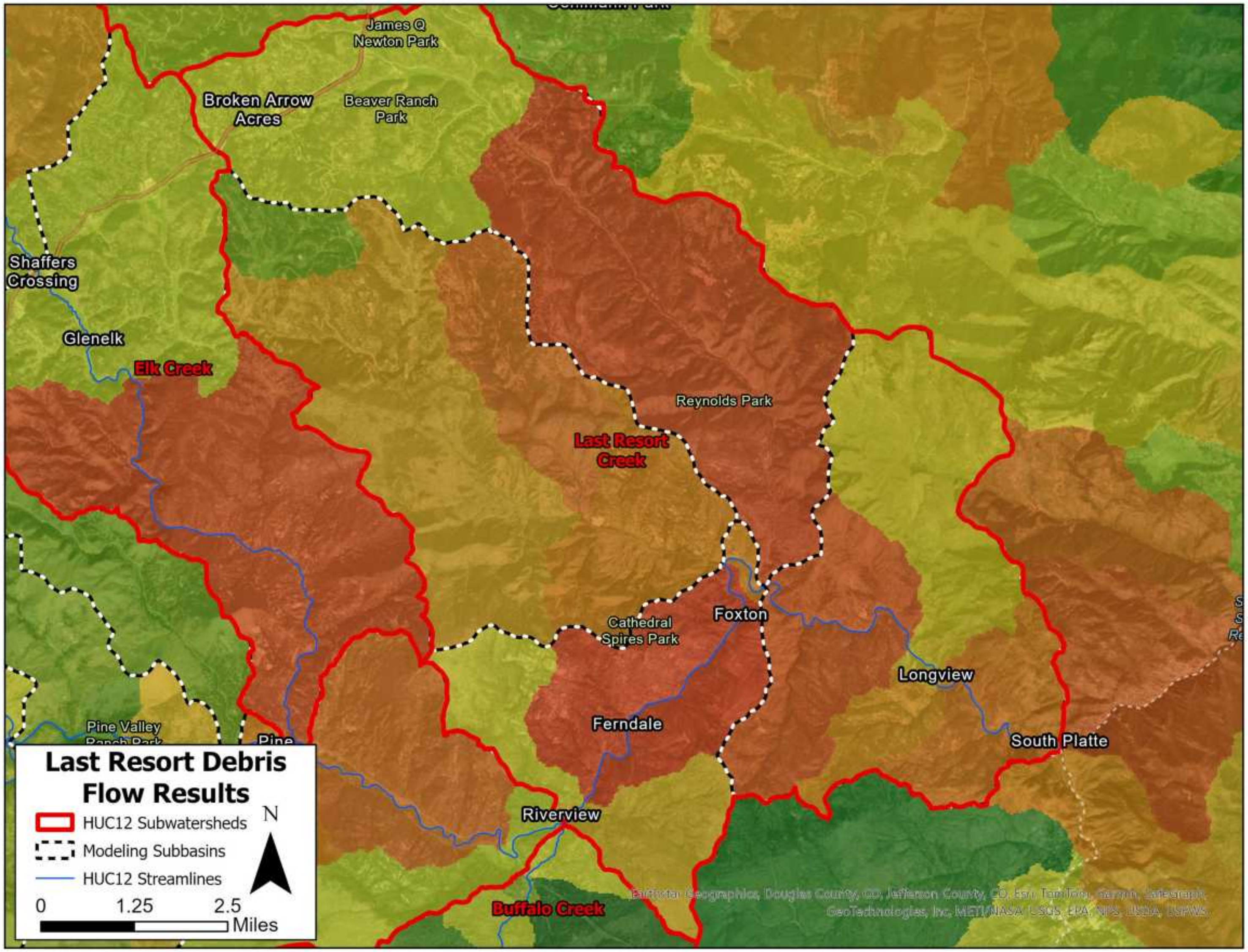

Figure 4.15. Debris flow hazard ranking results for each subbasin in the Last Resort HUC12 subwatershed.

4.5 Additional Watershed Hazards for Consideration

4.5.1 Floods After Fire

Wildfires alter forest, stream, and wetland processes in a number of unique ways, primarily stemming from loss of vegetative cover and alterations to soil chemistry and composition. Healthy forests function as natural sponges for precipitation, as they absorb precipitation and allow it to slowly drain into streams both through surface and ground water. Wildfires can greatly reduce this process by removing vegetation and reducing the soil's ability to absorb precipitation. Additionally, wildfires can alter the water cycle in a forest system by reducing residence time of snowpack and reducing evapotranspiration rates on the landscape. These impacts to forest-water interaction can heighten the amount and concentration of runoff reaching streams, which can lead to an increased risk of flooding. Flood risk on a post-fire landscape can increase from the 10% annual exceedance probability (AEP) event (referred to as the 10-year) to the equivalent of the pre-fire 1% AEP event (often referred to as the 100-year event). Additionally, post-fire impacts result in precipitation reaching streams quicker, concentrating runoff peaks, and creating a temporary increase in flashy behavior and flash flooding.

4.5.2 Debris Flow

Debris flows and mud slides in recently burned landscapes pose a serious risk to communities, critical infrastructure, and local travel routes. A debris flow is a mixture of water, soil, and rock that travels quickly down a slope. They can occur on hillsides, as well as in gulleys and channels. They occur because wildfires reduce or completely remove vegetative cover to various degrees dependent upon the severity of the fire. Additionally, high-severity burns will negatively impact soil composition, often reducing its ability to absorb water. These factors reduce the stability of soil so that when enough precipitation has fallen on the burned landscape, it begins to slide down the slope or channel. As debris flows move downhill, they will gather materials, such as trees and debris, gaining in size and speed. In addition to posing an immediate hazard to infrastructure and communities down slope, debris flows in channels completely block stream flow, altering the habitat and function of the stream for many years. Debris flows are most likely to occur on steep slopes and in areas that have experienced high burn severity followed by high-intensity rainfall.

4.5.3 Water Quality

Following a wildfire, the landscape and infrastructure may be directly and indirectly impacted, resulting in the release of pollutants and debris, which can be transported into waterways and affect water quality. The amount of human infrastructure and development in the burned area will directly impact the types and quantity of potential pollutants. For instance, homes that are burned will often contain asbestos, metals, plastic products, PFAS, polychlorinated biphenyls, solvents and chemicals from cleaning products and other household items, debris from structures, vehicles, other burned items, and other chemicals and materials common in homes. In less developed areas, fewer pollutants are likely present but are often still a concern and may include ash and sediment, bioavailable nutrients from burned vegetation, and fire retardants that were used to fight the fire. Historic mining operations are also an important consideration, as abandoned mine lands and tailing storage sites may be destabilized, allowing stored metals and pollutants to erode downstream.

As discussed above, soil may become hydrophobic, and sediment may become more easily erodible in burned areas. This surface alteration increases the ease with which these naturally occurring and introduced pollutant sources can be carried into waterways by rain, snowmelt, and stormwater, eventually ending up in reservoirs and natural water bodies. Because of the difference in potentially present pollutants, the severity of water quality hazards may vary between unpopulated wilderness areas and regions with human development. Additionally, it is important to recognize that water quality impacts following a wildfire can vary greatly depending on burn severity, burn area, and proximity to major stream and water bodies. Because of the many factors influencing water quality impacts in a post-fire landscape, burned area characterization is a critical first step in determining potential pollutants, their point source, and the route of runoff that will carry the pollutant to streams and water bodies. Additionally, stream monitoring will be a key undertaking to track shifts in nutrient and chemical concentrations.

5 SUSCEPTIBILITY ANALYSIS

This section provides information on values/assets in the planning area, the susceptibility analysis methods (hazards x values), an overview of the analysis results, and a summary of critical values at risk throughout the planning area.

5.1 Purpose

The watershed susceptibility analysis consists of analyzing watershed-related hazards and risks to infrastructure and communities in a post-wildfire landscape. Specifically, hazards and risks posed by post-fire debris flows, sediment yield, and flooding were analyzed in detail. The post-fire hazard analysis (see Section 4) analyzed the increased risk of sediment yield, debris flow, and flooding hazard at a subwatershed scale. The susceptibility analysis builds upon those results to identify specific locations where infrastructure, water resources, critical habitat, recreational values, and other values at risk (VAR) in the watershed overlap with identified areas of elevated post-fire hazard risk. Subwatersheds are ranked based on the number of VARs that are present in areas with high risk (high concentration of VARs = high susceptibility). The intent of this exercise is to prioritize pre- and post-fire resilience building and mitigation efforts based on subbasin hazard rankings, as well as quantity and importance of VARs within each subwatershed.

Based on this analysis, land managers, water utilities, counties, fire officials, emergency planners, and others can begin to prepare strategies and methods for reducing their risk exposure to post-wildfire watershed hazards, as well as work with community members to educate them about minimizing their risk exposure to post-wildfire watershed hazards. Because various treatments to reduce watershed-related risks can be implemented on both private and public lands, stakeholders can actively apply the treatments on their properties, as well as recommend treatments on public lands that have a high value to the community and require protection. Additional information on potential treatment options and considerations is presented in Appendix E.

5.2 Values at Risk

Values at risk (VARs) include any asset that may be impacted by post-wildfire hazards and that a community wishes to protect from post-wildfire hazards.

VAR data layers divide the VARs into broad asset categories—water infrastructure and life and property. Within these broad categories, six water infrastructure and 10 life and property subcategories were identified based on assessment of planning area features and input from the project partners, core team, and stakeholder group (see Table 5.1). Datasets that included VARs were obtained from publicly available databases, and others were provided to us by project partners, core team members, and stakeholders. A comprehensive list of datasets and data sources used in this analysis is provided in Appendix B.

Please note that although the CWCB guidance included wetlands and riparian areas as a VAR category, following discussions with the North Fork WRAP stakeholders, wetland and riparian areas were removed from the VAR scoring criteria due to their unequal contribution to overall watershed scores. When the susceptibility analysis was originally run with wetlands and riparian areas included, remote watersheds with few other VARs present showed significant susceptibility. Although the protection and restoration of these areas is critical to forest and watershed health, their inclusion in the susceptibility analysis made it difficult for stakeholders to identify priority projects with a more direct influence on the protection of life, property, and critical infrastructure. Additionally, it is worth noting that flooding intersect was only assessed for the Grant-Bailey and Pine reaches of the watershed where 2D hydraulic modeling was completed. These reaches were selected for modeling based on area of concern prioritization discussions with the core team and stakeholder group. Table 5.1 illustrates the VAR categories and the post-fire hazards that were analyzed for each. Green boxes with a check mark indicate that the VAR was assessed for its susceptibility to that hazard. Red boxes with Xs indicate that the VAR was not assessed for its susceptibility to that hazard.

Table 5.1. Values at Risk Categories and the Post-fire Hazard where each Value at Risk was Analyzed for its Potential to be Impacted

Framework Risk Matrix		Values-at-Risk															
		Water Infrastructure						Life and Property									
		Reservoirs (Total Storage Volume)	**Built Flowlines** (Total Length)	**Decreed Water** (Total Flow Rate)	**Source Water**	**Natural Conveyance**	**Water Infrastructure (Structures, Diversions, etc)**	**Buildings**	**Historic Buildings**	**Critical Infrastructure**	**Recreational Areas**	**Energy Infrastructure**	**Crossings**	**Roads**	**Trails**	**Abandoned Mining Lands**	**Hazardous Materials**
Post-Fire Hazards	**Hydrologic Change** (Watershed Level Intersection)	✓	X	X	✓	✓	✓	X	X	X	X	✓	✓	X	X	X	X
	Flooding (Direct Intersection)	X	X	X	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Sediment Yield Change (Watershed Level Intersection)	✓	✓	✓	✓	✓	✓	X	X	X	X	✓	✓	X	X	✓	X
	Debris Flow (Watershed Level Intersection)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X
	Fluvial Geomorphic Hazards (Direct Intersection)	✓	✓	X	X	X	X	✓	✓	✓	✓	✓	✓	✓	✓	X	✓

5.2.1 Water Infrastructure

Water is a critical resource and value in the watershed planning area, which is likely to be at an elevated risk following a fire on the surrounding landscape. As such, preventing water quality impairments and watershed degradation should be a priority of risk mitigation. The watershed planning area has a variety of water infrastructure exposed to post-fire watershed-related hazards. As discussed above, a list of infrastructure and values was developed based on publicly available data and input from the core team. If these infrastructure and resources are damaged in a post-wildfire setting, the region's water supply and quality of water could be threatened. To capture how water quality and supply could be threatened, the core team identified the following types of water infrastructure and resources to include in the watershed risk analysis:

Water Infrastructure VARs

- Reservoirs (total storage volume)
- Build flow lines (total length)
- Decreed waters (total flow rate)
- Source water
- Aquatic species habitat
- Water infrastructure (structures, diversions, treatment plants, etc.)

5.2.2 Life and Property

Life and property within the watershed planning area can also be threatened by post-wildfire watershed-related hazards. A large portion of the watershed planning area has life and property that could be exposed to adverse watershed-related hazard in a post-wildfire environment, including residential homes, critical infrastructure, and economically important structures. Other examples of values, resources, and concern sites include the following:

Life and Property VARs

- Buildings
- Historic properties
- Critical infrastructure (communication towers, transmission lines, transformers, etc.)
- Recreational areas (campsites, trailheads)
- Energy infrastructure
- Crossings (bridges and culverts)
- Roads
- Trails
- Abandoned mining lands
- Hazardous materials (brownfield sites, landfills, superfund sites, etc.)

The planning area has a high occurrence of roads and crossings in hazard-susceptible areas that are important to both local and regional travel. During discussions with the Core Team, it was determined that it was necessary to weight roads according to the amount of travel they accommodate and importance to regional travel. To do this, local and minor roads were assigned a value of 1, major roads were assigned a value of 3, and highways were assigned a value of 5. This same weighting system was applied to road crossings so areas where highways intersect a channel resulted in higher susceptibility scoring than areas where local roads were intersected.

5.3 Watershed Susceptibility Analysis Evaluation and Results

The susceptibility analysis was conducted using a GIS-based intersection approach to identify high-risk areas where hazards overlap with VARs. Detailed methodology for the susceptibility analysis is available in Appendix D. The results show risk levels for identified VARs, rated from low to high, on a hexagonal grid. Each hexagonal cell measures 1.1 miles in diameter, with darker purple cells indicating higher susceptibility than lighter or unshaded cells. It is important to note that unshaded cells still present post-fire hazards and risks; they simply do not contain VARs as defined by the North Fork WRAP core team and stakeholders. The high-susceptibility areas within the North Fork WRAP planning area, in conjunction with core team and stakeholder feedback, were used to inform the identification of the priority areas and projects detailed in Section 5.4 and Section 6 below.

5.4 Priority Areas

The planning area is extensive, with many regions highly susceptible to post-fire hazards. The susceptibility analysis identified areas where hazards and VARs overlap. Consequently, priority areas were developed (Figure 5.1) to narrow the geographic scope and pinpoint specific locations for project implementation to address hazards and protect VARs. These priority areas were selected based on hazard assessments, VARs, and stakeholder feedback. They were generally chosen because they 1) exhibit overlapping, high-potential post-fire hazards, 2) contain significant or concentrated VARs, and/or 3) were prioritized during stakeholder discussions. Table 5.2 summarizes the hazards and VARs within each priority area. Mitigation actions for these areas are detailed in the preparedness plans (Sections 6 and 7).

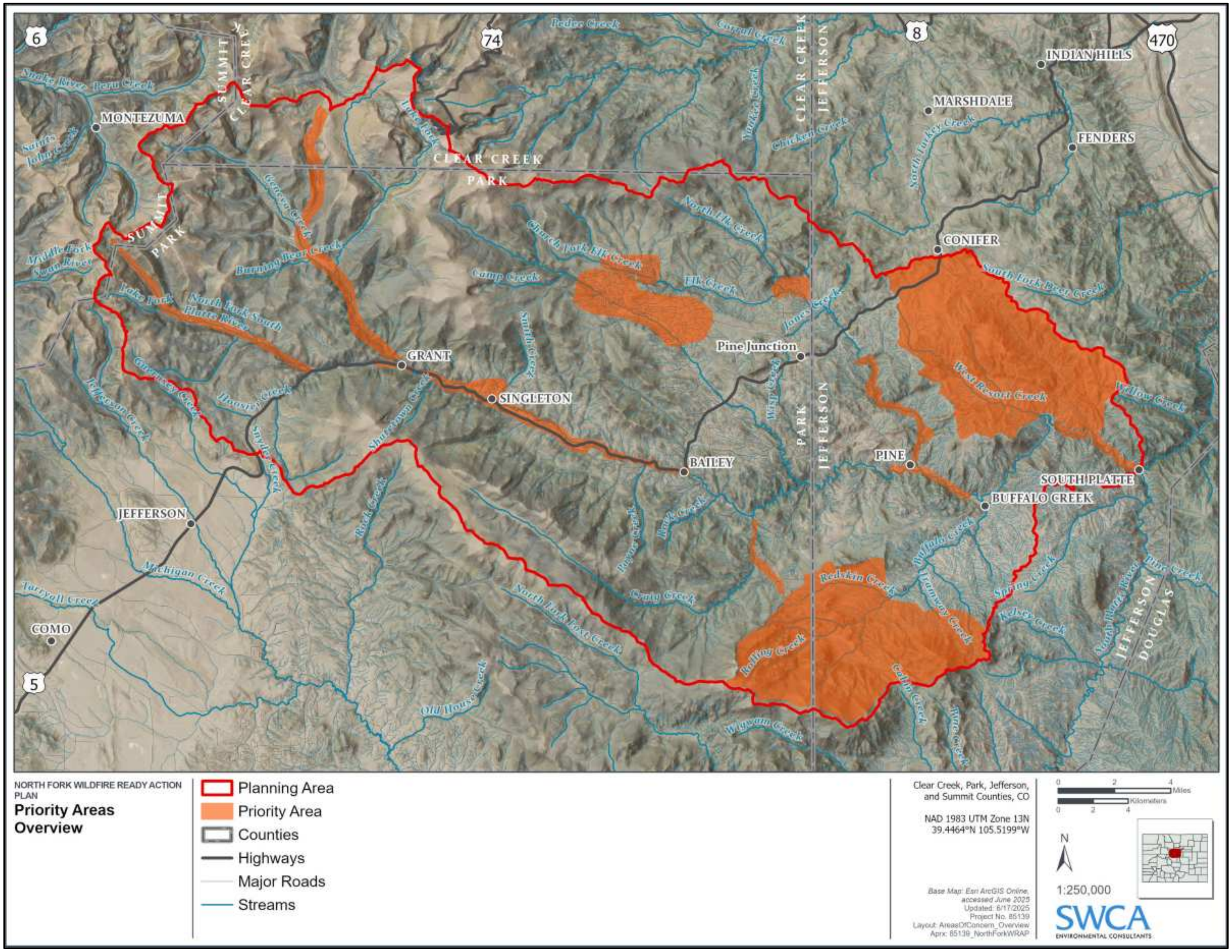

Figure 5.1. Priority areas selected based on overlapping high hazards, values at risk, and feedback from stakeholders.

Table 5.2. Areas of Concern, HUC12 location, and the Relevant Hazards and Values at Risk within each Area of Concern

Area of Concern	Priority Area ID	Project Subregion Name	Parent HUC12	Relevant Hazards	Vulnerable Infrastructure
Grant	GR-1	CR 60	Headwaters of North Fork River	• Debris flow • Fluvial hazards (confined canyon)	• Roadway (CR 60 and private) • Recreation • Private structures (houses near Webster)
	GR-2	CR 62	Geneva Creek	• Debris flow • Fluvial hazards (confined canyon)	• Roadway (CR 62 and private) • Recreation • Private structures (houses in canyon)
	GR-3	Grant	Geneva Creek	• Fluvial hazards • Debris flows (proximal but upstream) • Hydrology and hydraulics	• Roadway (U.S. 285 and private) • Private structures • Recreation • Water resource (Roberts Tunnel, diversion downstream of Geneva Creek)
U.S. 285 Corridor	RC-1	Santa Maria to Shawnee	Rock Creek	• Fluvial hazards (confinement transitions, alluvial fans) • Debris flows (many alluvial fans) • Hydrology and hydraulics	• Private structures • Recreation • Roadway (U.S. 285 and private; many private bridges) • Water resources (ponds and diversions)
	RC-2	Bailey	Rock Creek	• Debris flows (Crow Creek) • Hillslope erosion • Hydrology and hydraulics	• Drinking water sources • Private structures • Public services (bulk water station, fire station, post office)
Craig Creek	CC-1	Non-Wilderness (Lower)	Craig Creek	• Hillslope erosion • Debris flow	• Drinking water source
Pine Valley	PV-1	Pine	Roland Gulch	• Debris flows (Elk Creek) • Hydrology and hydraulics	• Private structures • Roadway (private bridges and access; CR 126 at Elk Creek)
	PV-2	Lower Elk Creek Canyon	Elk Creek	• Fluvial hazards (confined canyon) • Debris flows • Hydrology and hydraulics	• Roadway (South Elk Creek Road) • Private structures • Water resources (ponds and diversions)

Upper Deer Creek/Elk Creek	DE-1	Harris Park	Elk Creek	• Hydrology and hydraulics	• Roadway (three culverts over Elk Creek into Harris Park) • Private structures • Water resources (ponds)
	DE-2	Highland Park	Deer Creek	• Hydrology and hydraulics	• Roadway (CR 43, two culverts over Deer Creek to housing) • Private structures • Recreation • Water resources (ponds)
	DE-3	Staunton Park	Elk Creek	• Hydrology and hydraulics	• Roadway (CR 83) • Private structures • Water resources (ponds)
Buffalo Creek	BC-1	Upper Buffalo Creek	Buffalo Creek	• Hillslope erosion • Debris flow • Fluvial hazards • Hydrology and hydraulics	• Water resources (drinking water, Wellington Lake) • Roadway (South Buffalo Creek Road and private access) • Recreation • Private structures
Last Resort Creek	LR-1	Upper Last Resort Creek	Last Resort Creek	• Hillslope erosion • Burn severity (dense private property in high country) • Debris flow • Fluvial hazards (confined along South Foxton Road)	• Private structures • Recreation • Roadway (South Foxton Road) • Water resources (near Strontia Springs Dam) • Habitat (Preble's meadow jumping mouse)
	LR-2	Lower North Fork S Platte	Last Resort Creek	• Fluvial hazards (confined/partially confined canyon) • Debris flow	• Roadway (CR 96) • Recreation • Water resources (near Strontia Springs Dam)

6 PRE-FIRE PREPAREDNESS PLAN

This section outlines priority areas and suggested projects within each priority area. The sections details hazards, management strategies, and mitigation approaches to protect VARs from post-fire hazards before a fire occurs. These actions should be taken prior to a fire to reduce wildfire burn severity, to educate residents or provide warning systems, to protect or improve infrastructure resiliency, or to mitigate modeled post-fire impacts in a pre-fire setting. As illustrated on Figure 6.1, priority areas were identified based on hazards, VARs, and stakeholder feedback. Within each priority area, the suggested project locations pinpoint specific hazards, key VARs needing protection, and applicable treatments for risk mitigation. The section is organized by priority area, each containing one or more project suggestions. For each project, the primary hazards and VARs are identified, along with potential mitigation options for addressing these hazards in a post-fire setting.

Additional resources in this WRAP that will aid the planning process include the following:

- Relevant information on hazards (Sections 4 and 6), VARs (Sections 5 and 6), and pre-fire mitigation options for each project location (Section 6).
- Additional treatment options with descriptions, appropriate approach, setting, and rough cost estimates in Appendix E.
- An example project development case study and associated workflow that detail how to use the hazard and susceptibility analysis results to inform project site selection and holistic wildfire protection and recovery. This case study is provided as Appendix E.1.
- Summary treatment approach sheets in Appendix E.2, covering approach descriptions, benefits, limitations, stakeholders, implementation scale, and other relevant information for restoration, erosion and sediment capture, infrastructure protection, roadway improvements, stream stabilization, and administrative actions. These sheets also identify potential partners.
- Proposed Mitigation Actions Shapefiles:
    - Beaver_Locations – Conservation of existing valuable ecosystems is typically cheaper and more effective than the restoration of these environments. High functioning depositional environments, such as beaver complexes, are vital in absorbing post-fire sediment and water influxes. This shapefile is an initial attempt at documenting these locations for conservation by utilizing aerial imagery and the *Colorado Beaver Activity Mapper (COBAM).*
    - Strontia_Sed – Denver Water provided the data from the Strontia Sediment Management Plan in areas of overlap with this WRAP. The projects were lifted directly from the plan, with updates from Denver Water, and included in this study because of the overlapping goals in controlling pre-fire sedimentation to water infrastructure.
    - Proposed_Admin – Based on the risks identified within this study, individual communities were identified and prioritized for administrative action. The recommended types of administrative action are also detailed in the attribute tables, however this should be reviewed by specialists.
    - Proposed_PBR – A desktop analysis was performed using the datasets within this WRAP and aerial imagery to identify depositional reaches that may be appropriate for PBR projects, as laid out in the Mitigation Approach Sheets. Additional analysis of these areas should be performed in a site specific feasibility study that includes review of ownership, hydrology, existing geomorphic conditions, and access.

- Proposed_Stream_Stab – Limited areas of conflict between roadways and the North Fork are delineated in this dataset. Relocation, while potentially more difficult in the short term, should be explored as a long-term solution to these conflicts when possible.
- Priority_Access – Crossings at high to moderate risk were identified based imagery, risk modeling, and access options.

- The final project webmap, which will be hosted on a website managed by Denver Water, will be available to stakeholders and project sponsors.

Figure 6.1 outlines the process and resources for using this WRAP and the pre-fire preparedness plan to identify and plan pre-fire mitigation projects. Appendix E includes a comprehensive list of pre- and post-fire mitigation options, along with a summary of the suggested projects, relevant hazards, VARs, and mitigation strategies.

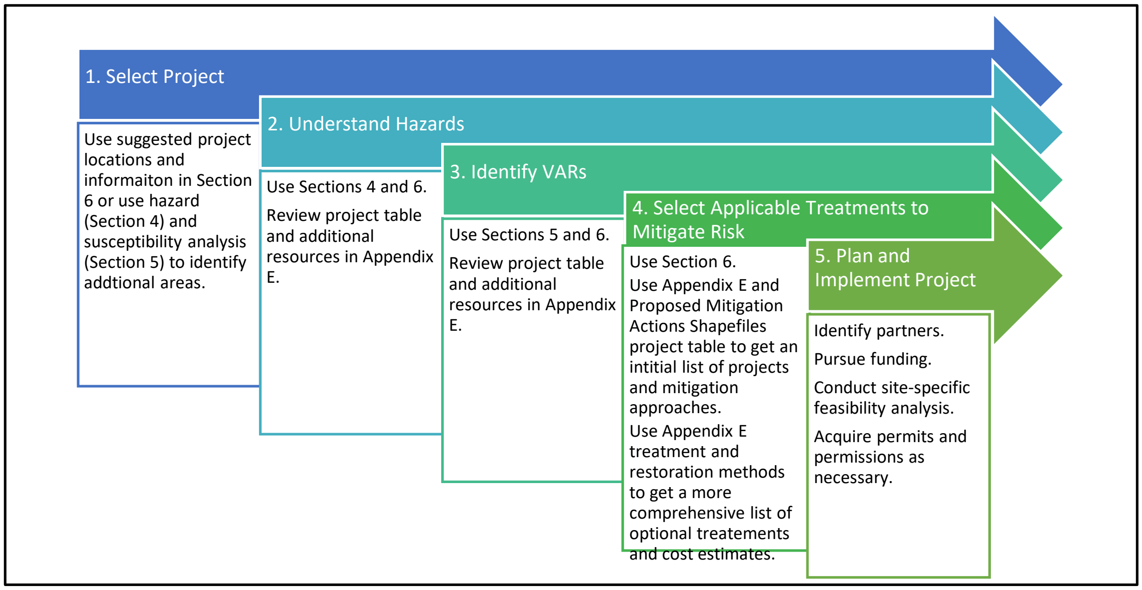

Figure 6.1. Process and resources within this WRAP to select a project area, understand the hazards and values at risk, identify potential treatments, and plan the project to mitigate post-fire risks before they occur.

6.1 Grant Area of Concern

The Grant Area of Concern (AOC) is in the headwaters of the North Fork of the South Platte and Geneva Creek HUC12s. There are three priority areas within this AOC, GR-1, GR-2, and GR-3 (Figure 6.2). In a post-fire setting, these priority areas have high potential to be impacted by debris flow, fluvial hazards, high flows, and inundation. Information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

Figure 6.2. Grant priority areas that include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.1. Grant AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
GR-1	• Debris flow • Fluvial hazards (confined canyon)	• Protection of roadways (CR 60 and private) • Recreational amenities • Private structures (houses near Webster)	• Process-based restoration (reaches higher in subbasin) • Roadway and access improvements • Hillslope Erosion and Sediment Control	• Some depositional meadows adjacent to road • Protection of existing beaver populations (along CR 202) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
GR-2	• Debris flow • Fluvial hazards (confined canyon)	• Protection of roadways (CR 62 and private) • Recreation • Private structures (houses in canyon)	• Process-based restoration (upper watershed). • Roadway and access improvements • Hillslope Erosion and Sediment Control	• Some depositional meadows adjacent to road • Implement applicable project identified in Strontia Sedimen Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

GR-3	• Fluvial hazards • Debris flows (proximal but upstream) • Hydrology and hydraulics	• Protection of roadways (U.S. 285 and private) • Private structures • Recreation • Water resources (Roberts Tunnel, Diversion downstream of Geneva Creek)	• Process-based restoration (upper watershed) • Infrastructure protection (at private structures along North Fork River) • Roadway and Access Improvements (U.S. 285 at Geneva Creek; Bridge upstream of Roberts Tunnel) • Stream stabilization (bank armoring, conveyance) • Administration (community outreach)	• Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

6.2 U.S. 285 Corridor Area of Concern

The U.S. 285 Corridor AOC is in the Rock Creek HUC12. There are two priority areas within this AOC, RC-1 and RC-2 (Figure 6.3). In a post-fire setting, assets in these areas are at higher likelihood of impacts from fluvial hazards, debris flow, high flows, and flooding. Additional hazard and mitigation options to implement before a fire occurs are provided in Table 6.2 and information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

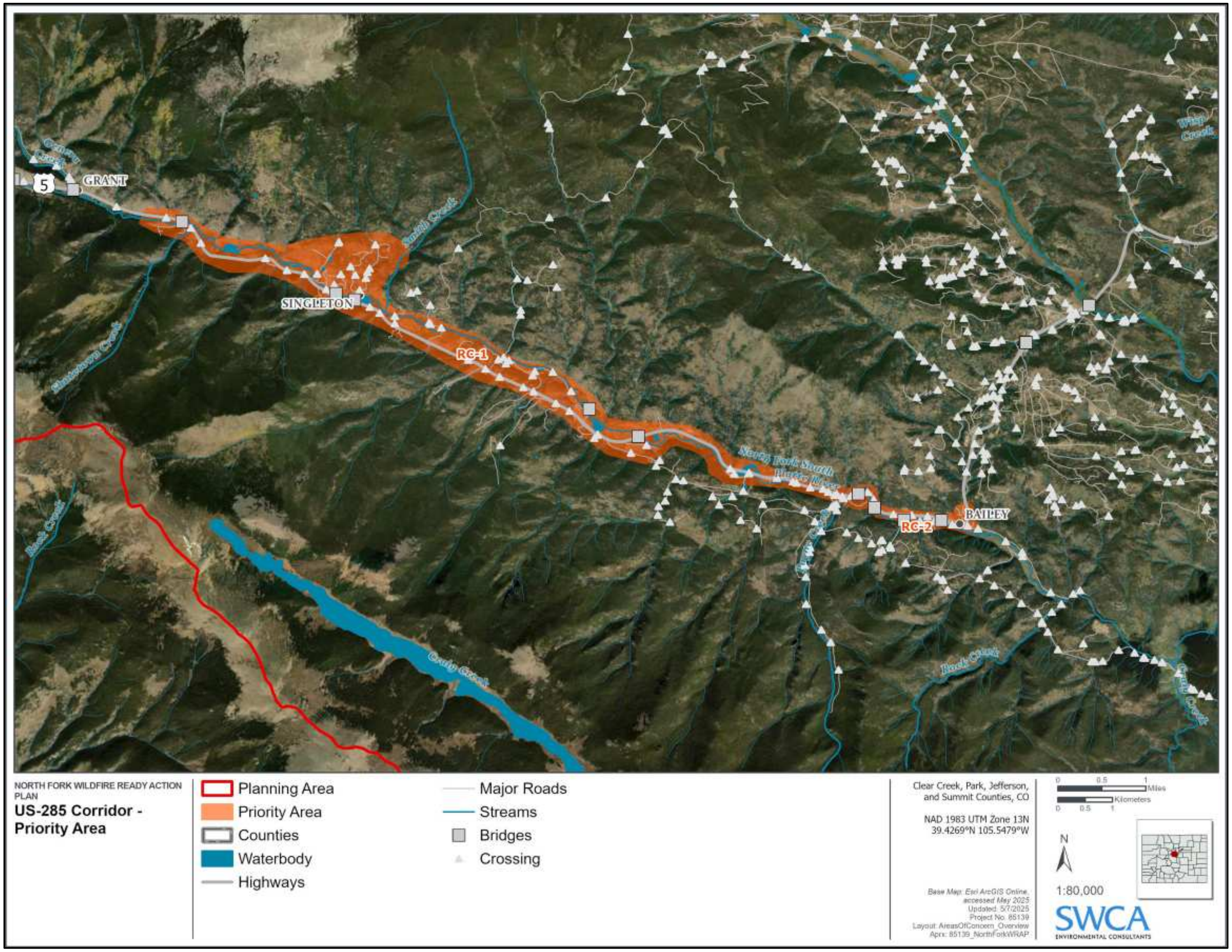

Figure 6.3. U.S. 285 Corridor priority areas that include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.2. U.S. 285 AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
RC-1	• Fluvial hazards (confinement transitions, alluvial fans) • Debris flows (many alluvial fans) • Hydrology and hydraulics	• Private structures • Recreation • Roadway (U.S. 285 and private; many private bridges) • Water resources (ponds and diversions)	• Process-based restoration (along main channel) • Roadway and access improvements • Infrastructure protection • Stream stabilization (bank armoring, conveyance) • Administration (community outreach) • Hillslope Erosion and Sediment Control • Forest treatment	• Many alluvial fans along U.S. 285 on south side of North Fork River. • Mountain Drive and Cline Drive are the only access to large housing development. • Mooredale Road: Stream realignment, creating an overly steep and confined reach. • Platte River Drive: Forces split and culverts on both bridge sections downstream. • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • Some initial Stream Stabilization needs and sites have been identified (Proposed_Stream_Stab.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
RC-2	• Debris flows (Crow Creek) • Hillslope erosion • Hydrology and hydraulics	• Drinking water sources • Private structures • Public services (bulk water station, fire station, post office)	• Process-based restoration (upper watershed of tributaries, especially Crow Gulch) • Roadway and access improvements (CR 64 at North Fork) • Hillslope erosion and sediment control • Infrastructure protection • Stream stabilization (bank armoring) • Forest treatment • Administration (alert gages, community outreach, buyouts)	• Crow Gulch is a large debris flow risk north of town. • In town, bridge is narrow, and culverts are undersized. • Bailey water sources are south of North Fork River. • Some initial Stream Stabilization needs and sites have been identified (Proposed_Stream_Stab.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

6.3 Craig Creek Area of Concern

The Craig Creek AOC is in the Craig Creek HUC12 and has one priority area, CC-1. (Figure 6.4). This HUC12 has a large wilderness area, so we did not consider projects in that area of the HUC12. In a post-fire setting, assets in these areas are at higher likelihood of impacts from hillslope erosion and debris flow. Impacts to water quality is of particular concern in this priority area because of limitations to a distributed mitigation approach, which is required with process-based restoration and hillslope treatments. Additional hazard and mitigation options to implement before a fire occurs are provided in Table 6.3 and information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

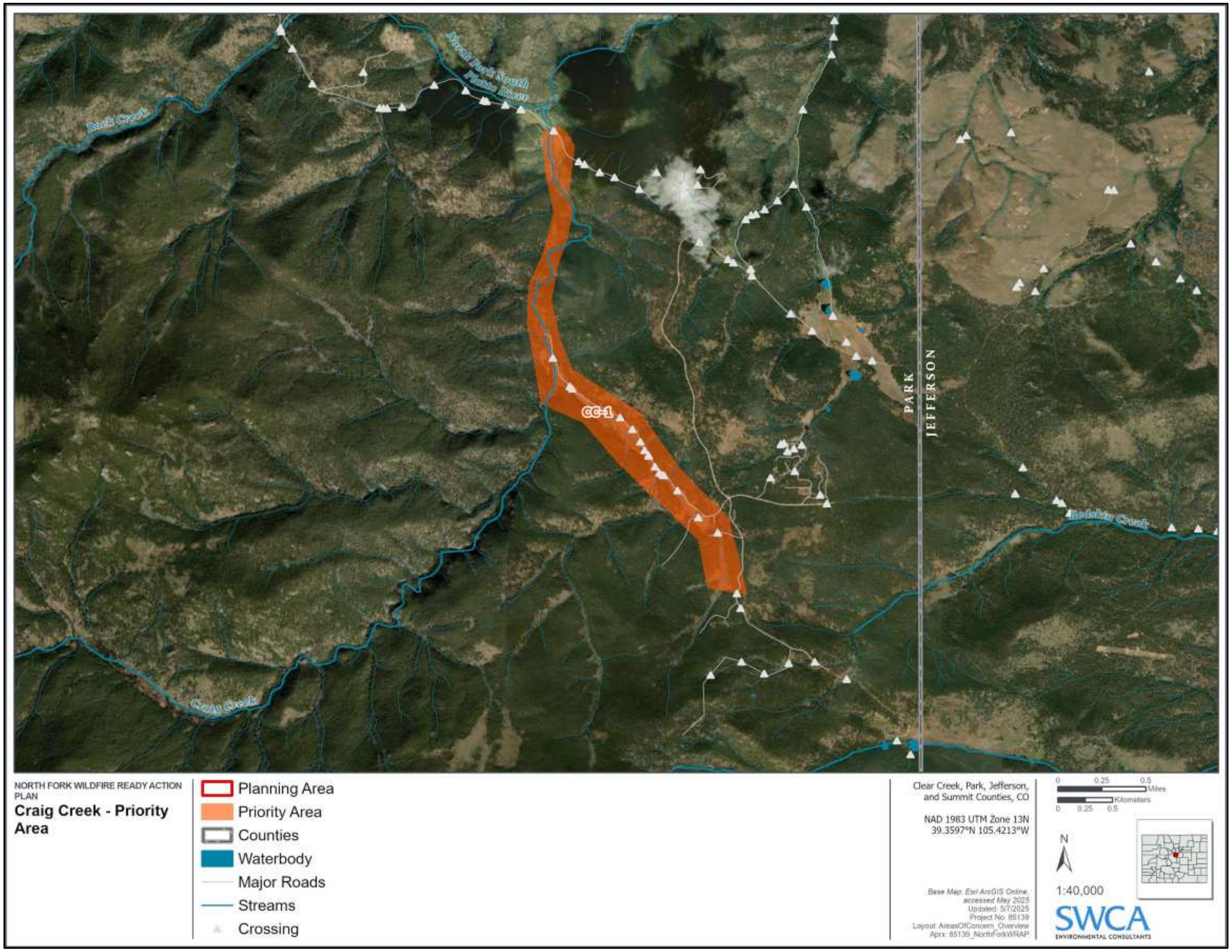

Figure 6.4. Craig Creek priority areas which include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.3. Craig Creek AOC: Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Vulnerable Infrastructure	Treatment Categories and Project Types	Notes
CC-1	• Hillslope erosion • Debris flow	• Drinking water source	• Process-based restoration (meadow just below wilderness) • Hillslope erosion and sediment control	• Most of HUC12 is wilderness, where it is highly unlikely to get approval to implement projects. • Some crossings have been identified in the lower portion of the basin (Priority_Access.shp) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

6.4 Pine Valley Area of Concern

The Pine Valley AOC is in the Roland Gulch and Elk Creek HUC12s and has three priority areas, PV-1, PV-2, and PV-3. (Figure 6.5). In a post-fire setting, assets in these areas are at higher likelihood of impacts from hillslope erosion, debris flow, elevated flows, flooding, and fluvial hazards (in the confined canyon). Additional hazard and mitigation options to implement before a fire occurs are provided in Table 6.4 and information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

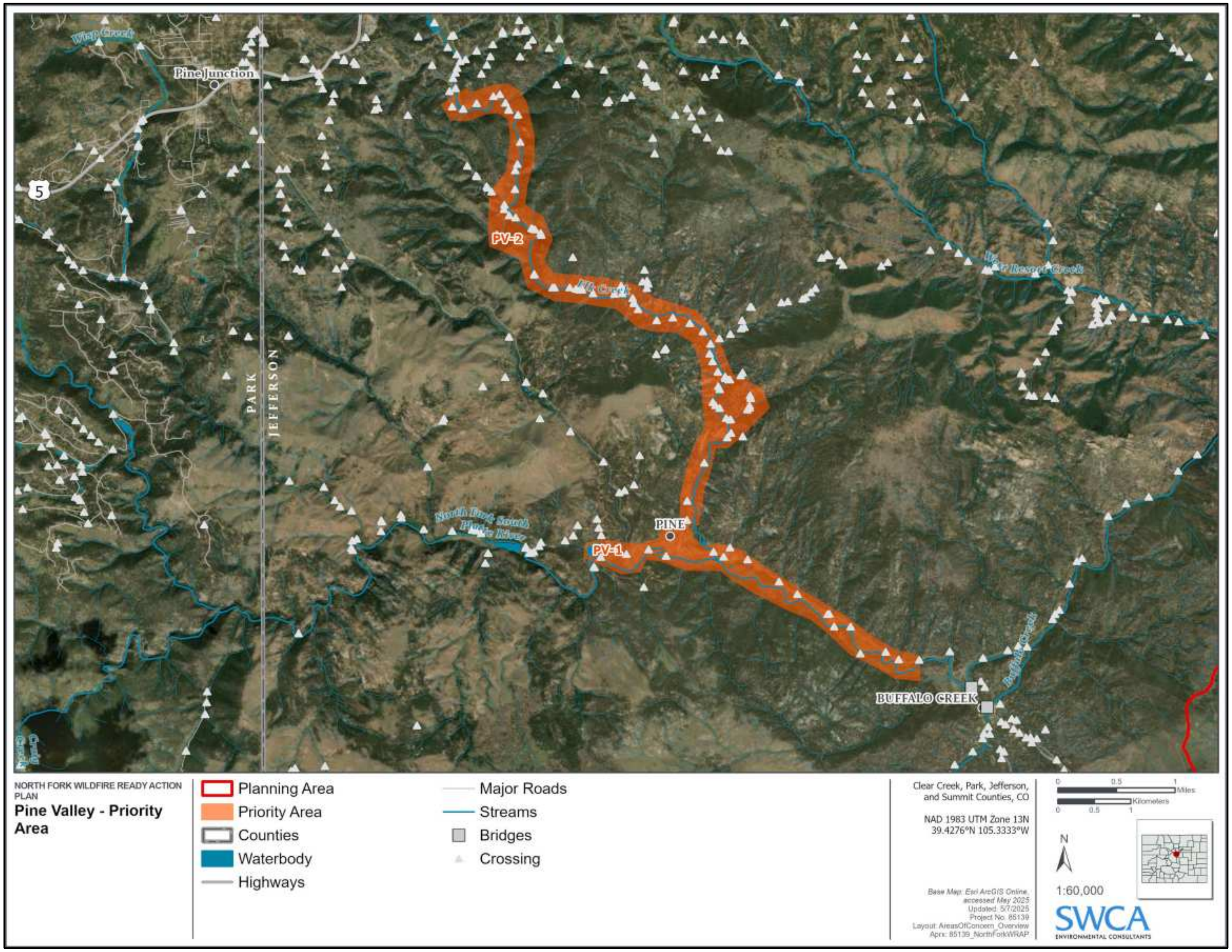

Figure 6.5. Pine Valley priority areas which include potential projects. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.4. Pine Valley AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
PV-1	• Debris flows (Elk Creek) • Hydrology and hydraulics	• Private structures • Roadways (private bridges and access; CR 126 at Elk Creek)	• Process-based restoration (Pine Valley Ranch, Pine Gulch, Elk Creek) • Hillslope erosion and sediment control • Administration (alert gages, community outreach, buyouts)	• Protection of existing beaver populations just upstream of the CR-126 crossing (Beaver_Locations.shp & Priority_Access.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
PV-2	• Fluvial hazards (confined canyon) • Debris flows • Hydrology and hydraulics	• Roadway (South Elk Creek Road) • Private structures • Water resources (ponds and diversions)	• Process-based restoration (Upper Elk) • Hillslope erosion and sediment control • Stream stabilization • Forest treatment	• Sphinx Park • Indian Springs Village • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

6.5 Upper Deer Creek and Elk Creek Area of Concern

The Upper Deer Creek and Elk Creek AOC is in the Deer Creek and Elk Creek HUC12s and has three priority areas, DE-1, DE-2, and DE-3. (Figure 6.6). In a post-fire setting, assets in these areas are at higher likelihood of impacts elevated flows and inundation. Additional hazard and mitigation options to implement before a fire occurs are provided in Table 6.5 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

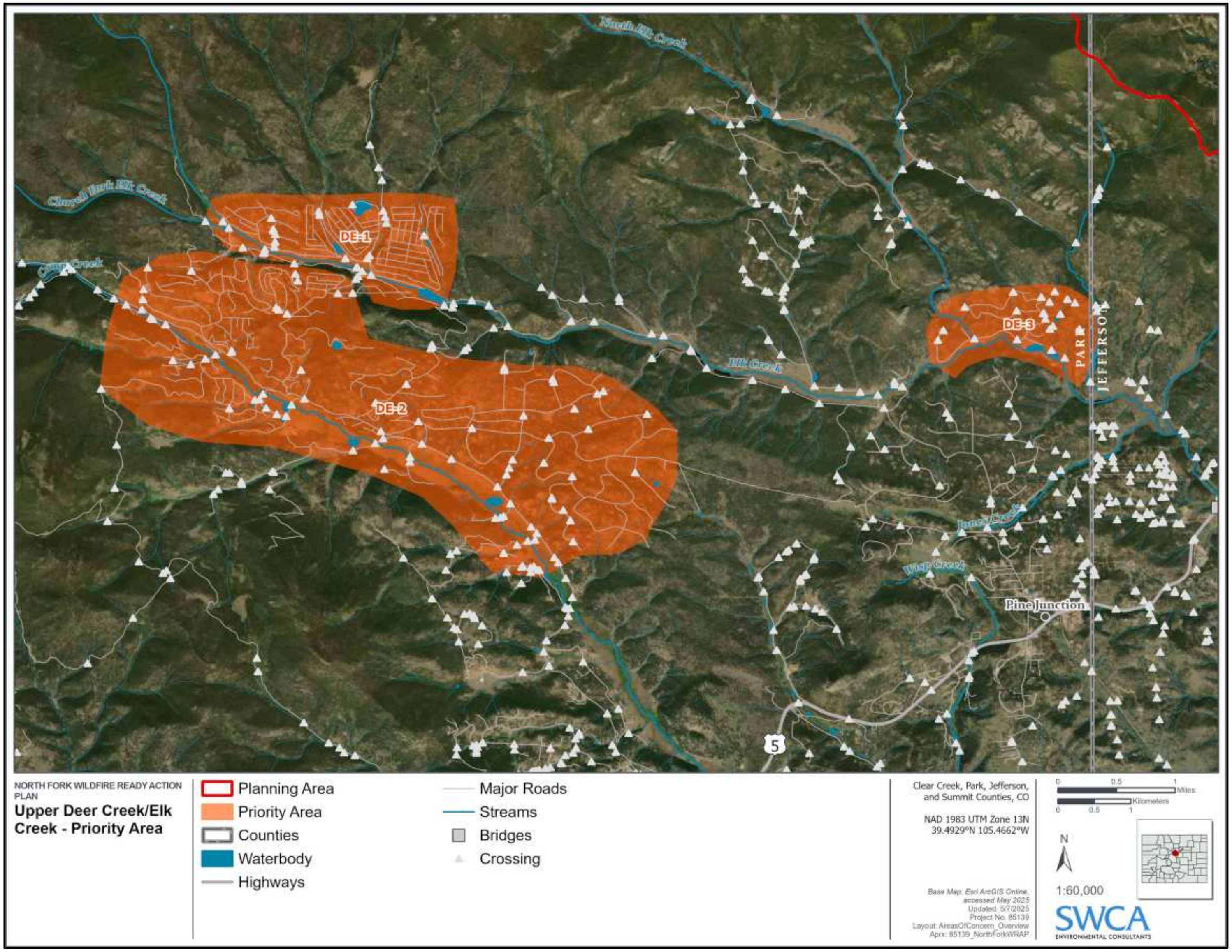

Figure 6.6. Upper Deer Creek and Elk Creek priority areas which include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.5. Upper Deer Creek and Elk Creek AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
DE-1	• Hydrology and hydraulics	• Roadway (three culverts over Elk Creek into Harris Park) • Private structures • Water resources (ponds)	• Process-based restoration (along main channel, some opportunity up northwestern tributaries) • Roadway and access improvements (additional egress route(s) • Hillslope Erosion and Sediment Control • Forest treatment	• • CR 43 is the single egress route from Harris/Highland Park - look into route out via Elk Creek HUC-12, maybe near Hidden Valley Ranch private access road (Priority_Access & Proposed_Admin.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
DE-2	• Hydrology and hydraulics	• Roadway (CR 43, two culverts over Deer Creek to housing) • Private structures • Recreation • Water resources (ponds)	• Process-based restoration (along main channel, some opportunity up western tributaries) • Roadway and access improvements (additional egress route[s]) • Forest treatment	• CR 43 is the single egress route from Harris/Highland Park - look into route out via Elk Creek HUC-12, maybe near Hidden Valley Ranch private access road (Priority_Access & Proposed_Admin.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

DE-3	• Hydrology and hydraulics	• Roadway (CR 83) • Private structures • Water resources (ponds)	• Roadway and access improvements (additional egress route[s]) • Process-based restoration (main channel of Elk Creek and tributaries)	• CR 83 is the single egress route—not much potential for alternate routes • Protection of existing beaver populations (between the crossing at Meadow Drive and at Elk Creek near the intersection of Elk Creek Road and Northwest Court) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

6.6 Buffalo Creek Area of Concern

The Buffalo Creek AOC is in the Buffalo Creek HUC12 and has one priority area, BC-1. (Figure 6.7). This area has a lot of excess sediment from the Buffalo Creek Fire in 1996, and the burn scar has still not reached full recovery. Because of this, both pre-fire and post-fire mitigation projects are appropriate in this area. This area has a higher likelihood of hillslope erosion, debris flow, and fluvial hazards (along South Foxton Road). Additional hazard and mitigation options to implement before a fire occurs are provided in Table 6.6 and information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

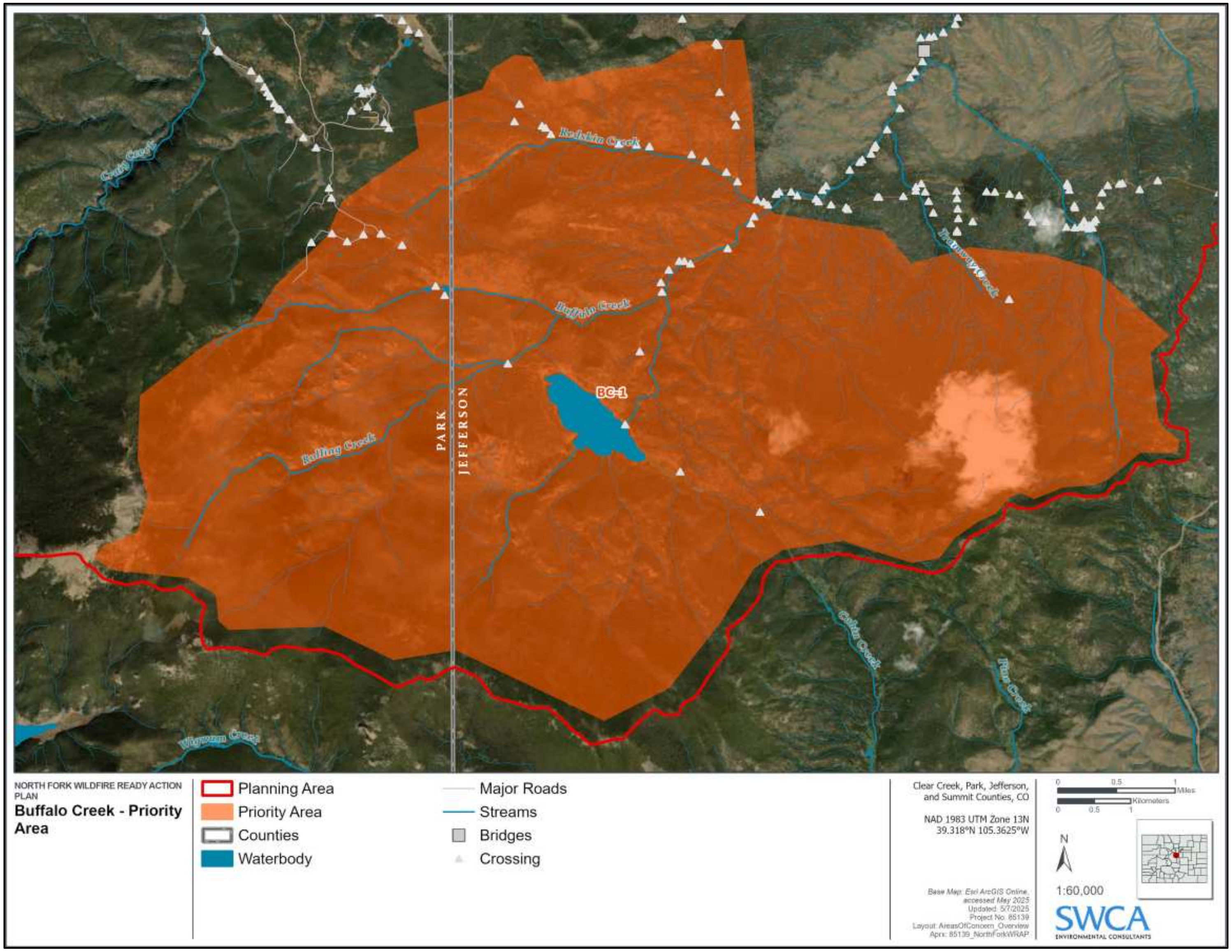

Figure 6.7. Buffalo Creek priority area which includes potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.6. Buffalo Creek AOC: Priority Area, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Vulnerable Infrastructure	Applicable Treatment Categories	Notes
BC-1	• Hillslope erosion • Debris flow • Fluvial hazards • Hydrology and hydraulics	• Water resources (drinking water, Wellington Lake) • Roadways (South Buffalo Creek Road and private access) • Recreation • Private structures	• Process-based restoration (along main channel and some tributaries) • Roadway and access improvements • Hillslope erosion and sediment control • Forest Management	• Excess sediment from past fire has impacted lower Buffalo Creek • Protection of existing beaver populations (upstream of the intersection of Redskin Creek Road and Buffalo Creek Road; areas along South Buffalo Creek Road at the confluence with North Fork) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

6.7 Last Resort Creek Area of Concern

The Last Resort Creek AOC is in the Last Resort Creek HUC12 and has two priority areas, LC-1 and LC-2 (Figure 6.8). This area is closest to the Strontia Springs Reservoir, a key VAR just downstream of the planning area. Because of this, pre-fire planning in this area is important. This area has a higher likelihood of hillslope erosion, debris flow, and fluvial hazards (along South Foxton Road). Additional hazard and mitigation options to implement before a fire occurs are provided in Table 6.7 and information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

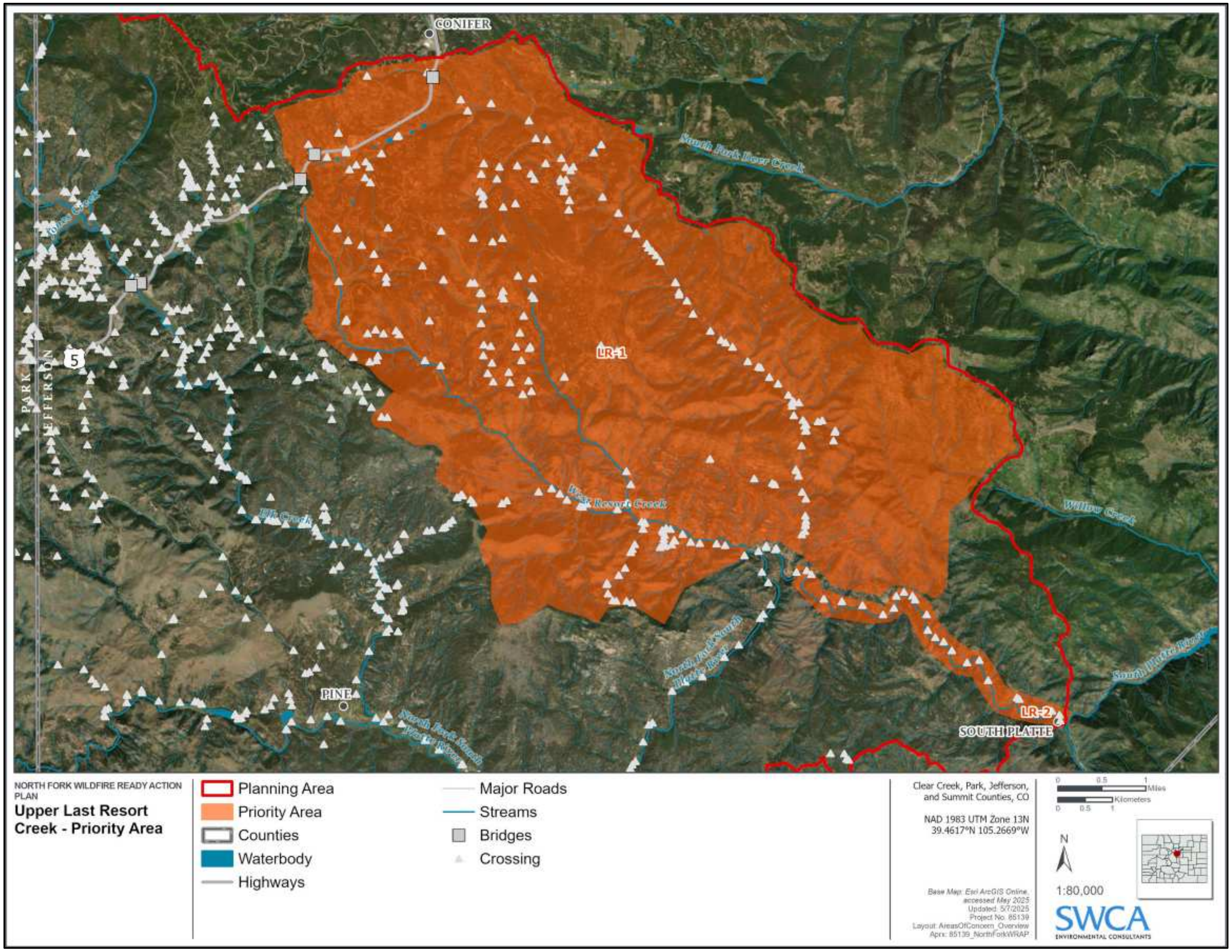

Figure 6.8. Last Resort Creek priority area which includes potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 6.7. Last Resort Creek AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Pre-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
LR-1	• Hillslope erosion • Burn severity (dense private property in high country) • Debris flow • Fluvial hazards (confined along South Foxton Road)	• Private structures • Recreation • Roadways (South Foxton Road) • Water resources (near Strontia Springs Dam) • Habitat (Preble's meadow jumping mouse)	• Process-based restoration (Beaver Ranch, JeffCo Open Spaces, Upper Last Resort Creek) • Hillslope erosion and sediment control • Stream stabilization (along Foxton) • Roadway and access improvements (Foxton) • Forest treatment	• Work in western portion of watershed will need more coordination with private landowners • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
LR-2	• Fluvial hazards (confined/partially confined canyon) • Debris flow	• Roadway (CR 96) • Recreation • Water resources (near Strontia Springs Dam)	• Stream stabilization (potential paired with process-based restoration) • Roadway and access improvements	• Likely requires stream stabilization to maintain access (Proposed_Stream_Stab.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7 POST-FIRE PREPAREDNESS PLAN

Rebuilding and recovery from wildfire can vary greatly across income levels and demographics. Rural areas, low-income neighborhoods, and immigrant communities may not have the necessary resources to cover insurance and rebuilding expenses that occur after a fire. Therefore, many of these areas take more time to recover than those with greater access to resources. According to After the Flames (ATF) and Coalitions & Collaboratives, Inc., "counties, tribes, municipalities, and water providers are typically the entities most directly and immediately impacted by wildfire and port-erosion flooding" (ATF 2021). Recovery can take anywhere from months to several years to complete rebuilding and restoration efforts. It is important to note that the impact of disaster events and recovery efforts differ between various communities and organizations, especially because Colorado is a home-rule state and disasters can occur at any time, so some people will be more prepared than others. "Home-rule" means that the state's agencies are made aware of restoration efforts, but, without direction from local governments, they are incapable of guiding the restoration efforts. Therefore, if a restoration-project sponsor is inexperienced in post-fire watershed restoration, the impacted area could experience a disadvantaged recovery process. Given the community cohesion and action required to improve forest health and fire recovery efforts, many guiding resources exist to help communities plan for natural disasters and effectively recover at the individual, community, and landscape scale. Specific state response and rehabilitation resources are discussed below.

7.1 Recommended Strategies and Actions

7.1.1 Post-fire Response and Rehabilitation

There are many aspects to post-fire response and restoration, including the following:

- Residents returning home and checking for hazards.
- Conducting post-fire damage assessments, such as Burned Area Emergency Response (BAER), USGS post-fire debris flow hazard assessments, Colorado Department of Transportation road assessments, Natural Resource Conservation Service (NRCS) Emergency Watershed Protection Program assessments, and other assessment prescription programs.
- Coordinating and mobilizing a group of teams in the community to respond to post-fire-related emergencies (not to be confused with initial fire response).
- Rebuilding communities and assessing economic needs—securing the financial resources necessary for communities to rebuild homes, business, and infrastructure.
- Restoring the damaged landscape, restoration of watersheds, soil stabilization, and tree planting. Initial assessments after a fire will determine the severity of the fire and necessary steps to restore the landscape. Burn severity will determine prerequisite steps needed to restore soil health, stabilize slopes, and other factors that impact recovery rate and efficacy.
- Coordination between governments, state and federal agencies, and other community groups is critical to successfully addressing the needs of the communities and landscape recovery.

This plan specifically focuses on the actions and coordination required to reduce post-fire hazards and restore the landscape for long-term stability. Local and county level CWPPs will provide additional information on returning home and community recovery steps. Jefferson County's 2024 CWPP can be found at https://togetherjeffco.com/cwpp; the Platte Canyon Fire Protection District and Park County CWPPs can be found at https://www.plattecanyonfire.com/community-wildfire-protection-plan; and the

Summit County CWPP can be found at https://www.summitcountyco.gov/services/community_development/csu_extension/forest_health/wildfire_protection_plan.php.

7.1.2 Post-fire Hazard Mitigation

Wildfires that cause extensive damage necessitate dedicated efforts to avert long-term landscape degradation. Following a fire, the primary priority is emergency stabilization to prevent additional damage to life, property, or natural resources. The soil stabilization work starts immediately and may proceed for many years after a fire depending on the need and difficulty of revegetation. For the most part, rehabilitation efforts focus on the lands not likely to recover naturally from wildfire damage (USDA 2006).

The recent increase in severe fires has highlighted the numerous complexities of post-fire response. Research indicates that high-severity burn areas may produce erosion and runoff rates 5 to 10 times higher than the rates produced by moderate-severity burn areas (Sierra Nevada Conservancy 2021). Following a fire, heavy rains may result in widespread floods, carrying trees, boulders, and soil through canyons, gulleys, and ephemeral stream channels, ultimately damaging communities and critical infrastructure.

Soil cover is dramatically reduced in areas with moderate soil burn severity (SBS), with minimal surface litter retained and some topsoil present. The loss of vegetative soil support will lead to decreased soil stability and higher erosion rates. By contrast, soil cover is nearly non-existent in areas that experience high SBS, as the surface soil will be burned to a fine, hydrophobic powder. Exposed, granular mineral soil is readily transported during rain events, resulting in elevated soil erosion and surface runoff, which creates sediment loading in streams, creeks, and rivers (USFS 2022).

7.1.3 Rehabilitation Resources

Coalitions & Collaboratives manages the ATF website, which includes numerous key recovery resources for homeowners, community leaders, and land managers. Both state and federal guidance documents, technology resources, and relevant agency information are available in the resources section. The ATF website may serve as a consolidated resource guide for mitigating post-fire hazards and rehabilitating land and watersheds.

Included in the ATF resources is the *Colorado Post Fire Playbook*, which provides a comprehensive, step by step guide for counties, municipalities, water providers, and other local governance agencies on organizing, assessing, and restoring burned landscapes, beginning with pre-fire preparation. The *2020 Post-Fire Watershed Restoration Lessons Learned* report is also linked and discusses recent efforts and recommendations for communities to improve post-fire watershed restoration.

The effectiveness of various treatments is described at: https://aftertheflames.com/.

In addition to these resources, the Colorado State Forest Service provides numerous guides and informational documents related to post-fire restoration, including species-specific management information, soil and erosion control guidance, and revegetation resources. All Colorado State Forest Service land restoration and rehabilitation resources are available at: https://csfs.colostate.edu/forest-management/restoration-rehabilitation/.

A comparison of potential hillside, channel, and road treatments is available at: https://www.afterwildfirenm.org/post-fire-treatments/which-treatment-do-i-use.

7.1.3.1 BURNED AREA EMERGENCY RESPONSE PROGRAM

Following a wildfire that impacts National Forest lands and other federally managed lands, BAER teams will be deployed if a fire is over 500 acres or poses a threat to human life and property or critical resources. BAER teams are composed of experts in hydrology, engineering, vegetation, fire ecology, and other specializations. They are deployed to assess the immediate impact on the land and determine if emergency rehabilitation actions are warranted. If fire severity warrants emergency action, BAER teams will work to implement emergency actions, such as channel stabilization, seeding and mulching, erosion and water control structures, blockading recovery areas, and other actions to address immediate post-fire watershed hazards. These actions are not intended to provide long-term fixes but rather bridge the gap between emergency safety concerns and long-term recovery (NIFC 2024).

7.1.3.2 U.S. GEOLOGICAL SURVEY EMERGENCY ASSESSMENT OF POST-FIRE DEBRIS FLOW HAZARDS

The USGS is available to complete post-fire debris flow hazard assessments in recently burned areas across the western United States. The service is available for free to any federal, state, or local agency. The assessment integrates both a desktop GIS exercise and field validation of burn severity. The requesting agency must be willing to provide burn ratio raster data, field-validated SBS raster data, and fire perimeter geospatial data. Using this information, the USGS will produce a model of the burned area that estimates the probability and volume of debris flows given the burned area conditions. The model considers watershed basin shape, extent, burn severity, soil properties, and rainfall. The outcome is a map of the burned area, illustrating the highest hazard areas and anticipated sediment yield in the basin (USGS 2018).

7.1.3.3 EMERGENCY WATERSHED PROTECTION PROGRAM

The NRCS's Emergency Watershed Protection program provides technical and financial services for watershed repair on public (state and local) and private land. It requires a local sponsor, typically a local municipality, to request assistance within 60 days of a disaster, wildfire, or post-fire flooding. The goal is to reduce flood risk and protect life and property through funding and expert advice on land treatments. The Emergency Watershed Protection program can provide up to 75% of implementation funds and 100% of technical assistance funds. The remaining match funding for implantation can be in-kind volunteer labor, although this will limit the implementation scale. This funding is used by the State Emergency Rehabilitation Team (a multi-agency group assembled by the NRCS) to develop specific recovery and treatment plans.

Examples of potential treatments include the following (Long et al. 2014):

- Hillside stabilization (e.g., placing bundles of straw parallel to the slope to slow erosion)
- Hazard tree cutting/salvage logging
- Felling trees perpendicular to the slope contour to reduce runoff
- Mulching areas seeded with native vegetation
- Performing stream enhancements and constructing catchments to control erosion, runoff, and debris flows
- Planting or seeding native species to limit spread of invasive species

7.2 Post-fire Areas of Concern and Mitigation Options

The following sections describe recommended actions to understand and mitigate post-fire hazards or assess impacts from fire. This section outlines priority areas and suggested project locations within each priority area, detailing potential treatments and mitigation projects to protect VARs from post-fire hazards after a fire occurs. As shown in Figure 7.1, priority areas were identified based on hazards, VARs, and stakeholder feedback. Within each priority area, project locations pinpoint specific hazards, key VARs needing protection, and applicable treatments for risk mitigation. This section is organized by priority area, each containing one or more suggested projects. For each project, primary hazards and VARs were identified, along with potential mitigation options for addressing these hazards in a post-fire setting.

Additional resources in this WRAP to aid the planning process include the following:

- Delivered models (particularly hydrology and hydraulic) that can be updated with fire behavior datasets after a fire occurs (Appendix C). Relevant information on hazards (Sections 4 and 7), VARs (Sections 5 and 7), and post-fire mitigation options for each project location (Section 7).
- Additional treatment options with descriptions and rough cost estimates in Appendix E.
- Summary treatment approach sheets in Appendix E, covering approach descriptions, benefits, limitations, stakeholders, implementation scale, and other relevant information for restoration, erosion and sediment control, infrastructure protection, roadway improvements, stream stabilization, and administrative actions. These sheets also identify potential partners.
- Proposed Mitigation Actions Shapefiles:
    - Beaver_Locations – Conservation of existing valuable ecosystems is typically cheaper and more effective than the restoration of these environments. High functioning depositional environments, such as beaver complexes, are vital in absorbing post-fire sediment and water influxes. This shapefile is an initial attempt at documenting these locations for conservation by utilizing aerial imagery and the *Colorado Beaver Activity Mapper (COBAM).*
    - Strontia_Sed – Denver Water provided the data from the Strontia Sediment Management Plan in areas of overlap with this WRAP. The projects were lifted directly from the plan, with updates from Denver Water, and included in this study because of the overlapping goals in controlling pre-fire sedimentation to water infrastructure.
    - Proposed_Admin – Based on the risks identified within this study, individual communities were identified and prioritized for administrative action. The recommended types of administrative action are also detailed in the attribute tables, however this should be reviewed by specialists.
    - Proposed_PBR – A desktop analysis was performed using the datasets within this WRAP and aerial imagery to identify depositional reaches that may be appropriate for PBR projects, as laid out in the Mitigation Approach Sheets. Additional analysis of these areas should be performed in a site specific feasibility study that includes review of ownership, hydrology, existing geomorphic conditions, and access.
    - Proposed_Stream_Stab – Limited areas of conflict between roadways and the North Fork are delineated in this dataset. Relocation, while potentially more difficult in the short term, should be explored as a long-term solution to these conflicts when possible.
    - Priority_Access – Crossings at high to moderate risk were identified based imagery, risk modeling, and access options.
- The final project webmap, which will be hosted on a website managed by Denver Water, will be available to stakeholders and project sponsors.

Figure 7.1 outlines the process and resources for using this WRAP and the pre-fire preparedness plan to identify and plan pre-fire mitigation projects. This includes working with partners to participate in fire response and/or recovery, updating hazard models, identifying values at risk, identifying immediate and short-term treatments, and planning for long-term watershed recovery. Appendix D includes a comprehensive list of pre- and post-fire mitigation options, along with a summary of suggested projects, relevant hazards, VARs, and mitigation strategies. Note that the models produced for this plan should be updated with relevant wildfire data after a fire occurs. That step is not included for each suggested project because it applies to all post-fire activities.

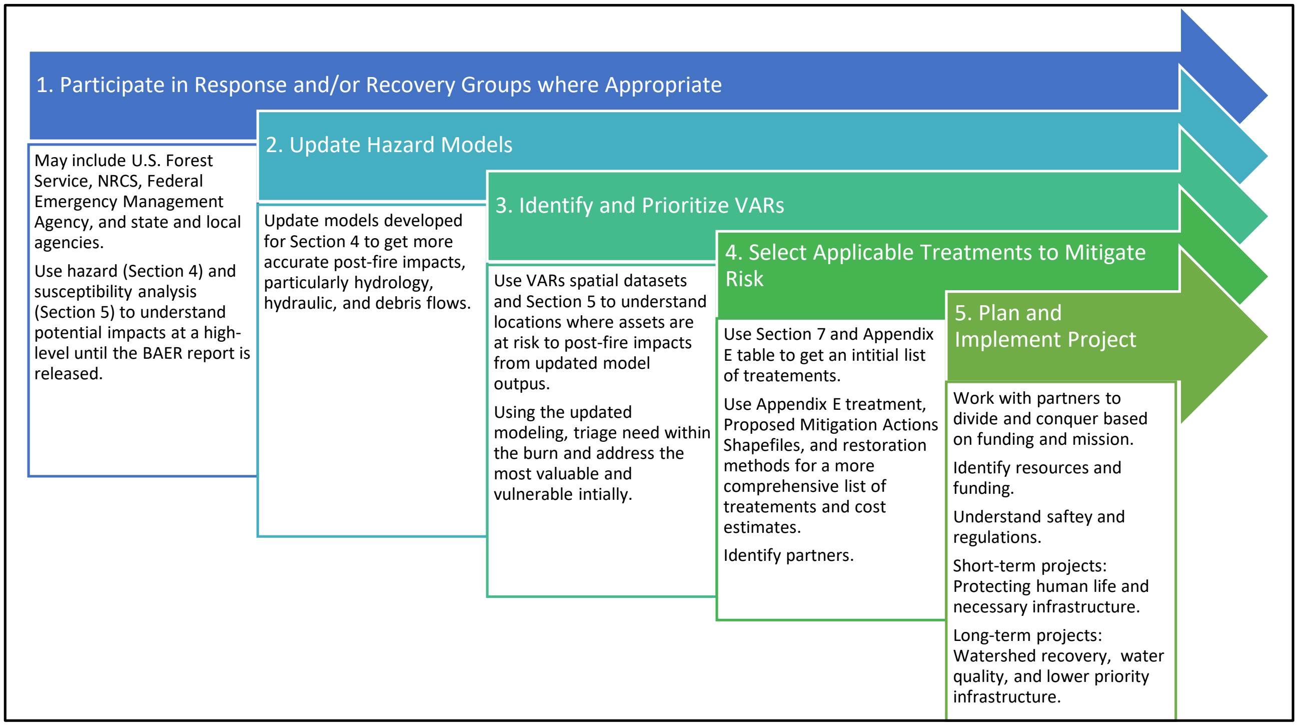

Figure 7.1. Process and resources within this Wildfire Ready Action Plan to mitigate post-fire impacts.

7.2.1 Grant Area of Concern

The Grant AOC is in the headwaters of the North Fork of the South Platte and Geneva Creek HUC12s. There are three priority areas within this AOC, GR-1, GR-2, and GR-3 (Figure 7.2). In a post-fire setting, these areas have high potential to be impacted by debris flow, fluvial hazards, high flows, and inundation. Information on each suggested project is provided below in Table 7.1 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

Figure 7.2. Grant priority areas that include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.1. Grant AOC: Priority Areas, Projects, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types
GR-1	• Debris flow • Fluvial hazards (confined canyon)	• Roadway (CR 60 and private) • Recreation • Private structures (houses near Webster)	• Some depositional meadows adjacent to road (Proposed_PBR.shp) Protection of existing beaver populations (Along CR-202) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • Roadway and access closures or protection • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
GR-2	• Debris flow • Fluvial hazards (confined canyon)	• Roadway (CR 62 and private) • Recreation • Private structures (houses in canyon)	• Some depositional meadows adjacent to road (Proposed_PBR.shp) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • Roadway and Access closures or protection • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

GR-3	• Fluvial hazards • Debris flows (proximal but upstream) • Hydrology and hydraulics	• Roadway (U.S. 285 and private) • Private structures • Recreation • Water resource (Roberts Tunnel, Diversion downstream of Geneva Creek)	• Process-based restoration (upper watershed) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp) • Infrastructure protection (at private structures along North Fork River) • Roadway and access closures or protection (U.S. 285 at Geneva Creek; bridge upstream of Roberts Tunnel) • Stream stabilization (bank armoring, conveyance) • Administration (alert gage, community outreach) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7.2.2 U.S. 285 Corridor Area of Concern

The U.S. 285 Corridor AOC is in the Rock Creek HUC12. There are two priority areas within this AOC, RC-1 and RC-2 (Figure 7.3). In a post-fire setting, assets in these areas are at a higher likelihood of impacts from fluvial hazards, debris flow, high flows, and flooding. Additional hazard and mitigation options to implement after a fire occurs are provided in Table 7.2 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

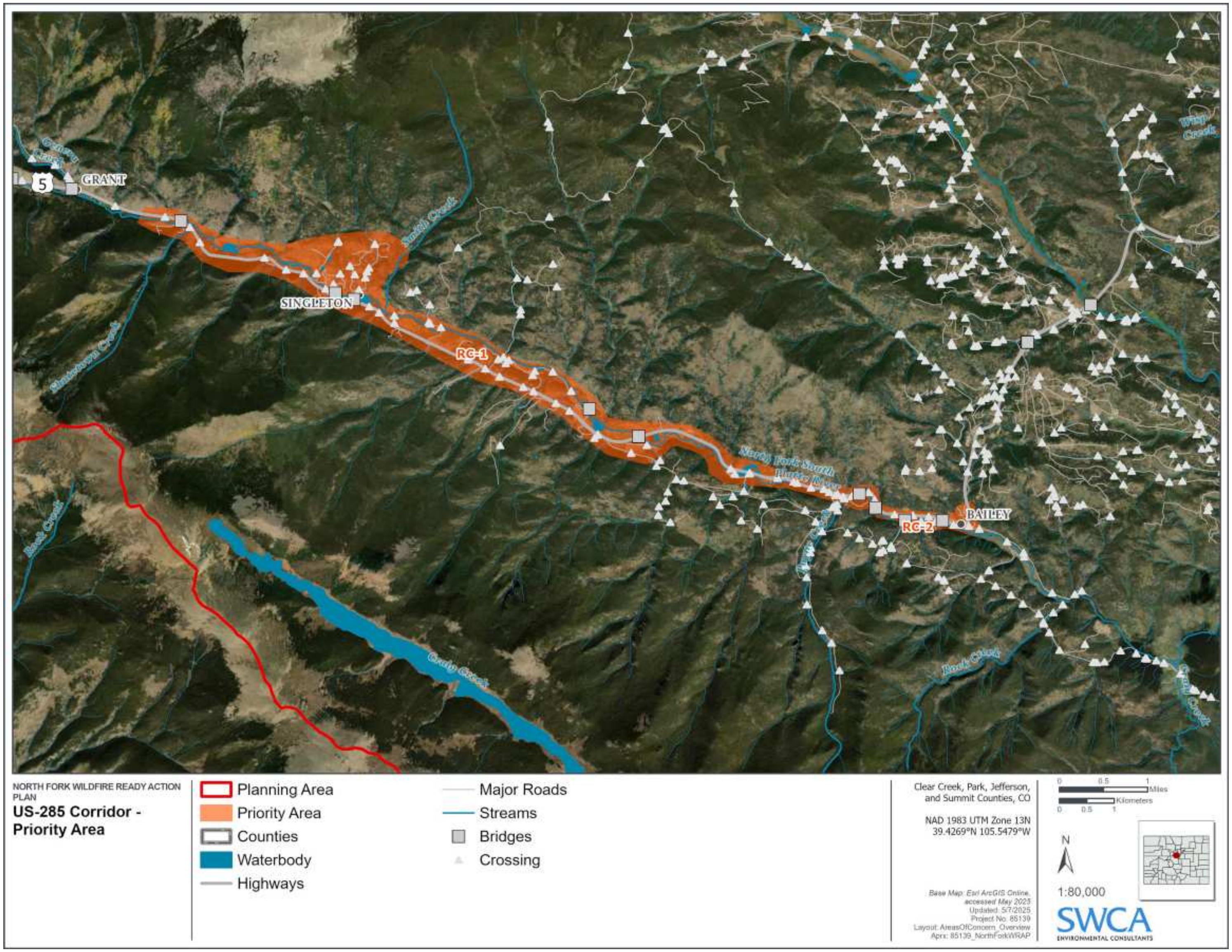

Figure 7.3. U.S. 285 Corridor priority areas which include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.2. U.S. 285 Corridor AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
RC-1	• Fluvial hazards (confinement transitions, alluvial fans) • Debris flows (many alluvial fans) • Hydrology and hydraulics	• Private structures • Recreation • Roadway (U.S. 285 and private; many private bridges) • Water resources (ponds and diversions)	• Process-based restoration (along main channel) • Roadway and access protection and closures • Infrastructure protection • Hillslope Erosion and Sediment Control • Stream stabilization (bank armoring, conveyance)	• Mountain Drive and Cline Drive are the only access to large housing development. • Mooredale Road: Stream realignment, creating an overly steep and confined reach. • Platte River Drive: Forces split and culverts on both bridge sections downstream. • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • Some initial Stream Stabilization needs and sites have been identified (Proposed_Stream_Stab.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
RC-2	• Debris flows (Crow Creek) • Hillslope erosion • Hydrology and hydraulics	• Drinking water sources • Private structures • Public services (bulk water station, fire station, post office)	• Process-based restoration (upper watershed of tributaries, especially Crow Gulch) • Roadway and access improvements (CR 64 at North Fork) • Hillslope erosion and sediment control • Infrastructure protection • Stream stabilization (bank armoring) • Forest treatment • Administration (alert gages, community outreach, buyouts)	• Crow Gulch is a large debris flow risk north of town. • In town, bridge is narrow and culverts are undersized. • Bailey water sources are south of North Fork River. • Some initial Stream Stabilization needs and sites have been identified (Proposed_Stream_Stab.shp). • Implement applicable project identified in Strontia Sediment Managemen Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7.2.3 Craig Creek Area of Concern

The Craig Creek AOC is in the Craig Creek HUC12 and has one priority area, CC-1. (Figure 7.4). This HUC12 has a large wilderness area, so we did not consider projects in that area of the HUC12. In a post-fire setting, assets in these areas are at higher likelihood of impacts from hillslope erosion and debris flow. Impacts to water quality is of particular concern in this priority area. Additional hazard and mitigation options to implement after a fire occurs are provided in Table 7.3 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

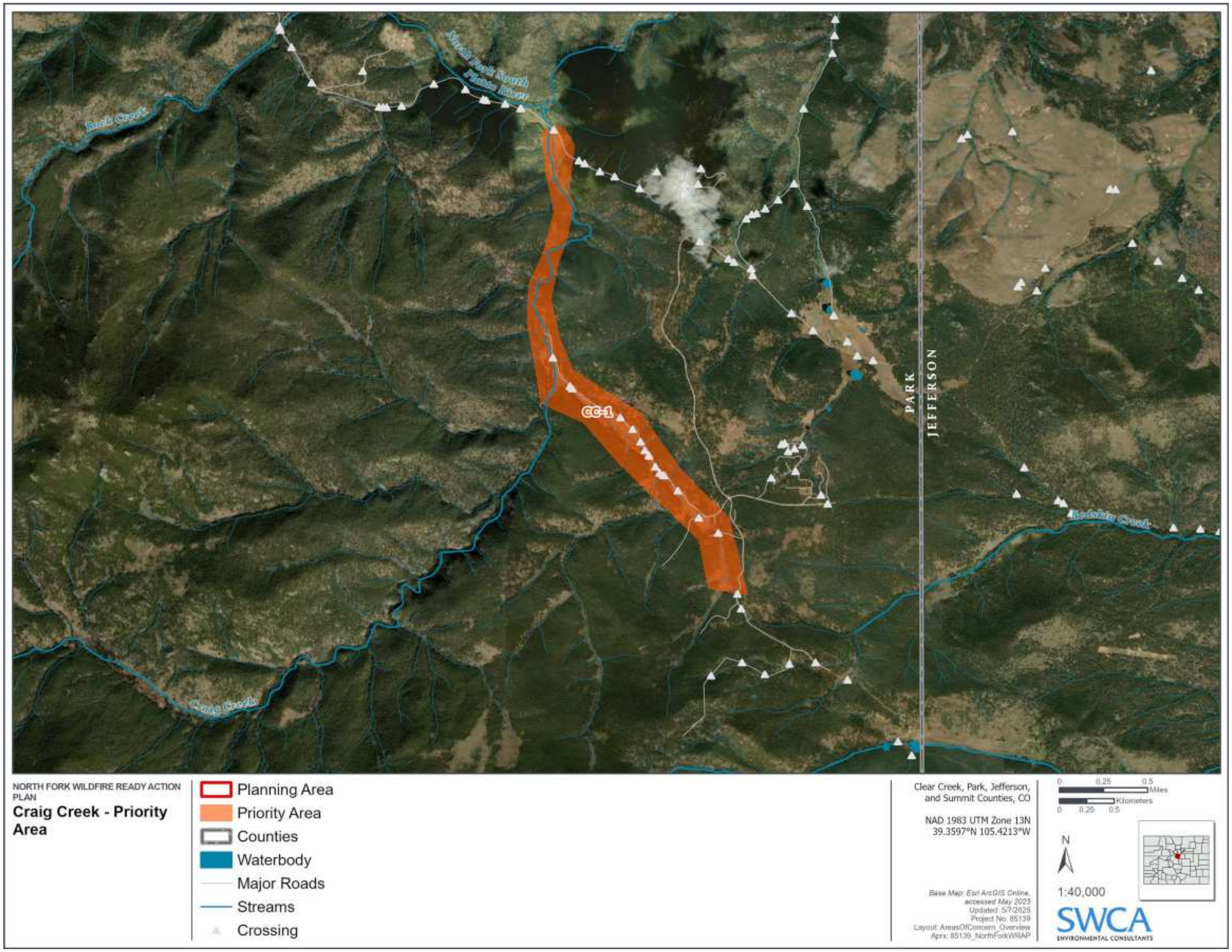

Figure 7.4. Craig Creek priority area which includes potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.3. Craig Creek AOC: Priority Area, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
CC-1	• Hillslope erosion • Debris flow	• Drinking water source	• Process-based restoration (meadow just below wilderness) • Hillslope erosion and sediment control	• Most of HUC12 is wilderness, where it is highly unlikely to get approval to implement projects. • Some crossings have been identified in the lower portion of the basin (Priority_Access.shp) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7.2.4 Pine Valley Area of Concern

The Pine Valley AOC is in the Roland Gulch and Elk Creek HUC12s and has three priority areas, PV-1, PV-2, and PV-3. (Figure 7.5). In a post-fire setting, assets in these areas are at higher likelihood of impacts from hillslope erosion, debris flow, elevated flows, flooding, and fluvial hazards (in the confined canyon). Additional hazard and mitigation options to implement after a fire occurs are provided in Table 7.4 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

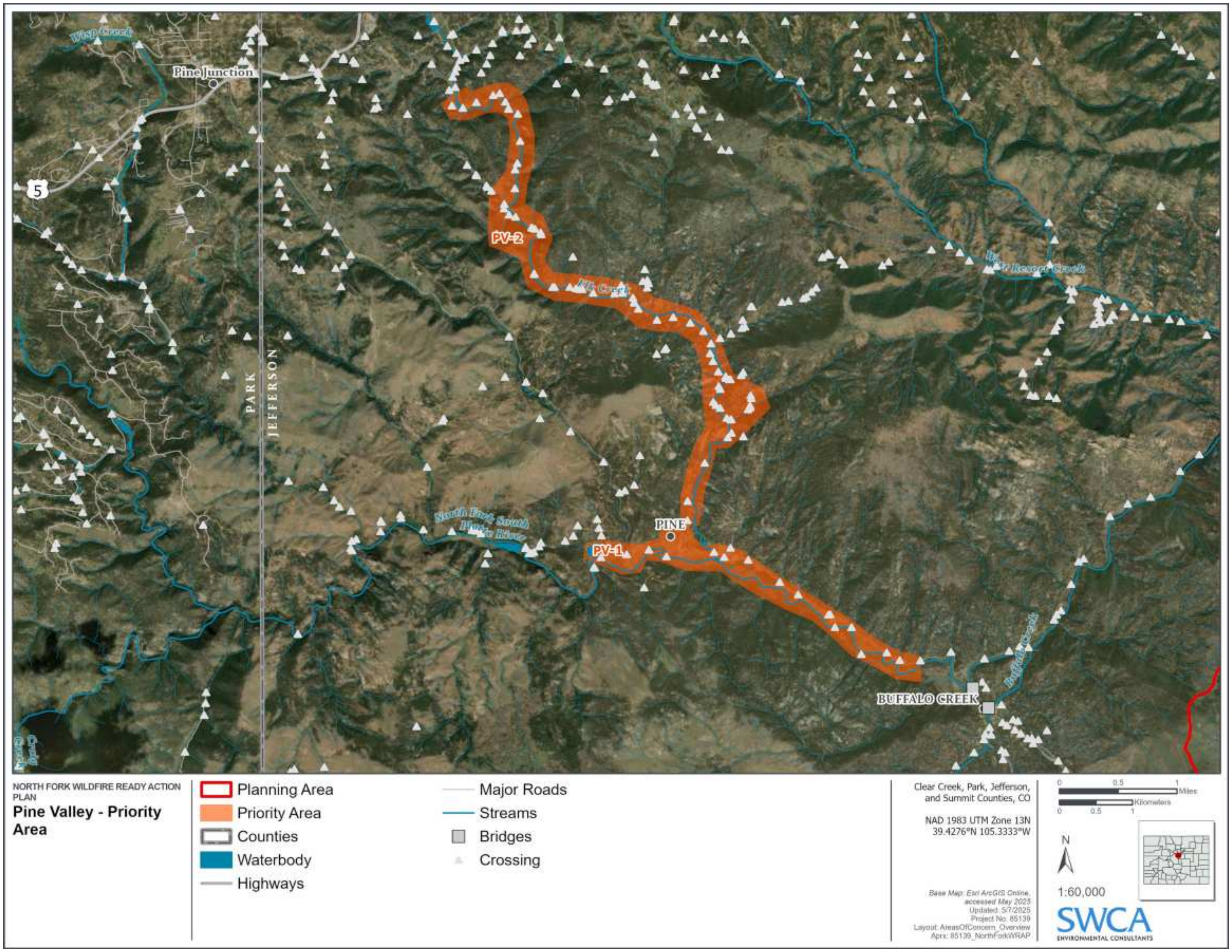

Figure 7.5. Pine Valley priority areas which include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.4. Pine Valley AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
PV-1	• Debris flows (Elk Creek) • Hydrology and hydraulics	• Private structures • Roadways (private bridges and access; CR 126 at Elk Creek)	• Process-based restoration (Pine Valley Ranch, Pine Gulch, Elk Creek) • Hillslope erosion and sediment control • Administration (alert gages, community outreach, buyouts)	• • Protection of existing beaver populations just upstream of the CR-126 crossing (Beaver_Locations.shp & Priority_Access.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
PV-2	• Fluvial hazards (confined canyon) • Debris flows • Hydrology and hydraulics	• Roadway (South Elk Creek Road) • Private structures • Water resources (ponds and diversions)	• Process-based restoration (Upper Elk) • Hillslope erosion and sediment control • Stream stabilization	• Two communities, Sphinx Park & Indian Springs Village, have been identified as needing administrative support and planning (Proposed_Admin). • Implement applicable project identified in Srontia Sediment Management Plan (2021) (Strontia_Sed.shp) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7.2.5 Upper Deer Creek and Elk Creek Area of Concern

The Upper Deer Creek and Elk Creek AOC is in the Deer Creek and Elk Creek HUC12s and has three priority areas, DE-1, DE-2, and DE-3 (Figure 7.6). In a post-fire setting, assets in these areas are at higher likelihood of impacts elevated flows and inundation. Additional hazard and mitigation options to implement after a fire occurs are provided in Table 7.5 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

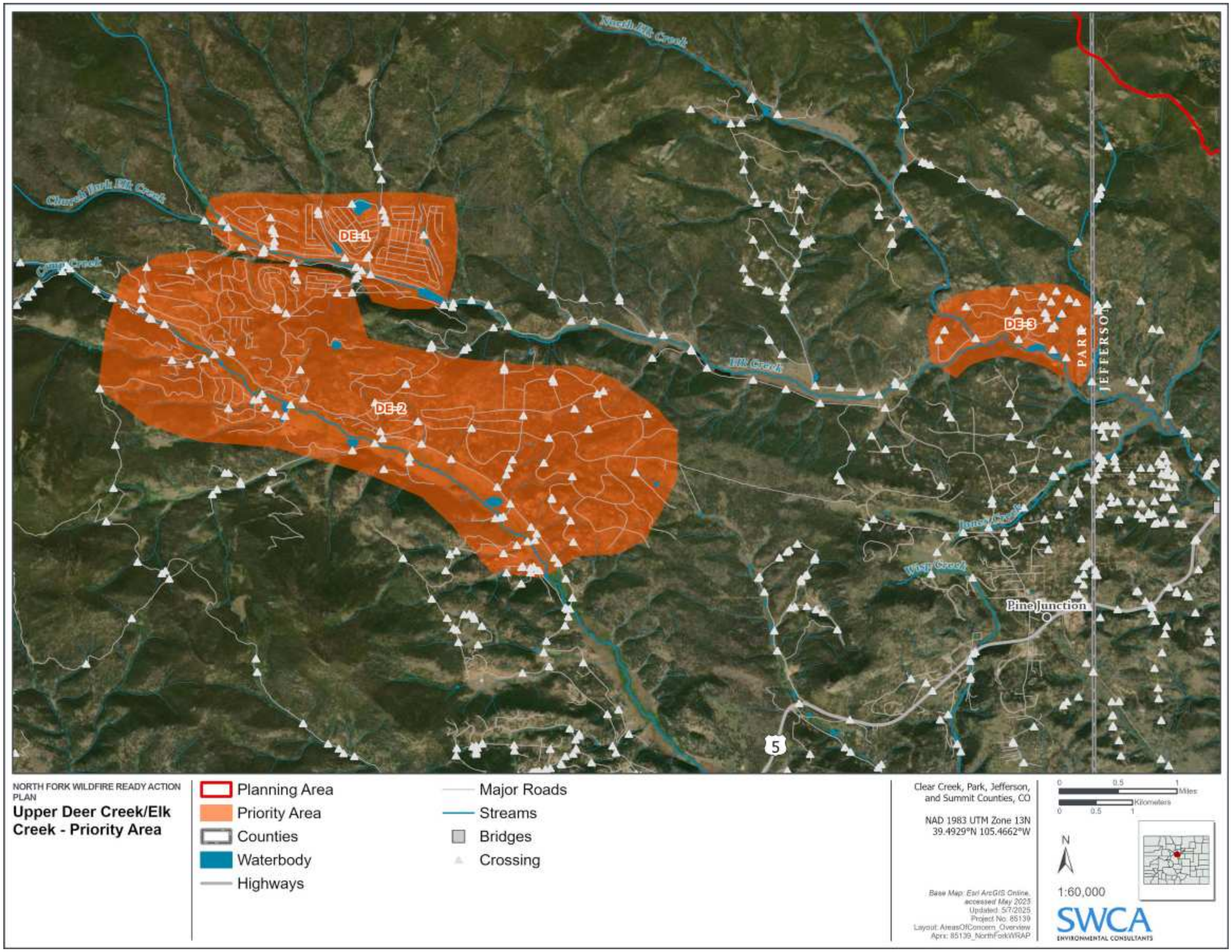

Figure 7.6. Upper Deer Creek and Elk Creek priority areas which include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.5. Upper Deer Creek and Elk Creek AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
DE-1	• Hydrology and hydraulics	• Roadway (three culverts over Elk Creek into Harris Park) • Private structures • Water resources (ponds)	• Process-based restoration (along main channel, some opportunity up northwestern tributaries) • Roadway and access closures or protection	• CR 43 is the single egress route from Harris/Highland Park - look into route out via Elk Creek HUC-12, maybe near Hidden Valley Ranch private access road (Priority_Access.shp & Proposed_Admin). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
DE-2	• Hydrology and hydraulics	• Roadway (CR 43, two culverts over Deer Creek to housing) • Private structures • Recreation • Water resources (ponds)	• Process-based restoration (along main channel, some opportunity up western tributaries) • Roadway and access closures or protection • Forest treatment	• CR 43 is the single egress route from Harris/Highland Park - look into route out via Elk Creek HUC-12, maybe near Hidden Valley Ranch private access road (Priority_Access.shp & Proposed_Admin.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

DE-3	• Hydrology and hydraulics	• Roadway (CR 83) • Private structures • Water resources (ponds)	• Roadway and access closures or protection • Process-based restoration (main channel of Elk Creek and tributaries)	• CE 83 is the single egress route - not much potential for alternates. • Protection of existing beaver populations (Beaver_Locations.shp: between the crossing at Meadow Drive and at Elk Creek near the intersection of Elk Creek Rd and Northwest Ct.) • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7.2.6 Buffalo Creek Area of Concern

The Buffalo Creek AOC is in the Buffalo Creek HUC12 and has one priority area, BC-1 (Figure 7.7). This area has a lot of excess sediment from the Buffalo Creek Fire in 1996, and the burn scar has still not reached full recovery. This area has a higher likelihood of hillslope erosion, debris flow, and fluvial hazards (along South Foxton Road). Additional hazard and mitigation options to implement after a fire occurs are provided in Table 7.6 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

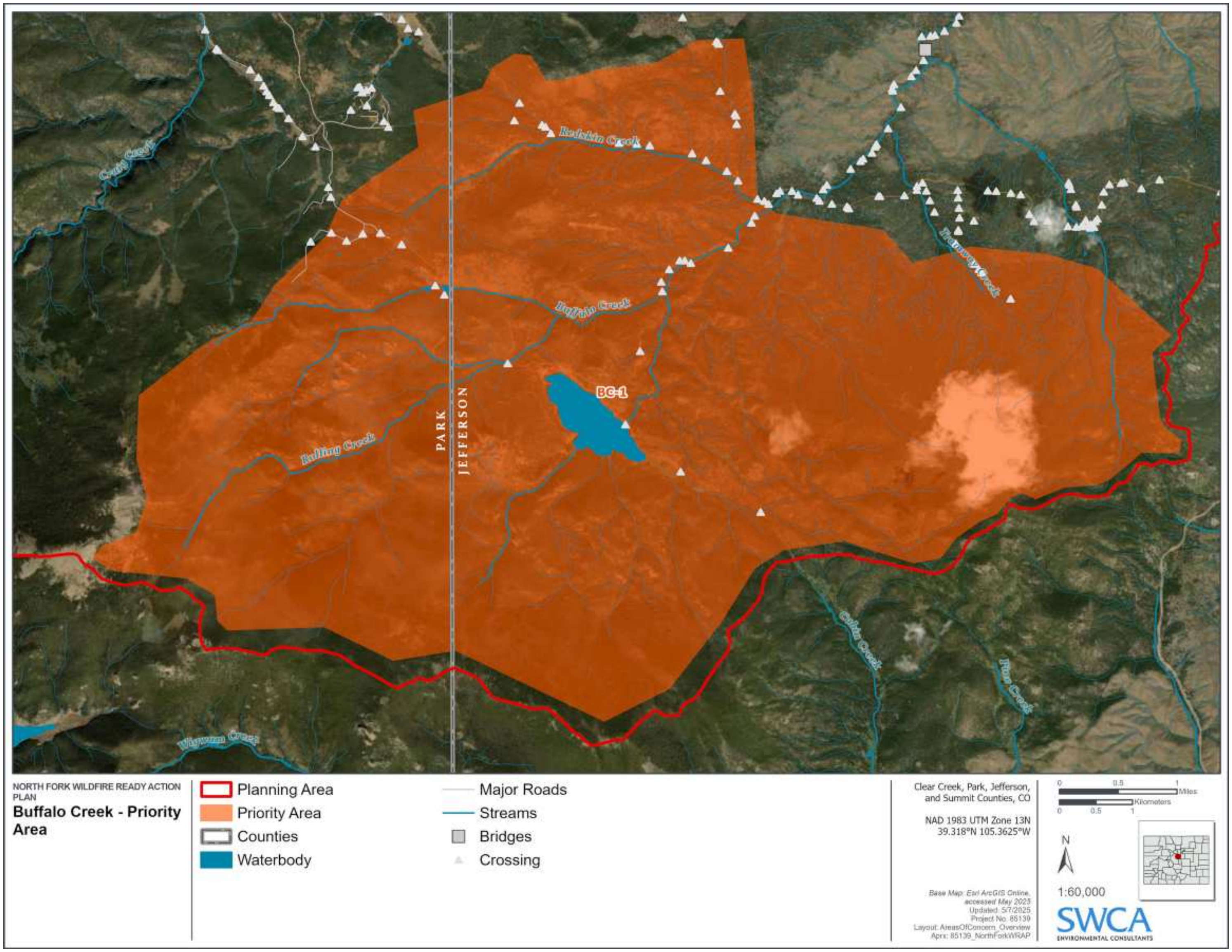

Figure 7.7. Buffalo Creek priority area which includes potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.6. Buffalo Creek AOC: Priority Area, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
BC-1	• Hillslope erosion • Debris flow • Fluvial hazards • Hydrology and hydraulics	• Water resources (drinking water, Wellington Lake) • Roadways (South Buffalo Creek Road and private access) • Recreation • Private structures	• Process-based restoration (along main channel and some tributaries) • Roadway and access protection or closures • Hillslope erosion and sediment control	• Excess sediment from past fire has impacted lower Buffalo Creek. • Protection of existing beaver populations (Beaver_Locations.shp: upstream of the intersection of Redskin Creek Rd & Buffalo Creek Rd; Areas along S Buffalo Creek Rd., At the confluence with North Fork) • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

7.2.7 Last Resort Creek Area of Concern

The Last Resort Creek AOC is in the Last Resort Creek HUC12 and has two priority areas, LC-1 and LC-2 (Figure 7.8). This area is closest to the Strontia Springs Reservoir, a key VAR just downstream of the planning area. The reach leading to Strontia Springs Reservoir is a canyon, with very little potential for post-fire mitigation opportunities. Because of this, pre-fire planning in this area is important. This area has a higher likelihood of hillslope erosion, debris flow, and fluvial hazards (along South Foxton Road). Additional hazard and mitigation options to implement after a fire occurs are provided in Table 7.7 information on specific project locations and types can be found in the Proposed Mitigation Actions shapefiles.

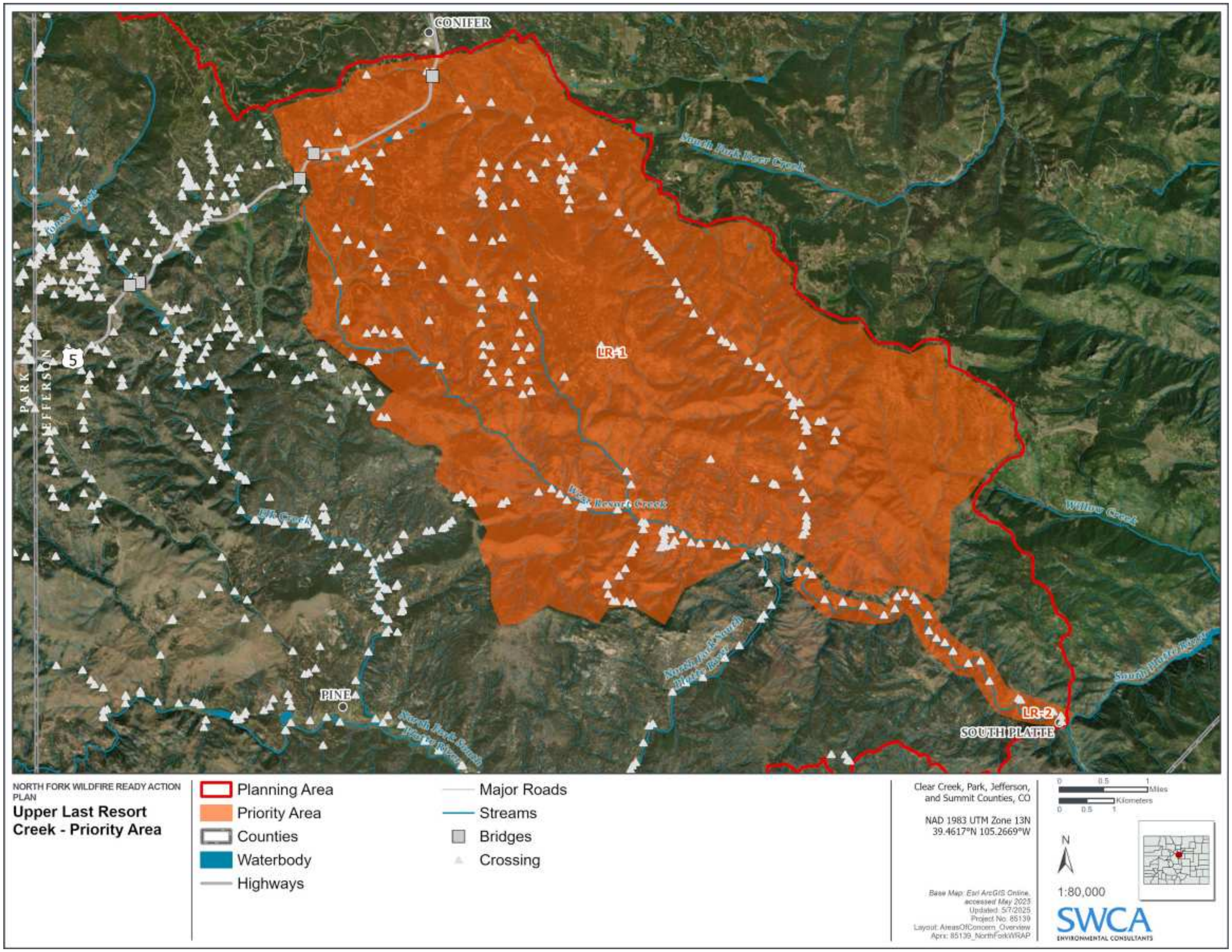

Figure 7.8. Last Resort Creek priority areas which include potential project locations. For detailed project locations, utilize the Proposed Mitigation Actions Shapefiles.

Table 7.7. Last Resort Creek AOC: Priority Areas, Relevant Hazards, Values at Risk, and Applicable Treatments to Mitigate Post-fire Hazards

Priority Area ID	Relevant Hazards	Benefits	Treatment Categories and Project Types	Notes
LR-1	• Hillslope erosion • Burn severity (dense private property in high country) • Debris flow • Fluvial hazards (confined along South Foxton Road)	• Private structures • Recreation • Roadways (South Foxton Road) • Water resources (near Strontia Springs Dam) • Habitat (Preble's meadow jumping mouse)	• Process-based restoration (Beaver Ranch, Jefferson County Open Spaces, Upper Last Resort Creek) • Hillslope erosion and sediment control • Stream stabilization (along Foxton) • Roadway and access improvements (Foxton) • Forest treatment	• Work in western portion of watershed will need more coordination with private landowners. • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.
LR-2	• Fluvial hazards (confined/partially confined canyon) • Debris flow	• Roadway (CR-96) • Recreation • Water resources (near Strontia Springs Dam)	• Stream stabilization (potential paired with process-based restoration) • Roadway and access improvements • Alert gage for water quality and flow	• Likely requires stream stabilization to maintain access (Proposed_Stream_Stab.shp). • Implement applicable project identified in Strontia Sediment Management Plan (2021) (Strontia_Sed.shp). • See Appendix E.2 and E.3 for details on project scope, permitting, partnerships, timing, and cost considerations. • Use project webmap and GIS data to generate more detailed maps based on final project footprint.

8 LITERATURE CITED

After The Flames (ATF). 2021. Colorado Post-Fire Recovery Playbook for Counties, Tribes, Municipalities, and Water Providers. https://csfs.colostate.edu/wp-content/uploads/2020/11/Colorado_Post_Fire_Playbook.pdf. Accessed January 2025.

Colorado Forest Restoration Institute (CFRI). 2024. From forest to Faucets Wildfire Risk Assessment. Available at: https://cfri.colostate.edu/wp-content/uploads/sites/22/2024/09/Rhea_etal_FromForeststoFaucetsPartnership_WildfireRiskAssessment_CFRI_2414.pdf. Accessed December 2024.

CWCB and DWR, 2024. CDSS Data & Tools: Stations. Colorado's Decision Support Systems. Retrieved June 27, 2024, from https://dwr.state.co.us/Tools/Home

Colorado Water Conservation Board (CWCB). 2022a. GIS Preparedness for Wildfire Planning and Recovery. WRW Fact Sheet. Version 22.01. Accessible at: https://enginuity.egnyte.com/dl/fYH2YHLXon/03P_WRW_Fact_Sheet_-_GIS_Preparedness.pdf_. Accessed August 26, 2024.

———. 2022b. Erosion and Sediment After A Wildfire. Available at: https://enginuity.egnyte.com/dl/ZC02NEvxy8/03H_WRW_Fact_Sheet_-_Erosion.pdf_. Accessed January 2025.

———. 2022c. Preserving Water Quality After Wildfires. Available at: https://enginuity.egnyte.com/dl/HOmSNSH4T7/06H_WRW_Fact_Sheet_-_Water_Quality.pdf_. Accessed January 2025.

———. 2022d. Debris Flows After A wildfire. Available at: https://enginuity.egnyte.com/dl/YhRB8vb9IH/02H_WRW_Fact_Sheet_-_Debris_Flow.pdf_. Accessed January 2025.

———. 2022e. Post-Fire Hazards and Water Infrastructure. Available at: https://enginuity.egnyte.com/dl/9OYi9vqsZ9/05H_WRW_Fact_Sheet_-_Water_Infrastructure.pdf_. Accessed January 2025.

———. 2022f. Fluvial Hazards After A Wildfire. Available at: https://enginuity.egnyte.com/dl/tE9qkhHt8i/04H_WRW_Fact_Sheet_-_Fluvial_Hazards.pdf_. Accessed January 2025.

———. 2022g. flooding After A Wildfire. Available at: https://enginuity.egnyte.com/dl/dndCSLGtKL/01H_WRW_Fact_Sheet_-_Flood_After_Fire.pdf_. Accessed January 2025.

Hydraulic Engineering Center, 2024. HEC-RAS (6.5) [Computer software]. U.S. Army Corps of Engineers.

Long, J. Skinner, C. Charnley, S. Hubbert, K. Quinn-Davidson, L. Meyer, M. 2014. Post-wildfire Management. Available at: https://research.fs.usda.gov/treesearch/46961. Accessed January 2025.

Madole, R., VanSistine, P., Michael, J. 1998. *Pleistocene Glaciation in the Upper Platte River Drainage Basins, Colorado.* Geological Investigations Series I-2644. United States Geological Survey.

Montgomery, David R., and John M. Buffington. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109.5 (1997):596–611. https://doi.org/10.1130/0016-7606(1997)109<0596:CRMIMD>2.3.CO;2

National Interagency Fire Center (NIFC). 2024. Post Fire Recovery. Available at: https://www.nifc.gov/programs/post-fire-recovery. Accessed November 2024.

Sierra Nevada Conservancy. 2021. 2020 megafires create risks for California's water supply. Available at: https://sierranevada.ca.gov/2020-megafires-create-risks-for-californias-water-supply/. Accessed January 2025.

SWCA Environmental Consultants. 2021. *Strontia Springs Reservoir Watershed Sediment Management Plan.* Prepared for Denver Water. Broomfield, Colorado: SWCA Environmental Consultants.

U.S. Army Corps of Engineers. 2024. Hydraulic Engineering Center. HEC-RAS 2D User's Manual Version 6.5. https://www.hec.usace.army.mil/confluence/rasdocs/r2dum/latest

U.S. Department of Agriculture Forest Service. 2006. Burned Area Emergency Response Treatments Catalog. Available at: https://www.fs.usda.gov/eng/pubs/pdf/BAERCAT/lo_res/06251801L.pdf. Accessed November 2024.

U.S. Forest Service. 2021. Post-fire Effects –Understanding soil burn Severity. Available at: https://inciweb.wildfire.gov/incident-publication/cabdf-radford-postfire-baer/postfire-effectsunderstanding-soil-burn-severity#:~:text=BAER%20Burned%20Area%20Emergency%20Response%20Information%20Brief&text=Pre%2Dfire%20ground%20cover%2C%20forest,burn%20severity%20(SBS)%20map. Accessed January 2025.

U.S. Geological Survey. 2018. Postfire debris-flow hazards. Available at: https://www.usgs.gov/programs/landslide-hazards/science/postfire-debris-flow-hazards. Accessed October 2024.

Vaill, J. E. 2000. *Analysis of the magnitude and frequency of floods in Colorado* (Water-Resources Investigations Report 99–4190). USGS. https://doi.org/10.3133/wri994190

APPENDIX A

Stakeholder Workshop Summaries

APPENDIX B

Data Gap Analysis Technical Memorandum

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295 Interlocken Boulevard, Suite 300
Broomfield, Colorado 80021
Tel 303.487.1183
www.swca.com

TECHNICAL MEMORANDUM

To: Cragen Davies
Jefferson Conservation District
Denver Federal Center, Building 56
6th Avenue and Kipling Street
Denver, Colorado 80226

From: Chloe Lewis, Project Manager and Christian Testerman, Environmental Scientist

Date: May 24, 2024

Re: **North Fork Wildfire Ready Action Plan Data Gap Analysis Technical Memorandum / SWCA Project No. 85139**

Background

SWCA Environmental Consultants (SWCA) conducted a data gap analysis to be used for the hazard risk and susceptibility analysis for the North Fork Wildfire Ready Action Plan (the project). This analysis, consisting of an initial review of available data, resulted in a compilation of studies, data, and descriptive information specific to the project's planning area (Figure B.1) and exposed several data gaps related to fire behavior, debris flow, erosion and sediment, flooding, and values at risk. This memorandum identifies and qualifies the impacts of missing or incomplete data on the hazard risk and susceptibility analysis and summarizes a strategy for addressing data gaps required for the analysis.

Methodology

SWCA sought data sources based on the requisite data list provided by the Colorado Wildfire Ready Watersheds Program (Colorado Water Conservation Board 2024). The project team, composed of SWCA and Ayres Associates staff, worked collaboratively to obtain relevant data from publicly available sources such as the Colorado Department of Public Health and Environment (CDPHE), the U.S. Geological Survey's (USGS's) National Hydrography Dataset (NHD), USGS, Colorado's Decision Support Systems, and Colorado Division of Water Resources. Additional coordination with the Core Team and CDPHE yielded data sets that were not publicly available. The Core Team is composed of representatives from Jefferson Conservation District, Denver Water, Aurora Water, Peak Communications, Colorado Water Conservation Board, Colorado State Forest Service, U.S. Forest Service, and Jefferson County. Park County has been invited to participate on the Core Team but has not been involved in the project to date. All data sets were reviewed for their relevance to the project, including geographic extent and data resolution.

SWCA provided the Core Team with an initial data table, which contained the review of available data sources and of their relevance to project analyses, described available data sources, and identified additional data needs. The Core Team then provided feedback and direction to potentially fill identified data gaps. Where required, project stakeholders were contacted for information on specific data needs and location. The Core Team and stakeholders sent data sources or links directly to SWCA contacts, or uploaded data sets to the shared project site.

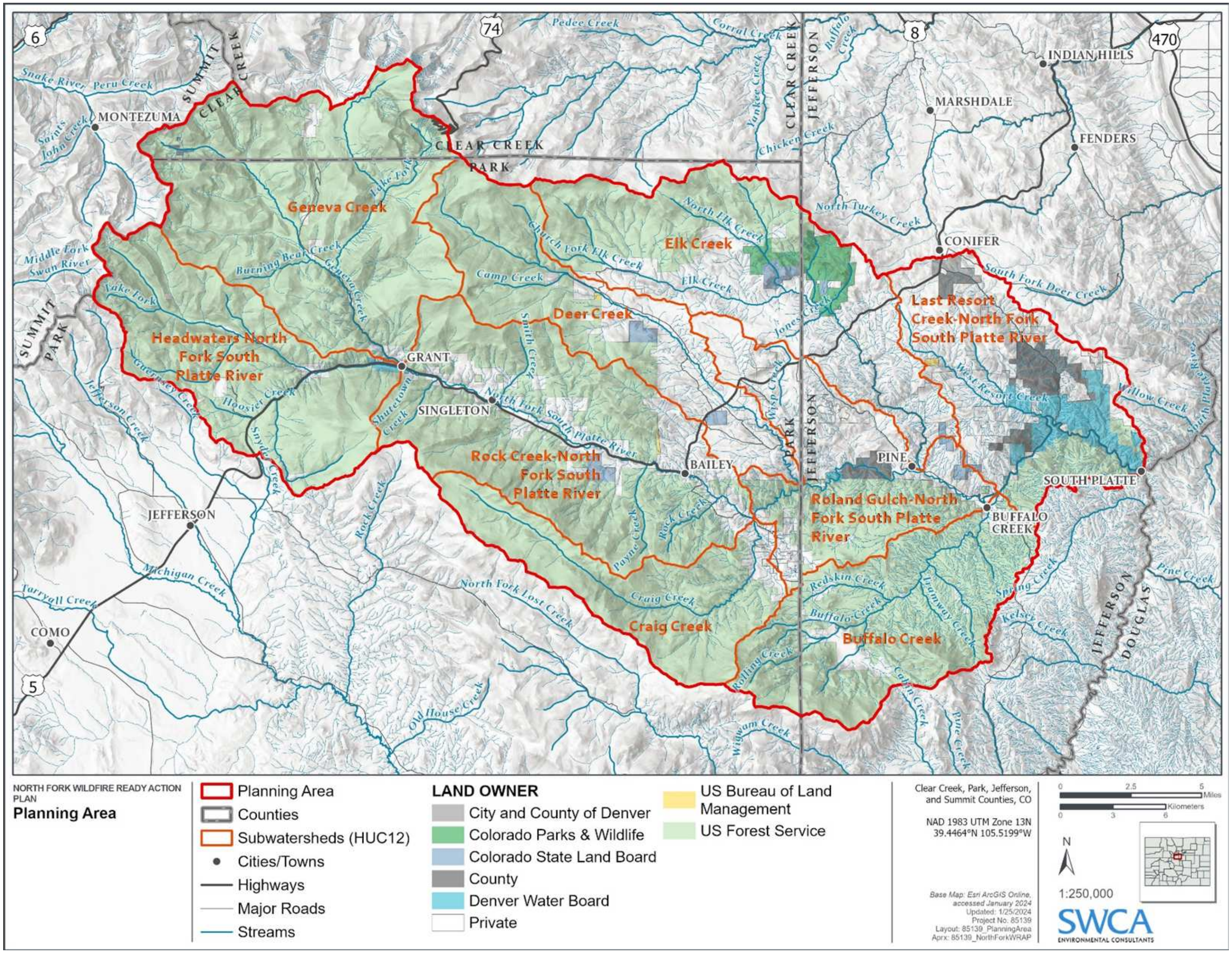


Figure B.1. North Fork Wildfire Ready Action Plan planning area.

Results and Recommendations

Table B.1 lists data gaps that still exist, discusses any implications to the hazard risk and susceptibility analysis, and provides recommendations for addressing persistent gaps. A full list of data sets considered for this project is included as Appendix A. Table B.1 also discusses instances where data were available but lacked local detail or did not cover the entire planning area. Where possible, proxy data sources will be used to represent the respective data category as accurately as possible (see the Proposed Approach Recommendations).

Table B.1. Planning Area Data Gaps

Data Gap	Implications	Proposed Recommendations
Hazard potential of abandoned mine lands (AML)	AML data are available from multiple sources, including the Colorado Division of Reclamation and Mining, CDPHE, and Colorado Geological Survey. Available data are limited to location, size, and type of mining. Available data may not accurately reflect the hazard potential each mine site has on water quality.	The location and age of AML sites can be used in the analysis to determine potential water quality hazards in the watershed. The risk that each mine site poses will be considered equal due to a lack of site-specific hazard information.
Decreed water rights	Specific information related to decreed water rights, such as water amount, is not available. The Colorado's Decision Support Systems includes information on active and unmaintained diversion records that provide sufficient information on diversion location. Data may not accurately reflect actual annual water diversion amounts for each water decree.	Colorado's Decision Support Systems data will be used to assess the location and active status of ditches, pipelines, and pumps in the planning area. The analysis may lack water quantity information for each water decree.
Stream crossing data (lacking desired information such as culvert size, bridge age, structure identification)	Precise location, size, and age of bridges and culverts are not available. The lack of this information is not anticipated to have a large impact on the overall analysis, and a proxy data source has been determined to work through this gap.	NHD data can be overlayed with road infrastructure data to determine crossing points in the planning area. A bridge data layer is available, so all other stream-road crossing points will be assumed to contain a culvert. The hazard assessment of each crossing will be considered equal due to a lack of feature-specific information.
Property access for private roads and driveways	Private road features are available in data sets from Jefferson County and from Pike-San Isabel National Forests & Cimarron and Comanche National Grasslands. These data do not include coverage for the entire planning area, and some private roads may not be identified.	The analysis will be completed with the currently available data. Some portions of the planning area may not have private roads accurately reflected.
Priority watersheds and stream reaches identified for stream and wetland restoration	Multiple stream reach and watershed prioritization data sets are available, including Denver Water prioritization completed during work on the Strontia Springs Reservoir watershed sediment study and management plan (SWCA 2019 and 2021). The prioritized projects focused on addressing sediment supply, bank stability, and transport and are not specific to post-fire watershed impacts. Additionally, the Core Team had the opportunity to identify priority watersheds and locations using the studies' webmap. Data cover the entire planning area but currently do not include priority areas identified by other land managers. Stakeholders provided input during Stakeholder Meeting No. 1 and Core Team members provided additional priority areas using a web map.	The analysis will be completed with the available watershed prioritization data from Denver Water. Some recommended projects and actions are relevant for post-fire resilience such as riparian buffering and channel complexity improvements. Priority reaches identified by other groups and agencies will not be reflected, so some local restoration or management priorities may not be accurately assessed.

Data Gap	Implications	Proposed Recommendations
Grazing lands data	Specific data on grazing lands are not available, but a suitable proxy has been identified that will accurately assess grazing lands in the planning area.	Land use and zoning data sets will be used in place of grazing land data to assess lands where livestock grazing is occurring.
Rainfall-runoff erosivity	No data exist, but proxy data can be used to reflect erosivity based on land cover and slope. Data may not accurately portray post-burn erosivity.	Vegetation cover type and topography can be used to approximate likely erosivity of slopes. Burn severity will need to be linked with land cover to assess vegetation changes under burn severity conditions.
Anticipated development	A source for future development trends was not identified. Analysis may not accurately reflect future conditions in the watershed as dictated by development. Changes in development would likely impact erosion, stormwater infrastructure, water conveyance, and values at risk within the planning area.	This information will not be included in future analyses. A lack of data in this category is not anticipated to negatively impact the analysis because development is not projected to increase greatly in rural watersheds in a way that would greatly influence project outcomes.
Most probable and worst-case burn severity	Burn severity is needed to gage hydrologic and sediment response to varying severity levels. Burn severity is directly correlated with watershed changes in post-fire environments and accurately assessing potential burn outcomes is necessary for determining potential watershed impacts.	Denver Water Risk Assessment and Decision Support will be used to assess fire behavior and burn severity in the planning area. Crown fire activity and intensity can be used as a proxy for anticipated burn severity.

Table B.2. Comprehensive List of Data Sets

Data Type	Dataset Name or Description	Data Information	Data Source	WRW Hazard
Colorado Forest Restoration Institute (CFRI) fire behavior data	Scott and Burgan Fuels Methods	Fire behavior fuel models showing fire spread under varying vegetative conditions	U.S. Forest Service (USFS)	Post-fire hazards and burn severity
Crown fire activity, flame length, and burn probability	CFRI and Denver Water Risk Analysis and Decision Support System (RADS) update	Fire severity and spread potential based on Scott and Burgan fuel models	Denver Water	Post-fire hazards and burn severity
Fire history	Monitoring Trends in Burn Severity	Burn severity for previous large wildfires	U.S. Department of Agriculture (USDA)	Post-fire hazards and burn severity
Fire history	National Interagency Fire Center	Provides size, year, and cause of wildfires. Can be used for comprehensive wildfire history.	National Interagency Fire Center	Post-fire hazards and burn severity
Fire history	FireSev	Model platform for estimating burn severity	USDA	Post-fire hazards and burn severity
Fire behavior modeling	Colorado All-Lands Quantitative Wildfire Risk Assessment (COAL)	Provides fire behavior data for Colorado. Provides methods and fuel layers used. Also provides crown fire activity, which can be used as a proxy for fire severity. Other fire behavior metrics (e.g., flame length and rate of spread) can also be mapped out.	Pyrologix	Post-fire hazards and burn severity

Data Type	Dataset Name or Description	Data Information	Data Source	WRW Hazard
Gross hillslope erosion (megagrams per hectare)	CFRI and Denver Water Risk RADS update	Raw data to be used with Revised Universal Soil Loss Equation (RUSLE) soil loss equation	Denver Water and CFRI	Hillslope erosion
Sediment to Infrastructure (weighted) – likely conditional net value change (cNVC)	CFRI and Denver Water RADS update	Erosion combined with weighted channel transport (hillslope sediment delivery ratio [hSDR] and a channel sediment delivery ratio [cSDR]) and infrastructure relative importance weights	Denver Water and CFRI	Hillslope erosion
Sediment to infrastructure (unweighted)	CFRI and Denver Water RADS update	Erosion combined with weighted channel transport (hSDR and cSDR)	Denver Water and CFRI	Hillslope erosion
Sediment yield expected net value change (eNVC)	CFRI and Denver Water RADS update	cNVC × burn probability	Denver Water and CFRI	Hillslope erosion
Rainfall-runoff erosivity	USDA isoerodent maps	Soil erosivity map of United States	USDA	Hillslope erosion
Soil composition data	Soil Survey Geographic Database (SSURGO)	Information about soil as collected by the National Cooperative Soil Survey	Natural Resources Conservation Service (NRCS)	Hillslope erosion, debris and mud flow, and hydrologic response
Soil composition data	State Soil Geographic dataset (STATSGO)	Broad-based inventory of soils and non-soil areas	NRCS	Hillslope erosion, debris and mud flow, and hydrologic response
Digital elevation models (DEMs)	U.S. Geological Survey (USGS) 1/3 arc-second DEM	Elevation layer of The National Map. Provides foundational elevation information for earth science studies and mapping applications in the United States.	USGS	Hillslope erosion and debris and mud flow
Land cover data	National Land Cover Database 2019 Land Cover (CONUS)	Land cover and change data	USGS	Hillslope erosion and hydrologic response
Reservoirs/water storage	Colorado Division of Water Resources Dam Safety	Jurisdictional dam locations and details.	Mile High Flood District	Hillslope erosion, debris and mud flow, hydrologic response, and values at risk
Waterbodies acreage	The National Map (USGS)	Location of waterbodies. Data will be joined with Mile High Flood District data to calculate acreage.	USGS	Hillslope erosion, debris and mud flow, and values at risk
Build flow lines	National Hydrography Dataset (NHD) flowline features	Human-made water infrastructure including pipelines, canals, and ditches	USGS	Hillslope erosion, debris and mud flow, and values at risk
Decreed water rights	Colorado's Decision Support System Decreed Features	Includes ditches, ditch systems, pipelines, and pumps with a use code of A (active structure with contemporary diversion records) or U (active structure but diversion records are not maintained)	Colorado's Decision Support Systems	Hillslope erosion, debris and mud flow, and values at risk

Data Type	Dataset Name or Description	Data Information	Data Source	WRW Hazard
Source water	Various municipal surface water intake sources	Data from Colorado Rural Water Association, Mountain Water and Sanitation District, Bailey Water and Sanitation District, and Buffalo Creek Water District for surface well and storage tank locations	Multiple	Hillslope erosion, debris and mud flow, and values at risk
Waste water	Various municipal sources	Data for wastewater conveyance, treatment facilities, and discharge points	Multiple	Hillslope erosion, debris and mud flow, and values at risk
Stormwater infrastructure	Jefferson County data features	Stormwater features in Jefferson County	Jefferson County	Hillslope erosion, debris and mud flow, and values at risk
Aquatic resources	Colorado Parks and Wildlife (CPW) aquatic management waters data	Aquatic Sportfish Management Waters (ASMW), Aquatic Native Species Conservation Waters (ANSCW), Aquatic Gold Medal Waters (AGMW), Aquatic Cutthroat Trout Designated Crucial Habitat (ACTDCH), and aquatic species of greatest conservation need (SGCN)	CPW	Hillslope erosion, debris and mud flow, and values at risk
Wetland and riparian areas	NHD/National Wetland Inventory	NHD location and composition of wetlands	USGS and U.S. Fish and Wildlife Service	Hillslope erosion, debris and mud flow, fluvial hazard, and values at risk
Stream crossings	Combining NHD and OpenStreetMap	Using both NHD and OpenStreetMap data allows assumptions about locations of culverts and stream crossings.	Multiple	Hillslope erosion, debris and mud flow, flooding, and values at risk
Bridges	USFS internal data	Critical infrastructure spanning a flow line	USFS	Hillslope erosion, debris and mud flow, flooding, and values at risk
Abandoned mining lands (AMLs)	Division of Reclamation, Mining and Safety (CDRMS) map	Location, age, and type of abandoned mine lands	CDRMS	Hillslope erosion, flooding, and values at risk
AMLs	AMLs information hub	Location of AMLs	CDPHE	Hillslope erosion, flooding, and values at risk
Active mines	CDRMS map	Location, age, and type of abandoned mine lands	CDRMS	Hillslope erosion, flooding, and values at risk
Debris flow probability	CFRI and Denver Water RADS update	Provides probability of occurrence. Methods provided in CFRI correspondence.	Denver Water and CFRI	Debris and mud flow
Debris flow volume	CFRI and Denver Water RADS update	Provides volume of debris flow. Methods provided in CFRI correspondence.	Denver Water and CFRI	Debris and mud flow

Data Type	Dataset Name or Description	Data Information	Data Source	WRW Hazard
Debris flow cNVC (conditional net value change)	CFRI and Denver Water RADS update	Combines debris flow hazard (probability X volume) with weighted channel transport and IRI. This is a risk metric.	Denver Water and CFRI	Debris and mud flow
Debris flow eNVC (expected net value change)	CFRI and Denver Water RADS update	cNVC X burn probability	Denver Water and CFRI	Debris and mud flow
Precipitation data	Precipitation Frequency Data Server	Precipitation frequency estimates and associated information	National Oceanic and Atmospheric Administration	Debris and mud flow
100-year floodplains	U.S. Environmental Protection Agency (EPA) 100-year floodplain data set	Based on Federal Emergency Management Agency (FEMA) floodplains	FEMA	Flooding
500-year floodplains	FEMA 500-year floodplain	Used for potential fluvial hazard zones	FEMA	Flooding
Zone A, Zone AE, Zone X, floodway, floodplain delineations	FEMA Special Flood Hazard Area (SFHZ) data	Includes much of 100- and 500-year floodplains information	FEMA	Flooding
Building footprints Number of structures	Microsoft Building Footprints	Identifies building footprints in flood zone	Microsoft	Flooding and values at risk
Population density	Homeland Infrastructure Foundation-Level Data (HIFLD)	Identifies populations within flood zones	U.S. Department of Homeland Security	Flooding and values at risk
Private roads or driveways	Property access	Ingress and egress crossing flood zones	USFS	Flooding and values at risk
Roads	OpenStreetMap	Shows roads to identify those within flood zones	OpenStreetMap	Flooding and values at risk
Hazardous materials	Hazardous Materials and Waste Management Division map	Identifies hazardous material locations (brownfield, compost sites, landfills, superfund sites, etc.)	CDPHE	Flooding and values at risk
Topographic data - high resolution	Topographic data (lidar)	Topographic information for routing and more detailed channel coverage	USGS	Hydrologic response and fluvial hazard
Topographic data - lower resolution	Topographic data (lidar)	Topographic data for determining slope and landscape characteristics	USGS	Hydrologic response and fluvial hazard
Flow release and augmentation data/stream gage data	USGS stream flow conditions	Annual flow changes and basin imports/exports	USGS	Hydrologic response
Historical imagery	Various federal and stakeholder sources	Repeat historical imagery of the major river segments in the watershed	USGS, National Agriculture Imagery Program, Google Earth, stakeholders	Fluvial hazard
Bedrock geological maps	National Geologic Map Database	Geological mapping	USGS	Fluvial hazard
Surficial geological maps	National Geologic Map Database	Geological mapping	USGS	Fluvial hazard

Data Type	Dataset Name or Description	Data Information	Data Source	WRW Hazard
Flood images	Various federal and stakeholder sources	Historic flood images to determine high flow trends, migration patterns, etc.	USGS, National Agriculture Imagery Program, Google Earth, stakeholders	Fluvial hazard
Parcel data	Multiple sources; data from Park and Jefferson Counties	Information on county parcels (boundary lines, area, etc.)	Jefferson and Park Counties	Values at risk
Schools	National Map Schools k-12 Public and Private	Location of schools	EPA	Values at risk
Various infrastructure (hospitals, fire stations, emergency medical centers, pipelines, power plants, transmission lines, communication towers, etc.)	Homeland Infrastructure Foundation–Level Data (HIFLD)	Various infrastructure and values	U.S. Department of Homeland Security	Values at risk
Priority watersheds and stream reaches identified for stream and wetland restoration	*Colorado Water Plan*, Denver Water Strontia Springs Reservoir watershed sediment studies, and Strontia Springs Reservoir watershed sediment management plan	Location of priority restoration and conservation reaches and wetlands	Colorado Water Conservation Board and SWCA Environmental Consultants	Values at risk
National Historic Trails	National Trail System	Location and distance of trails	USGS, National Park Service, and other data sets	Values at risk
National scenic byways	National Scenic Byways and All-American Roads	Location and distance of nationally recognized byways	USGS, U.S. Department of Transportation, and other data sets	Values at risk
Parks	Various data from Park and Jefferson Counties	Location of parks	Park and Jefferson Counties	Values at risk
Cultural resources	Various sources	Location of culturally significant sites	Stakeholder input	Values at risk
Wilderness (designated and study area)	Wilderness areas	Location and extent of wilderness areas	USGS and USFS	Values at risk
National conservation areas	National conservation areas	Location and extent of conservation areas	USGS and Bureau of Land Management (BLM)	Values at risk
National recreation areas	National recreation areas	Location and extent of recreation areas	USGS and U.S. Department of the Interior	Values at risk
Special management areas	Special management areas	Location, use, and extent of special management areas	USGS and BLM	Values at risk
Irrigated land	Data from Colorado's Decision Support Systems	Land cover and use data used to determine irrigated lands	Colorado's Decision Support Systems	Values at risk
Grazing	USFS grazing allotments	Location of grazing lands	USFS	Values at risk
Timber harvest	USFS timber harvest	Location of timber harvests	USFS	Values at risk

APPENDIX C

Hazard Analysis and Methodology

HAZARD ANALYSIS REPORT

Project Background

Purpose

This report provides the methods and results for the hydrologic model, hydraulic models, and fluvial hazard zone mapping for the North Fork WRAP (NF WRAP). These three components, along with debris flow and the revised universal soil loss equation (RUSLE) model, inform where post-fire hazards (e.g. flooding and debris flow) are the most likely to occur in the project area (Figure C.1). The sections below provide a brief watershed description of the project area, the approach for the hazard analysis, and the methods and results for the hydrologic model, hydraulic models, and the fluvial hazard zone analysis. The results from these datasets and models will be fed into the susceptibility analysis, which will identify areas where hazards and assets overlap. The hazard analysis and susceptibility analysis will then be utilized to identify priority areas and projects to include in the pre-fire and post-fire preparedness plans for the NF WRAP.

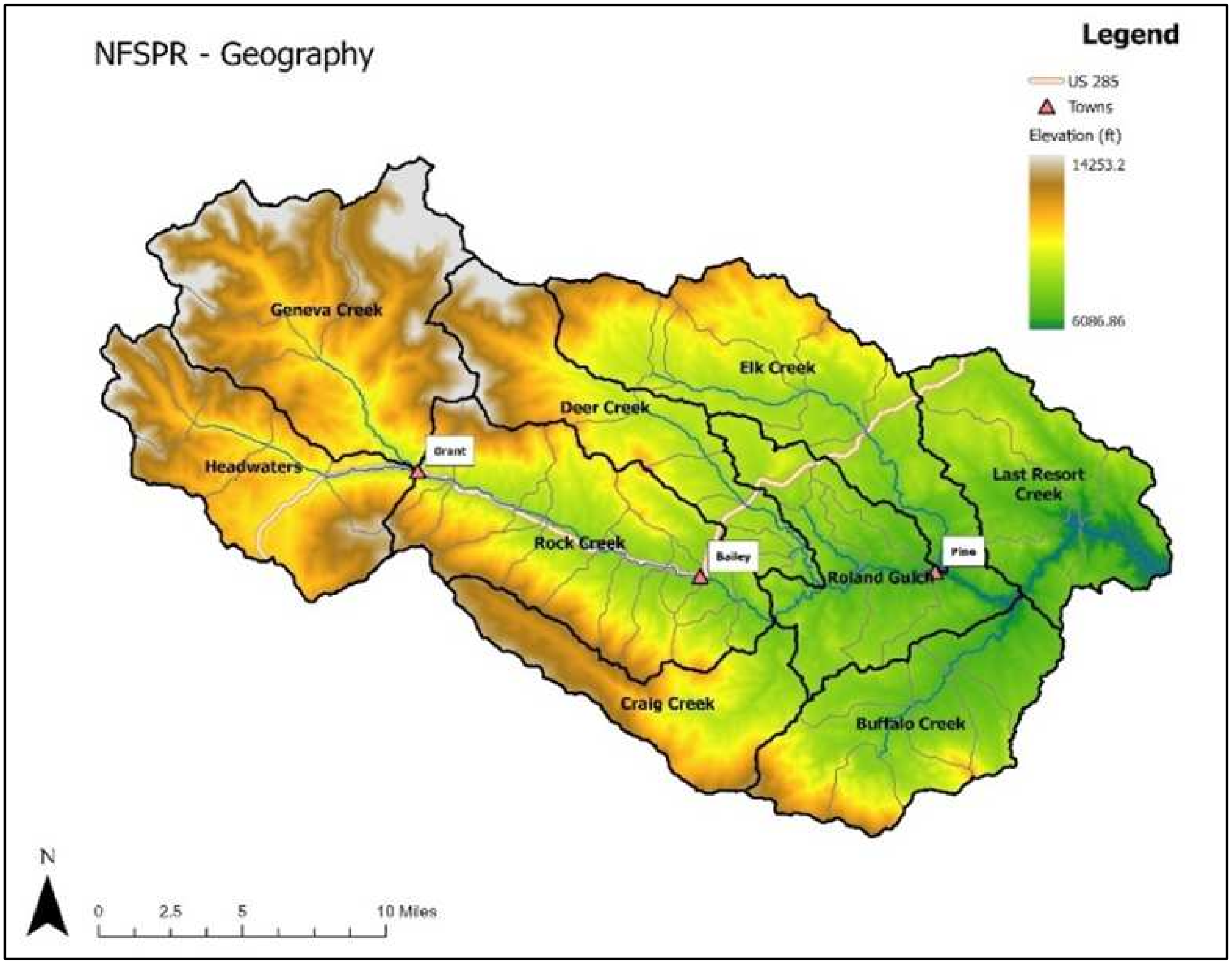


Figure C.1. North Fork of the South Platte River project area and elevation.

Watershed Characteristics and Description

The North Fork of the South Platte River (NFSPR) is located within the Colorado Front range southwest of Denver. The mainstem spans approximately 43 mi from Webster, CO to the confluence with the South Platte River (Figure C.1). It is composed of 9 hydrologic unit code (HUC)-12 basins covering a total area of approximately 476.2 sq. miles. The river is located within the Southern Rocky Mountain ecoregion and is primarily in a temperate arid semi-arid steppe climate. The bedrock is comprised of igneous and metamorphic rock such as gneiss, schist, and granite with some areas of glacial drift. Alluvial deposits are in the NFSPR valley system and most of the urban development in the project area has been built on these deposits.

Watershed-level characteristics are important in understanding the potential for flooding and the overall dynamic forces governing stream response. The characteristics relevant to the hydrologic, hydraulic, and fluvial hazard zone analysis are listed below. The fluvial hazard zone has additional relevant characteristics that are outlined in that discussion section.

- **Physiographic -** The watershed begins at the Continental Divide and travels east, conferencing with the South Fork of the South Platte River roughly 10 miles upstream of the transition of the South Platte River into the high plains. The elevations span from over 13,000 feet to 6,000 feet (Figure 1). This watershed is a source area for sediment. The steep tributary channels and gullies source the sediment from the hillslopes initially conveying the material to the North Fork and the wider valley system that it has created. While some of that material is attenuated within the valley, it will continue to be transported to the high plains over geologic time.
- **Geologic -** The two primary rock units are Rocks of Pikes Peak Batholith (32%) and biotic gneiss, schist, and migmatite (39%). Other rock units in the watershed include granitic rocks (16%), glacial drift (4%), and felsic and hornblendic genesis (9%) (USGS,1979). Generally, these rocks are characterized as metamorphic units that are resistant to erosion. This generally means that the bedrock margins constrain and limit the fluvial systems. Energy from large flood events will be focused and preserved in confined reaches until it is unleashed in more open floodplain settings where the river is less confined. Fluvial change and hazards will be focused on these regions.
- **Hydrologic -** This watershed spans two different climate zones, the Orographic Sheltered and Eastern Slopes and the Great Plains South, according to a detailed study used to estimate flood potential in the Southern Rocky Mountains (Yochum, 2019). Flooding in the watershed is driven primarily by high-intensity thunderstorm events. The current geomorphic processes appear to be active during large events, however the modal flow regime has been dramatically increased due to trans-basin import and conveyance through the North Fork. This has created an oversized bankfull channel for the system, but has minimal impacts compared to larger events that are most likely to create hazards.
- **Ecoregion -** The watershed is located almost entirely within the Southern Rockies Crystalline Mid-Elevation Forests ecoregion. This region is found at elevations between 7000 and 9000 ft and contains vegetation such as aspen, ponderosa pine, Douglas-fir, lodgepole pine, and limber pine. The headwater portions of the watershed are in the Crystalline Subalpine Forests, which are found between elevations of 12,000 and 8,500 feet and dominated by spruce and fir with pockets of aspen and lodgepole pine (Chapmann et al, 2006). The forested nature of the watershed means that fluvial systems are heavily influenced by large wood, which is important to attenuate sediment and flows within tributary channels, but it can also impact flooding dynamics and infrastructure.

Hazard Analysis Overall Approach

The hazard approach includes five models, which are listed in Table C.1. The USGS Debris Flow probability model and the RUSLE model are preexisting datasets that were collected during the data gathering phase of the NF WRAP. These layers, along with the fire behavior modeling data layers, were received from the Colorado Forest Restoration Institute technical report titled *From Forests to Faucets Partnership Wildfire Risk Assessment.* The full report is available here: https://cfri.colostate.edu/wp-content/uploads/sites/22/2024/09/Rhea_etal_FromForeststoFaucetsPartnership_WildfireRiskAssessment_CFRI_2414.pdf. They are utilized to determine potential locations for debris flow and post-fire sediment yields, respectively. The hydrologic model was developed to fill a data gap for pre-fire and post-fire flow quantification—where the focus is on the magnitude of increases from pre- to post-fire flows. The hydraulic model fills in gaps to better understand the direct impacts of flow within a channel system, including stream power, velocities, depth, and inundation boundaries. Fluvial hazard zones were delineated to predict potential movement of the stream system and related hazards for long-term planning. Together, these models provide insight into locations where post-fire impacts may be the greatest and therefore warrant consideration for pre-fire projects or a focus during post-fire recovery efforts.

Table C.1. Models and analyses included in the North Fork WRAP hazard analysis

Model Name	Focus, Advantages, Limitations
USGS Debris Flow Probability Model (Regression Equations)	Focus: Debris flow prediction. Smaller channel and gulley systems and the probability of debris flow occurrence during high-intensity rainfall. Advantage: Good communication of post-fire and post-flood debris flow risk and prioritization. Great for smaller clusters of VARs located at the outlet of tributaries on alluvial fans. Limitations: Difficult to utilize for infrastructure and mitigation design. Large uncertainty on sediment yield predictions. Academic focus with a limited user base.
Revised Universal Soil Loss Equation (RUSLE) Model	Focus: Sediment yields. High resolution data across a large area. Calculated post-fire impacts continuously across the landscape. Advantage: Provides the best estimate of pre- and post-fire sediment yields. Data can be pulled at many different scales. Limitations: Difficult to utilize for infrastructure and mitigation design. Academic focus with a limited user base.
Watershed-Wide Hydrologic Model using HEC-HMS	Focus: Converts rainfall to flow volumes and accounts for timing. A calibrated HMS model will focus on quantifying accurate flows within the NFSPR. This data can drive flood prediction estimates, and order of magnitude increase estimates along the mainstem of the North Fork. Advantage: Modeling can be used for mitigation design. Large user base in post-fire settings. Limitations: Not focused on storm events that drive post-fire risk, like high intensity-short rainfall in smaller tributary channels. Calibration is important but is usually costly and difficult.
2D HEC-RAS Modeling	Focus: Works to convert the discharge estimates from HEC-HMS to flow on the landscape, including velocity, depth, and stream power. Advantage: Critical for site-level design for many project types including infrastructure protection, stream enhancement, and community planning. Limitations: Doesn't incorporate erosion and deposition of sediment or wood debris dynamics (While sediment transport and non-Newtonian flow modules are available, they will not be utilized for this effort). The detailed outputs can provide false confidence in a highly uncertain post-fire flood environment.
Fluvial Hazard Zone Delineation	Focus: Provides a long-term planning boundary that estimates and predicts potential fluvial hazards. Advantage: Appropriate for engineering and geologic timescales. Reorients risk in fluvial environments to "when" not "if". Limitations: Not as detailed as other products. Estimates processes that occur over engineering timescales (Life span/design life of large infrastructure ~50-100 years) and can be difficult to plan around.

Watershed-Wide Hydrologic Model (HEC-HMS)

Purpose

The hydrologic model is utilized to estimate pre-fire and post-fire flow conditions in the project area. The focus of this effort for the NF WRAP is the **difference** between the pre- and post-fire results, rather than the independent model results. Where the **magnitude of change** is the largest is where the post-fire impacts for flooding are predicted to be the greatest. The areas of greatest change between the models are where the "risk" is for post-fire hydrology.

Inputs

Subbasins. The nine HUC-12 subwatersheds were further subdivided into subbasins during the hydrology model development. The basis for the HUC-12 subwatershed divisions included USGS Debris Flow basin delineations, stakeholder areas of interest, road crossing locations, isolating large tributary basins, and reservoir locations. After the first round of subdividing, the USGS Debris flow basins were matched to downstream points of interest (assets, stakeholder priorities, etc). All basins upstream of a point of interest were merged into one subbasin. The NFSPR model contains 50 subbasins (Figure C.2).

Excess precipitation. Soil Conservation Service (SCS) were utilized to estimate excess precipitation. The Soil Conservation Service (SCS) models were chosen because they are widely used in post-fire response and well-known within the industry, resulting in large amounts of academic research, methods, and utilization across post-fire environments. The SCS Curve Number (CN) Method estimates excess precipitation, the precipitation that exceeds the capacity of the landscape to absorb, based on precipitation depth, soil cover, and land use. The SCS lag time equation estimates how long it will take the excess precipitation to reach the watershed outlet based on watershed slope and hydraulic length of the watershed. CNs and lag times were calculated for each basin using Watershed Model System (WMS) by Aquaveo which utilized publicly available GIS data, including USGS terrain data, National Land Cover Database, and Soil Survey data from the National Resource Conversation Service (NRCS). The data used is listed in the Data Gap Analysis (Appendix B) and includes the National land Cover Database (NLCD), soil data, and topographic data (Table C.2).

Table C.2. HMS input datasets

Data	Source	Year	Data Resolution
Terrain	USGS DEM	2014, 2016, 2020, 2021	10 -meter pixels 1/2-meter pixels
Landcover	NLCD	2011	30-meter pixels
Soils	STATSGO (NRCS)	N/A	N/A (Shapefiles not raster)

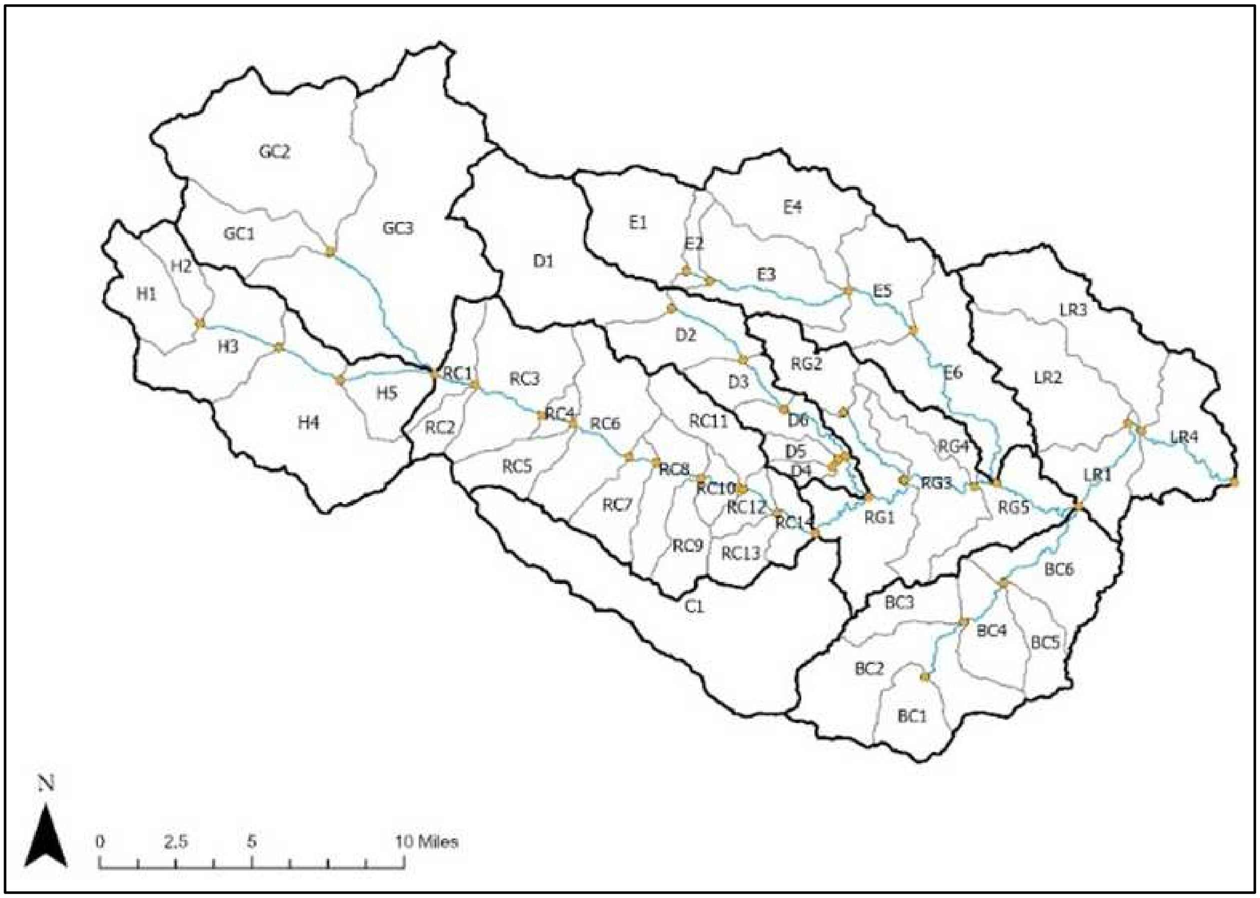


Figure C.2. NFSPR Subbasins, reaches, and junctions.

Rainfall. Rainfall was modeled using an SCS Type 2 storm distribution, which best represents the type of storm that typically occurs in this geographic area, within HEC-HMS. We selected the 10-year post-fire flows because of the relatively high probability of occurrence (65% chance of occurrence) over the roughly 10-year watershed recovery period (USDA, 2016), the fact that many post-fire recovery agencies (NRCS EWP) use this as a design standard for many practices, and, in our teams experience, these flow values strike a good balance between practical design outcomes and level of protection. The 100-year post-fire flow is the best tool for communication, emergency planning, and alert gage planning, but mitigation to this event is typical impractical and cost prohibitive. The CWCB technical advisory team also supported this decision based on their experience with post-fire flood events and recovery. Each HUC-12 subwatershed was considered as a different rainfall zone with NOAA Atlas 14 Point Precipitation Depths for 24 hours pulled from centroid of the basin. A TP40 area reduction, which refers to area-reduction curves presented in NOAA Technical Paper Number 40, was applied in the HMS meteorological model across the entire watershed area (Bartles et al., 2022). An area-reduction factor is important to address the likelihood of storm covering large positions of the watershed during a given event. See Table C.3 for the 10YR and 100YR event precipitation zones and values.

Table C.3. Precipitation Depth Values for a 24-hr 10YR and 100YR Hypothetical Storm Events

HUC12 Basin Name	24-hr Precipitation Depth (in)	
	10-yr	100-yr
Headwaters NFSPR	2.06	3.44
Geneva Creek	2.06	3.49
Rock Creek-NFSPR	2.28	3.81
Deer Creek	2.36	3.94
Elk Creek	2.65	4.35
Roland Gulch - NFSPR	2.59	4.23
Last Resort Creek - NFSPR	2.9	4.71
Buffalo Creek	2.62	4.23
Craig Creek	2.5	4.12

Model Components

HEC-HMS Version 4.11 was used to model hydrology (Hydraulic Engineering Center, 2022). The model had a total of 123 components: 50 subbasins, 39 stream reaches, and 34 junctions (Figure C.2). The model applied the Kinematic Wave method for routing flows throughout the model. Physical parameters for the reaches were generated using WMS Version 11.1 and index flow was generated within the model iteratively. Index flow is an indirect way for the model to estimate flow travel time, a necessary metric for the model to find its starting distance step for initial iterations (Bartles, 2022). Mannings' n values, which accounts for friction losses within the hydraulic models, for the reaches ranged from 0.06 – 0.12 estimated from aerial imagery and the NLCD (HEC, 2024a). Side slopes for the reach components were assigned according to Table C.4. They were developed confinement classification for each reach compared to topographic cross-section sampling within each confinement type.

Table C.4. HMS Channel Side Slopes

Channel Type	Slope (xH:1V)
Small - Confined	1
Medium - Confined	2
Small - Unconfined	3
Medium - Unconfined	4

Model Calibration

Based on experience in other post-fire disaster responses, the technical team was committed to providing the most accurate hydrology model possible, knowing that in post-fire disaster response, there is very little time or resources for detailed calibration. The calibration of the existing conditions model allows for increased usability, confidence, and support for models resulting from this study meaning that post-fire effort can focus on project implementation and recovery rather than technical modeling.

Three gages with a robust dataset, over 30 years of records, were chosen within the basin for the calibration efforts. The gage data set for the NFSPR contains three stations listed below in Table C.5. Analysis data for the gage at Geneva Creek and Headwaters, and NFSPR Outlet were pulled from the

USGS Vaill, 2000 report. The third gage was a CWCB gage at NFSPR and Craig Creek (Junction 2). The CWCB gage data was analyzed by using PeakFQ Version 7.4.1 (USGS, 2023). More information on the PeakFQ calculations can be found in the **Supplemental Data**. Flows at all HUC-12 junctions were examined in the model and the CNs for each HUC-12 was adjusted to align the modeled flow with the 10-YR gage data. A map of HUC12 junctions is shown below in Figure C.3. Gage flows versus the final calibrated model junction flows is shown below in Figure C.4. Following the calibration of the HUC12 model, the curve numbers of all the subbasins were adjusted by the same percentage and applied to the Existing Conditions Model, shown in the **Summary_Parameter_Data.xlsx** in the **Supplemental Data** folder.

Table C.5. Gage data used for the calibration effort.

HUC-12/Junction Point	Gage Number	Gage Name	Source	Years of Record	Analysis Method	10-YR Flow Value (cfs)
Geneva Creek and Headwaters (Junction 1)	06706000	North Fork South Platte River below Geneva Creek, at Grant, Colo.	USGS (Vaill, 2000)	31	(Vaill, 2000)	780
NFSPR and Craig Creek (Junction 2)	N/A	CWCB – North Fork South Platte River at Bailey (PLABAICO)	(CWCB and DWR, 2024)	31	PeakFQ *1996 outlier removed. Without Regional Skew	1027
NFSPR Outlet (Junction 6)	06707000	North Fork South Platte River at South Platte, Colo.	USGS (Vaill, 2000)	60	(Vaill, 2000)	1600

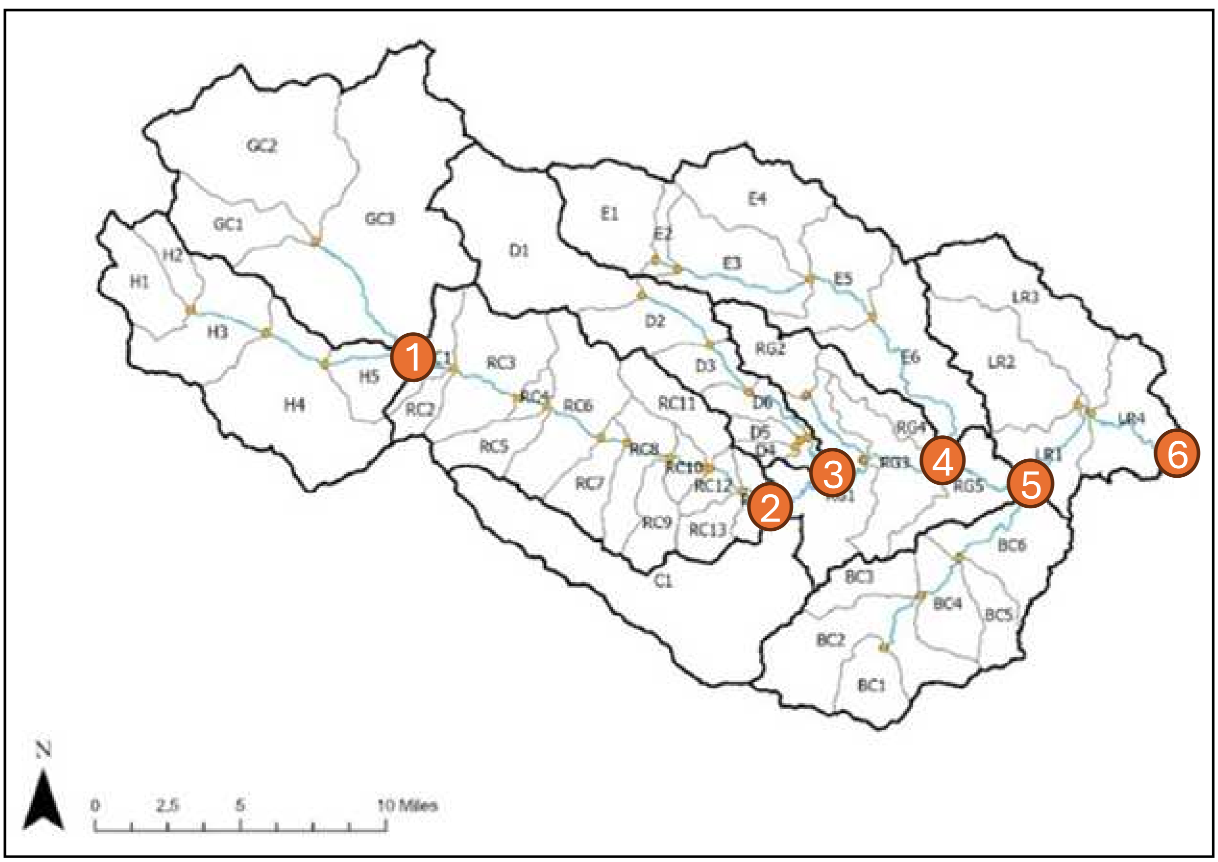


Figure C.3. Junctions points used in the HEC-HMS model calibration run

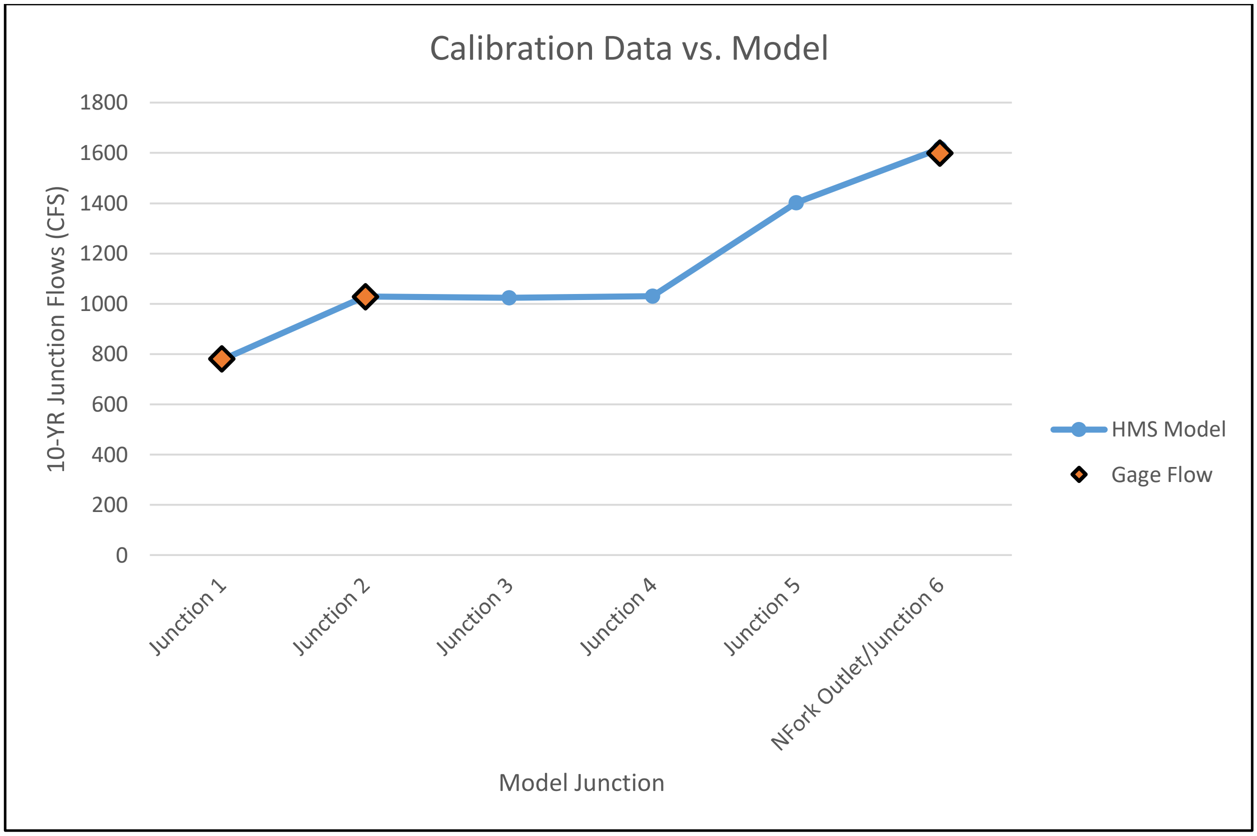


Figure C.4. Existing Conditions Model Results Calibration Data

Post-Fire Scenario Adjustments

Based on the project area's vegetation composition, fire behavior experts determined Crown Fire activity to be the best proxy for predicted fire burn severity. The CFRI's modeled Crown Fire Activity during 97th percentile weather conditions (CFRI, 2024) within the North Fork watershed was used as a proxy for burn severity. Table C.6 shows how the Crown Fire Activity was converted to burn severity so that post-fire modeling procedures could be applied to the hydrologic model to create post-fire flow predictions.

Table C.6. A conversion table for Crown Fire Activity and Burn Severity.

Crown Fire Activity	Burn Severity
Non-burnable	No Burn
Surface Fire	Low
Passive Crown Fire	Moderate
Active Crown Fire	High

The area for no, low, moderate and high burn was calculated for each of the subbasins. Curve number adjustments were calculated using the Higginson and Jarnecke's (2007) method, which was developed based on the 2007 Salt Creek Fire in Utah, as shown in Equations 1 and 2.

Equation 1

$$CN\ Adjutsment\ Value = 15\left(\frac{High\ Burn\ Area}{Watershed\ Area}\right) + 10\left(\frac{Moderate\ Burn\ Area}{Watershed\ Area}\right) + 5\left(\frac{Low\ Burn\ Area}{Watershed\ Area}\right)$$

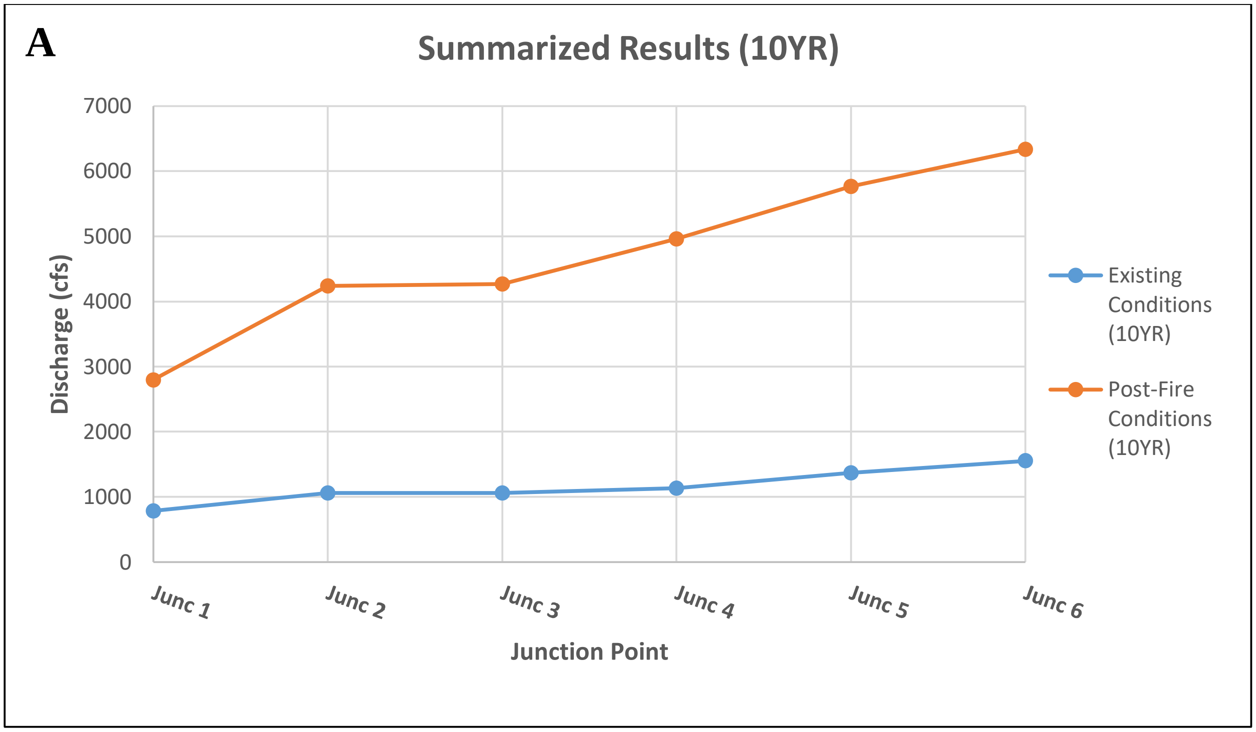
Equation 2

$$PostFire\ CN = PreFire\ CN + CN\ Adjutsment\ Value$$

After post-fire CN and lag time adjustments were calculated, the model was rerun to calculate post-fire flows for 10- and 100-year flood events.

Results

For hydrologic modeling of flow hazards, the focus is on the magnitude of change in the subbasins from the pre-fire model to the post-fire model. Generally, areas with the largest percent change from pre- to post-fire flow conditions have the greatest potential for post-fire impacts from high stream flows and flooding. In this section, the high-level takeaways for each HUC12 Subwatershed area discussed, and 10-Year Recurrence Intervals are shown in the Figures below. Full results can be seen in the Modeling Subbasin shapefile and a workflow (Online Map Data Review Workflow.docx) is available to toggle through several different results layers within the Online Map: North Fork WRAP Web Map. Figure C.5 shows summary results for the 10- and 100-year flood events. A more detailed interpretation of results can be found in the **Summary of Findings by HUC-12** section.



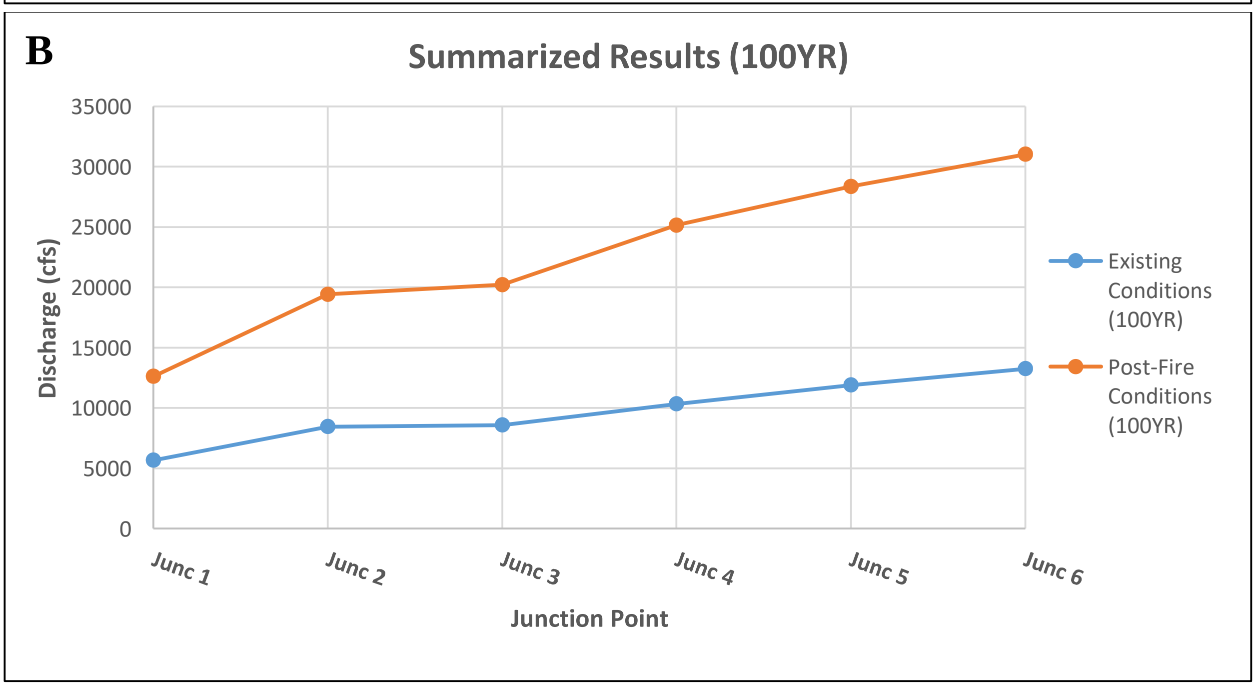


Figure C.5. Results of Pre- and Post-Fire Impacts on the North Fork Hydrology for the 10-year (A) and 100-year (B) events.

Hydraulics

Inputs

HEC-RAS 2D Version 6.5 was used to model the hydraulics of two stretches along the NFSPR (Hydraulic Engineering Center, 2024b). The hydraulic model provides estimates for how flow will impact the channel system, including stream power, velocities, depths, and potential move sediment. Inundation boundaries within the 2D model provide a proxy for high-risk areas within the system. The two stretches that were selected for this modeling effort were chosen because they are not confined by bedrock, limiting channel movement and response, are in more populated areas, are priority areas for stakeholders, and/or are areas where mitigation project work is feasible. The first stretch was the town of Grant to Town of Bailey corridor which spanned the entire length of the Rock Creek HUC-12. This reach runs parallel to US 285 along the entire model. The second stretch spanned from the Town of Pine to just past the confluence of the NFSPR with Buffalo Creek.

Inputs to the model included terrain, land use and 10-year post-fire flows from the hydrology model. A bulking model was incorporated into the flows to capture higher sediment loads post-fire. Datasets used in the hydraulic model include the Colorado Hazard Mapping and Risk MAP Portal[3] and were collected by Photo Science in 2014, Merrick and Co. in 2016, Quantum Spatial in 2020, and Sanborn Map Company Inc. in 2021. This lidar data feeds the 2D modeling and Relative Elevation Model (REM).

Terrain modifications were made to adjust for post-fire debris impacts on culverts and bridges. Culverts were assumed to be blocked by debris for this modeling effort. In these cases, roadway embankments were left in place, causing the water to back up and overtop the roadway prior to continuing downstream. Bridges with few to no piers were assumed to better maintain conveyance capacity during a post-fire flood event, so these were modeled as a continuation of the channel and unblocked. In these cases, roadway embankments were removed, allowing the water to continue downstream with little disruption. Terrain files, satellite images, and Google Earth Street view were used to identify bridges and culverts in the two stretches. In the two models, modifications to the terrain file were made to ensure bridge decks were removed near Pine (7 bridge modifications) and that the culverts were put back in near Bailey (2 culvert modifications). This was done to offer the best accuracy for the 2D modeling results in these more densely populated areas with a higher number of VARs.

Land use and Mannings' n zones were created using the terrain layer and satellite imagery. The NLCD data was too coarse to estimate zones for the hydraulic model. See Table C.7 for list of land use types and associated Mannings' n values used in the hydraulics models. The resulting land use layer for the two hydraulics models can be seen in detail on the online map.

Table C.7. Mannings' n values for 2D hydraulic models (HEC, 2024a)

Land Use	Mannings' n
Developed Mid	0.08
Road	0.04
River	0.035
Developed Low	0.06
Open Water	0.03

[3] https://coloradohazardmapping.com/

Land Use	Mannings' n
Mountain Shrub	0.05
Floodplain	0.03

A bulking model was applied to the model to incorporate increased sediment loads for post-fire flows. Bulking of flows is important to account for suspended sediment in the water column which displaces water and, if present in high enough concentrations, can increase water surface elevations. The bulking model is an option in HEC-RAS 2D as part of Unsteady Flow Data options. The model applied Newtonian assumptions with a bulk fluid volume approach (Hydraulic Engineering Center, 2024c & 2024d). The volumetric concentration of sediment was set to 40%, corresponding to a bulking factor of 1.67. Following the CWCB guidance, this volumetric concentration was chosen because it places the flow towards the upper end of the hyper-concentrated flow regime which is 40% (CWCB, 2024).

Modeling Domain

GRANT TO BAILEY

The Grant to Bailey model stretched approximately 17 miles along the main NFSPR stem and had 16 main input flow boundary areas which corresponded to all the subbasins along the modeled reach (Figure C.6).

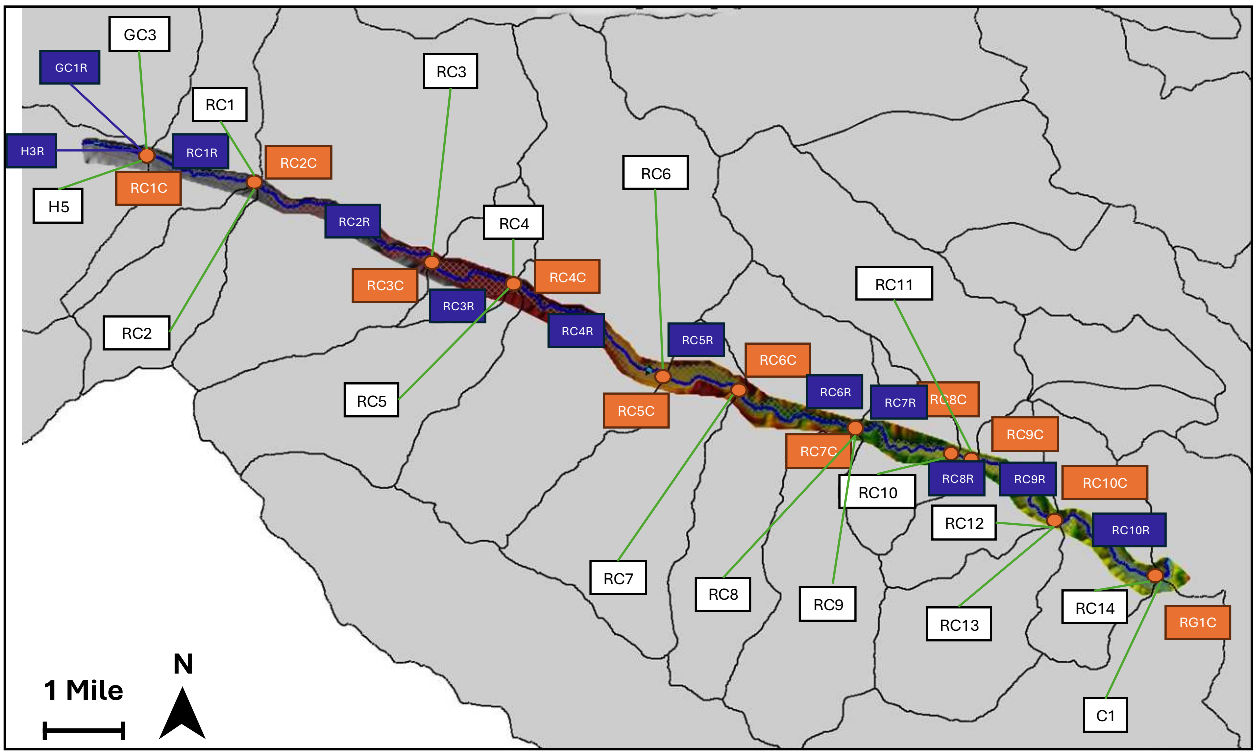


Figure C.6. Grant to Bailey hydraulic model and inflows. The blue labels show the reach elements, the white labels show basin elements are, and the orange label show junction elements.

Results for inundation extents, depth, flow velocity and stream power for the Grant to Bailey 2D flow model can be viewed in the shapefiles and modeling files within the **Supplemental Data**. A high-level summary of the results is in the **Summary of Findings by HUC-12** section.

PINE

The Pine model stretched approximately 6.5 miles along the main NFSPR stem and had 3 main input flow boundary areas, which are as numbered in Figure C.7, (1) NFSPR Inflow from junction point RG6C (2) Elk Creek and (3) Buffalo Creek.

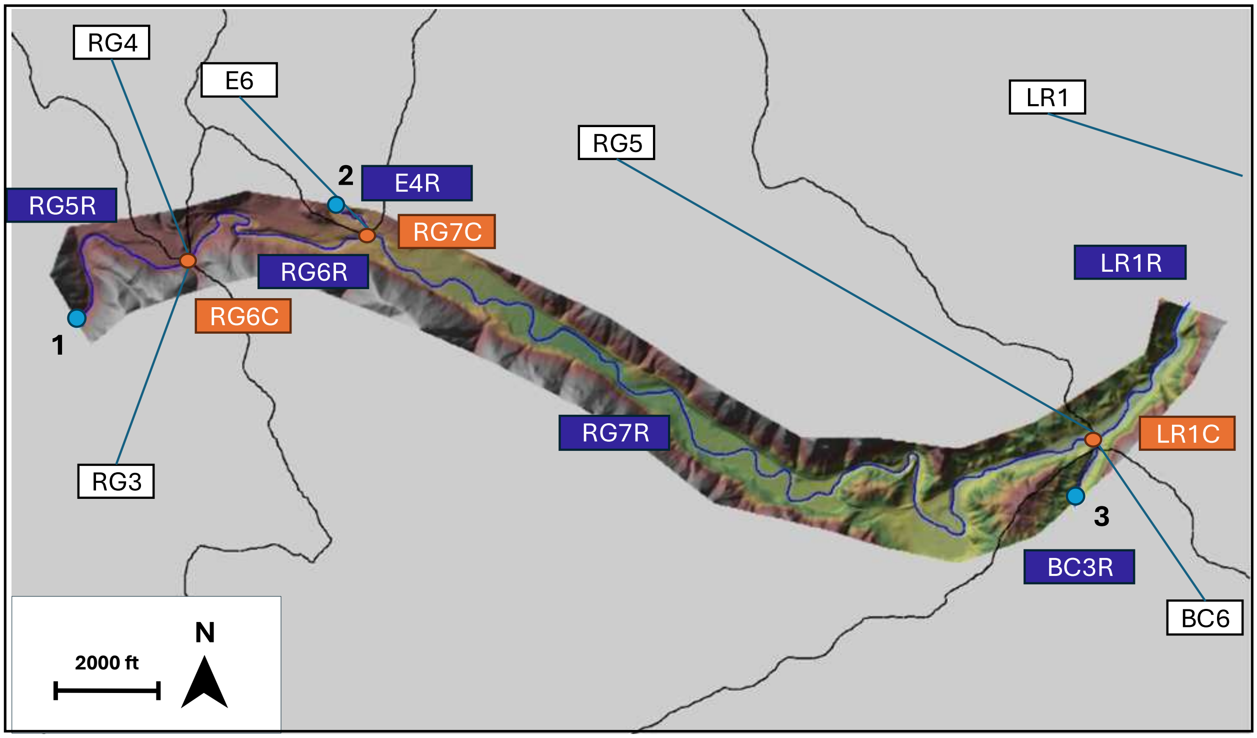


Figure C.7. Pine hydraulic model and inflows. The blue labels show the reach elements, the white labels show basin elements are, and the orange label show junction elements.

Results for inundation extents, depth, flow velocity and stream power for the Pine 2D flow model can be viewed in the shapefiles and modeling files within the **Supplemental Data**.

More information on the impact of these results, the vulnerability of the different areas within the North Fork Watershed and driving elements of risk will be discussed in the Susceptibility Analysis section.

Fluvial Hazard Zone

A Fluvial Hazard Zone (FHZ) is defined as the area a stream has occupied in recent history, may occupy in the future, or may physically influence as it stores and transports water, sediment, and debris (Blazewicz, et al 2020). Fluvial systems are dynamic, and streams naturally shift and change in response to hydrology, geology, biology, and anthropogenic interventions or influences (Blazewicz, et al 2020). This report uses the Fluvial Hazard Zone Protocol for Colorado and is not a complete FHZ but rather a preliminary map product for purposes of the WRAP planning effort. Further refinement is recommended if used in more detailed emergency hazard or conservation planning.

Channel Morphology

The channel morphology for the project area was assessed using aerial imagery and terrain data. The channel sinuosity[4] was estimated to be 1.45, indicating a meandering river. The slopes ranged from 0.0054 and .0251 ft/ft and channel confinement alternated between confined and partially confined with some unconfined areas. To better describe the geomorphic conditions in the area, the channel was divided into geomorphic reaches which are described below.

Geomorphic Reaches & Characteristics

The channel was divided into 12 geomorphic reaches based on channel confinement and morphology (Table C.8). Geomorphic reaches ranged in length from roughly 11 miles to 0.4 miles with channel widths between 25 ft and 83 ft. Channel confinement tended to rotate between partially confined and confined except for reaches 1, 2, and 10 which were classified as unconfined. Sinuosity was also measured for each reach and is calculated by dividing the channel length by the length of a straight line going from the starting to end point. This is used to measure the curvature of the reach and ranged from 1.1 (Straight) to 3.3 (Highly Meandering) among the reaches identified in the North Fork of the South Platte River. Lastly, the channel type was identified using the Montgomery and Buffington classification scheme (Montgomery and Buffington, 1997). This classification considers the channel shape, slope, bed material, confinement, and pool spacing to determine the channel type. The channel type switched between a cascade and step pool primarily due to changes in channel slope between reaches.

Table C.8. Geomorphic reaches and their characteristics.

Reach ID	Length (mi)	Average Channel Width (ft)	Sinuosity	Average Slope (%)	Confinement	Channel Type
1	11.5	30	1.1	1.86	Unconfined	Pool-Riffle
2	1.8	32	1.2	2.51	Unconfined	Pool-Riffle, with large Plane-Bed stretches and engineered steps/diversions
3	4.0	39	1.2	1.22	Partially Confined	Pool-Riffle
4	1.8	39	1.2	1.12	Partially Confined	Pool-Riffle
5	5.2	25	1.6	2.24	Partially Confined	Pool-Riffle
6	2.3	53	1.6	0.85	Partially Confined	Pool-Riffle
7	0.8	66	1.8	1.49	Confined	Forced Pool-Riffles
8	1.1	60	1.6	0.68	Partially Confined	Pool-Riffle
9	3.4	61	1.3	0.58	Partially Confined	Pool-Riffle
10	0.5	65	3.3	0.54	Unconfined	Pool-Riffle
11	10.2	66	1.9	0.96	Confined	Pool-Riffle
12	0.4	83	1.4	0.55	Partially Confined	Pool-Riffle

[4] Measure to determine if channel is straight or meandering, calculated by the length of the river/valley line length for the same start and stopping points.

Fluvial Hazard Zone Delineation

The FHZ and fluvial hazard buffer (FHB) delineations were conducted following the methods described in the Fluvial Hazard Zone Protocol for Colorado (Blazewicz et al., 2020). First, the active stream corridor (ASC) was identified using a digital elevation model derived from lidar data. The ASC is where stream channels within a stream corridor may widen or migrate. Next, channel confinement ratios were calculated to determine the FHB size (Table C.9). Channel confinement was calculated using the channel width over the valley width at four representative locations in each reach to determine the average channel confinement ratio, channel width, and valley width for each geomorphic reach. The FHB represents the area where stream channels might result in erosion and mass wasting of the hillslopes adjacent to the floodplain.

Table C.9. Geomorphic reaches and their confinement ratios with associated FHB factor and FHB size in feet.

Reach ID	Channel Confinement Ratio	Confinement Type	Average Channel Width (ft)	FHB Factor	FHB Size (ft)
1	16.9	Unconfined	30	1	30
2	12.4	Unconfined	32	2	65
3	7.3	Partially Confined	39	3	118
4	10.8	Partially Confined	39	3	189
5	7.0	Partially Confined	25	3	75
6	8.1	Partially Confined	53	3	160
7	2.5	Confined	66	4	266
8	9.7	Partially Confined	60	3	180
9	11.0	Partially Confined	61	3	184
10	15.5	Unconfined	65	1	65
11	4.1	Confined	66	4	264
12	8.2	Partially Confined	83	3	249

Relative Elevation Model

A relative elevation model (REM) was created using an inverse distance weighted tool within Global Mapper v24.1. Elevations within the lidar data was compared to the adjacent stream centerline elevation. The REM was used to identify local fluctuations in elevation and make it easier to identify fluvial patterns (Lind, 2023). This dataset is available within the **Supporting Shapefile Map** in the **Supplemental Data**.

Alluvial Fans

Alluvial Fans were identified throughout the basin and marked as triangles in the online map. There are three types of fans identified in the FHZ Protocol, persistent (green triangle), erodible (blue triangle), and ephemeral (purple triangle). The type of alluvial fan determines how the ASC is delineated around it. For example, ephemeral fans are highly erodible and therefore the ASC would be delineated along the valley margin. In contrast, persistent fans are unlikely to be eroded and therefore the ASC would be delineated along the toe of the fan. This dataset is available within the **Supporting Shapefile Map** in the **Supplemental Data**.

Final Fluvial Hazard Zone

The FHZ map can be found in the online map and contains three layers, the ASC, FHB, and alluvial fans. The map can be used to assess risk associated with fluvial processes. Areas that fall within the ASC have the highest risk as they are most likely to be impacted during flooding events or channel realignments. Areas within the FHB have the next highest risk as they may be impacted during slope failures or mass wasting events. Areas that do not fall within the ASC or FHB have the lowest risk of damage from fluvial processes within the North Fork of the South Platte River. Alluvial fans identified in this analysis are likely at risk in a post-fire environment. Fans of note included Ben Tyler Creek, McArther Creek, Buck Gulch, and Slaughterhouse Gulch.

The Fluvial Hazard Zone delineation can be viewed in the shapefiles and modeling files within the **Digital Submittal**. Discussion is also detailed for each HUC-12 Watershed in the **Summary of Findings by HUC-12** section.

Summary of Findings by HUC-12 Subwatershed

Geneva Creek

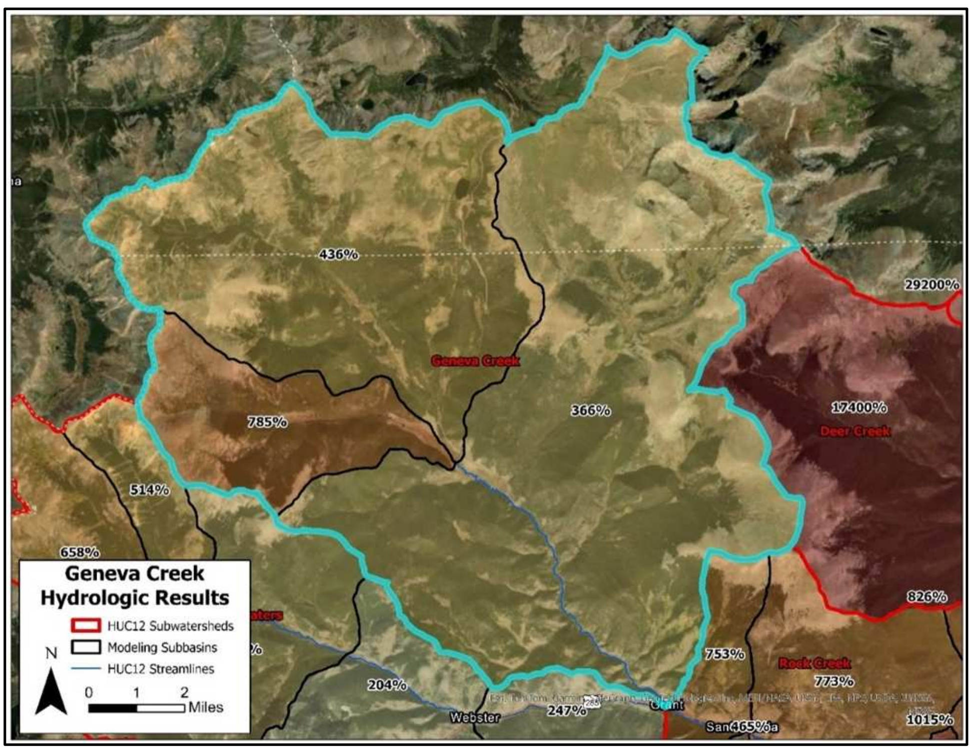


Figure C.8. Percent change in 10-year flows for each subbasin in the Geneva Creek HUC-12 Watershed.

- **Burn severity**- Limited moderate and high burn severity due to the large areas above tree line. Historically, these high alpine areas, within the permanent snow zone, have had a lower probability of burn severity due to the high altitude, which increases snow presence and soil moisture. However, this is likely to change in the future because of climate change.

- **Hydrologic Response-** The subbasins within Geneva Creek are moderately impacted by the post-fire scenario with flows increasing roughly five times throughout the basin (Figure C.8). When combined with post-fire sediment, this is likely to overwhelm culvert crossings. Within the lower canyon portion, CR-62 and all infrastructure are vulnerable to fluvial hazards, particularly erosion, widening, and channel realignment.
- **Fluvial Hazards & Function-** The upper portions of Geneva Creek appear to be resilient to post-fire impacts given the wide valley bottom geometry, which is a product of past glaciation (Madole et al, 1998). However, degradation is evident in the middle basin and may limit the stream function and resilience to post-fire.
- **Debris Flow Risk-** Overall risk increases from low to moderate when moving from the headwaters to the outlet with the moderate risk existing in the lower confined canyon.
- **Hillslope Erosion-** Hillslope erosion is most likely to impact forested tributary channels in the lower watershed, including Threemile Creek and Scott Gomer Creek.

Headwaters of North Fork

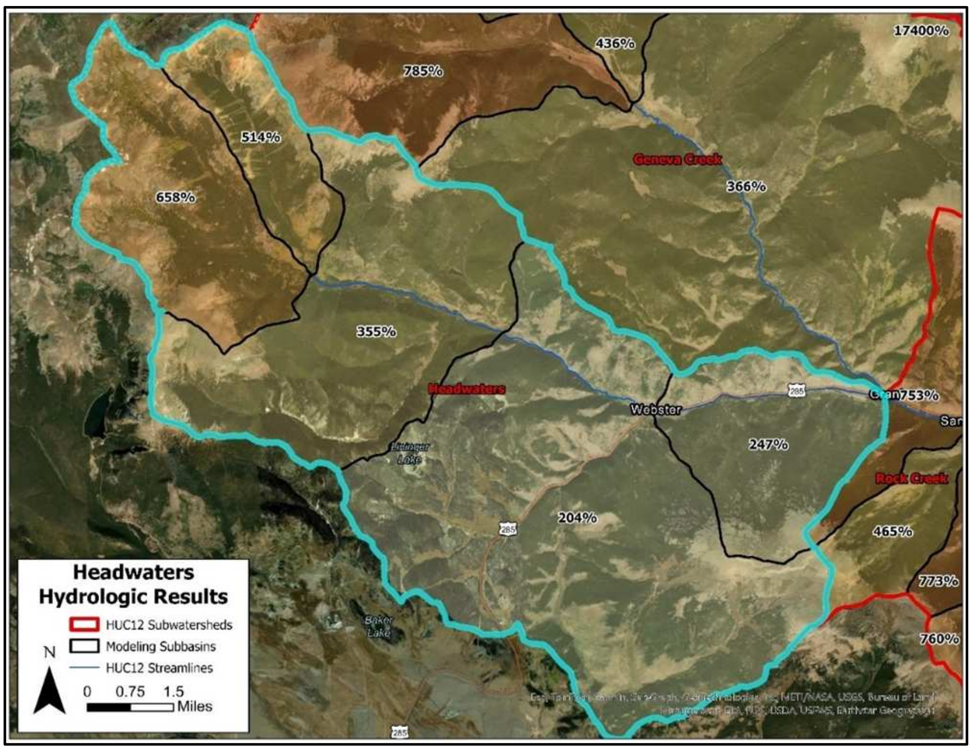


Figure C.9. Percent change in 10-year flows for each subbasin in the Headwaters of North Fork HUC-12 Watershed.

- **Burn severity-** Limited moderate and high burn severity due to the large areas above tree line. Historically, these high alpine areas, within the permanent snow zone, have had a lower probability of high burn severity due to the high altitude, which increases snow presence and soil moisture. However, this is likely to change in the future because of climate change. Burn severity increases lower in the watershed.
- **Hydrologic Response-** The subbasins within the Headwaters are moderately impacted by the post-fire scenario with flows increasing roughly four times throughout the basin (Figure C.9).

When combined with post-fire sediment, this is likely to overwhelm culvert crossings. CR-60 and all infrastructure are vulnerable to fluvial hazards, particularly erosion, widening, and channel realignment when in close proximity to the channel and particularly in the lower watershed, above HWY-285.

- **Fluvial Hazards & Function** - The upper portions of Headwaters appear to be resilient to post-fire impacts given the wide valley bottom geometry, which is a product of past glaciation (Madole et al, 1998). Beaver complexes along CR-60 appear active and will assist in attenuating post-fire sediment and flows. Downstream, along U.S. 285, the active stream corridor is confined by the highway, limiting its attenuation ability.
- **Debris Flow Risk**- Overall risk is low within the basin and the highest risk in the upper watershed is in more remote areas.
- **Hillslope Erosion**- Hillslope erosion is most likely to impact forested tributary channels including Beaver Creek, and the steep south slopes along CR-60.

Rock Creek

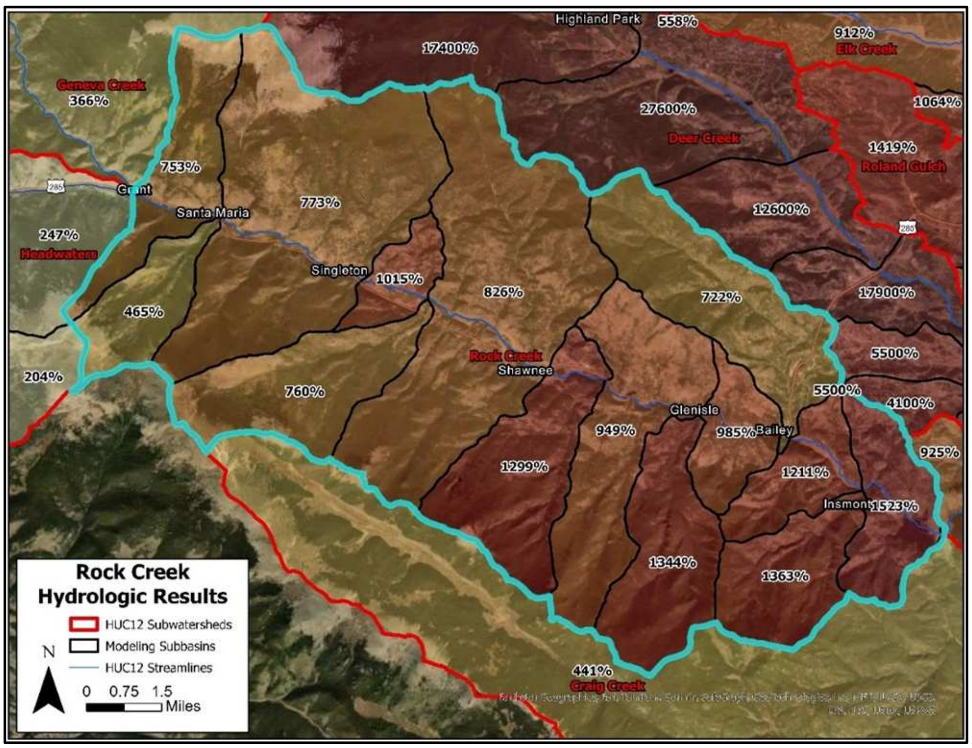


Figure C.10. Percent change in 10-year flows for each subbasin in the Rock Creek HUC-12 Watershed.

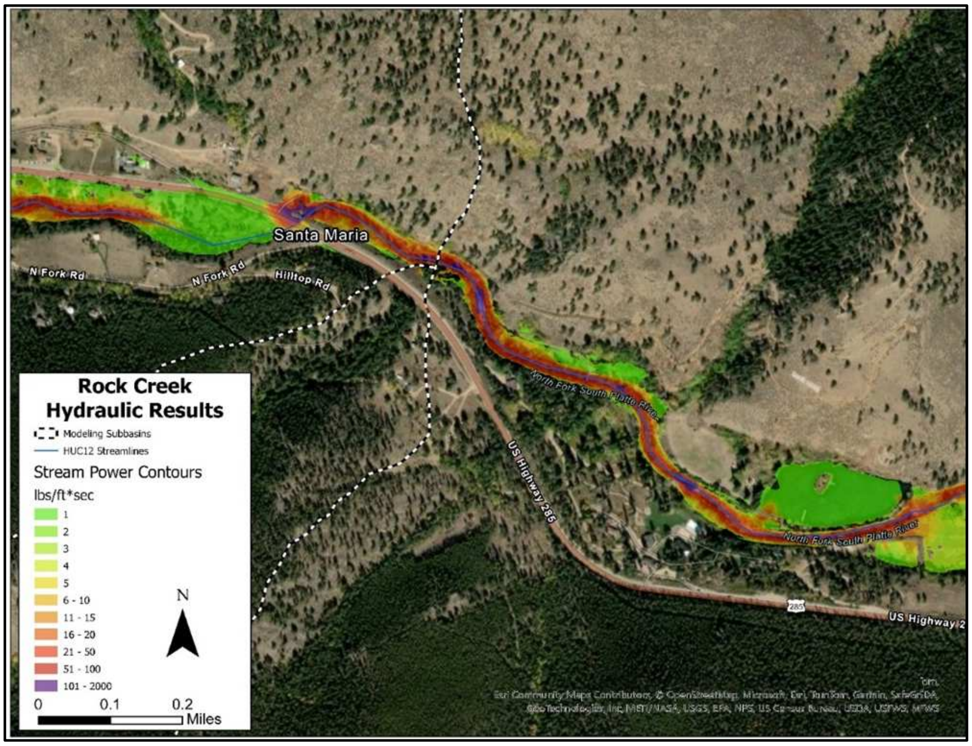


Figure C.11. 2D modeling results showing stream power in a portion of the Grant to Bailey hydraulic model. This area is indicative of other transition zones in this corridor.

- **Burn severity-** Most of these basins are characterized by 30% high severity burn, with the most heavily impacted watersheds on the south and southeast side of the basin. This high burn severity drives risk in the other hazard assessments.
- **Hydrologic Response-** The fire-impacted hydrology in this watershed is averaging roughly an order of magnitude (10x) increase (Figure C.10). While this is not uncommon for post-fire impacts, the consistency throughout the corridor is concerning. Additionally, the slopes of these watersheds (>30%) limits the ability for natural attenuation, enhancing overall risk within the corridor.
- **Hydraulic Insights-** A 2D hydraulic model was developed for this entire watershed to better understand the detailed flow dynamics within the wider NFSPR valley within the Rock Creek HUC-12 Subwatershed. The river system in this valley oscillates between highly confined reaches and more open partially confined sections (Figure C.11). Typically, these confined portions occur when the river is squeezed by an alluvial fan or when the river moves through a less erodible rock unit. The transitions into and out of these confined sections, which occurs roughly 8 times in this corridor, pose a high risk of fluvial hazards, namely erosion, through widening and downcutting, at the entrance of a confined reach and deposition at the entrance to an unconfined reach.

  The inundation boundary for the 10-year post-fire should be used as a high-risk zone in any pre- and post-fire planning. There are at least 50 residential structures in this high-risk zone within the analysis area. The Fluvial Hazard Zone delineation, outside of the inundation boundary, should be used to approximate a moderate risk zone in a post-fire setting. Below is a list of specific high-risk areas:

- The southern portions of Bailey adjacent to CR-64 are a densely populated high-risk area. The fire station is built about the floodplain, likely on fill, and forces the river to constrict setting up migration even further south.
- In Grant, many of the structures south of HWY-285 are in the floodplain and at risk from erosional hazards from river widening during large events. Combined with the risk from Geneva Creek outflow and alluvial fan complex, this area is likely to be highly dynamic and a focal point of risk following a fire.
- Floodplain ponds are likely to be recaptured during large post-fire flooding events, potentially falling victim to local channel realignment, overtopping, or filling. About 15 exist within this corridor.
- At the intersection of Mooredale Rd and HWY-285, the channel has been realigned, creating a large meander cutoff that is now a pond. It is likely that this was done to remove a crossing under HWY-285, however the current channel alignment is through an artificial channel which is too narrow to contain large flood flows. HWY-285, along with the upstream and downstream communities are at increased risk to fluvial hazards because of this channel modification.

- **Fluvial Hazards & Function** – Tributary channels will be extremely vulnerable to post-fire flooding, leading to both direct and indirect impacts to the valley. HWY-285 will be impacted directly whenever it is between a tributary and the North Fork. Floods and debris flows will also likely increase deposition within the North Fork which will impact water quality and lateral stability of the stream. Offline but adjacent ponds will be vulnerable to channel realignments as the river fills and reclaims these areas.
- **Debris Flow Risk-** This basin is at the highest risk of post-fire debris flows due to the steep topography and high burn severity. Impacts to communities on alluvial fans will be pronounced and drive catastrophic in the study area. Specific tributaries at risk according to the debris flow modeling include Crow Gulch, Corbin Gulch, Quiner Gulch, Payne Gulch, Brookside Gulch, and McArthur Gulch. The lower portion of Crow Gulch parallels HWY-285 and flows through Bailey threatening this community. Payne and Brookside Gulch flow through several communities and pose a direct threat to private property and structure in the area. Additional basins that could pose a risk to adjacent infrastructure include Ben Tyler Gulch, Bill Tyler Gulch, Foster Gulch, and Shutetown Gulch.
- **Hillslope Erosion-** Hillslope erosion mirrors the high severity burn areas and debris flow risk, which are concentrated in the basins to the south of HWY-285. The high yield areas are concentrated in Roadless and Wilderness areas which will make direct treatment challenging.

Criag Creek

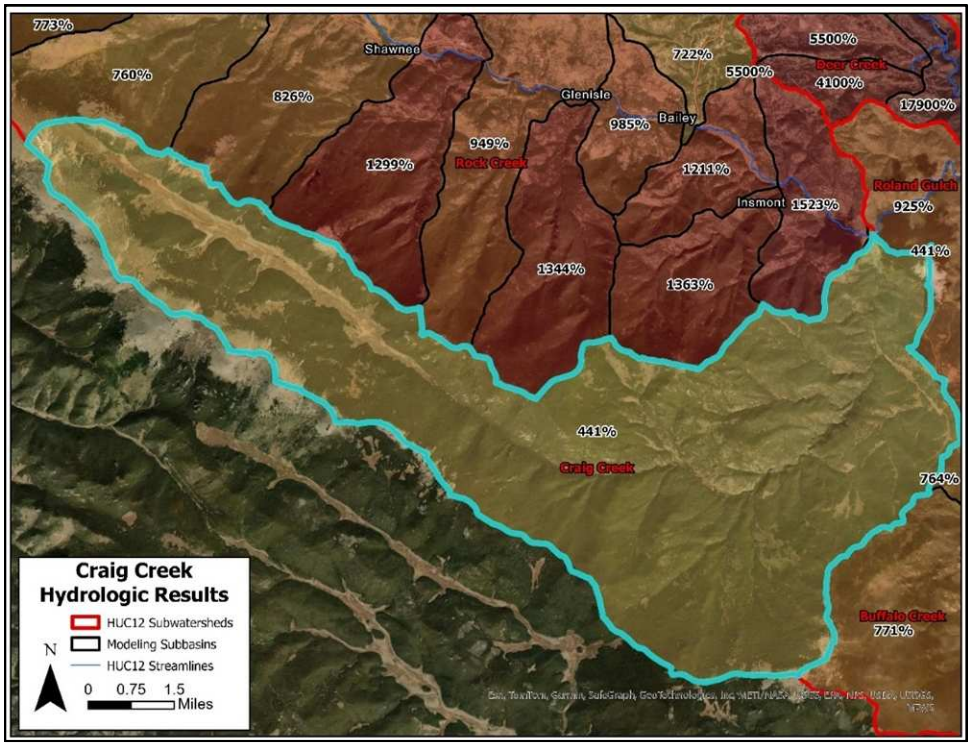


Figure C.12. Percent change in 10-year flows for each subbasin in the Craig Creek HUC-12 Watershed.

- **Burn severity-** This heavily forested watershed is predicted to experience 75% moderate and high severity burn with the concentration of high severity on the north facing slopes to the south.
- **Hydrologic Response-** Because of the remoteness and vast Wilderness designation of this basin, it was not subdivided to add resolution. The subbasins within Craig Creek are moderately impacted by the post-fire scenario with flows increasing roughly four times throughout the basin (Figure C.12). The basin is defined by an unconfined alpine meadow in the upper portion, a confined canyon in the middle, and a partially confined valley just upstream of the confluence with the North Fork. Hydrologic change will be difficult to combat in the non-wilderness areas in the lower watershed and will likely need to focus on flood protection.
- **Fluvial Hazards & Function** – The upper watershed flows through a 6-mile-long riparian corridor that is home to several beaver complexes in the upper half. The lower half appears more channelized and may not support beaver currently, dampening the floodplain connectivity and post-fire mitigation potential. Steep tributary channels in the middle canyon portion do not appear to support depositional environments that are key to disrupting longitudinal connectivity and downstream sediment transport in a post-fire landscape (Wohl et al, 2022). This reach is a source and transport segment of the stream and mitigation should not be focused on reversing these processes. A deposition meadow may exist at the intersection of CR-858 and CR-827, and, if so, this could be a key project site. The lower alluvial fan along CR-68 is also depositional but appears to house some structures.
- **Debris Flow Risk-** Overall is low due to the lack of infrastructure, however, several small drainages in the middle canyon and the lower alluvial fan pose high risk of a debris flow event. This event could create downstream water quality issues that would be difficult to mitigate before the confluence with the North Fork.

- **Hillslope Erosion-** High yield areas include the hillslopes adjacent to the lower meadow in the upper watershed and the southern tributaries in the middle canyon. Treatment at the source will be challenging due to Wilderness areas, making stream enhancement activities downstream of the main sources vital.

Buffalo Creek

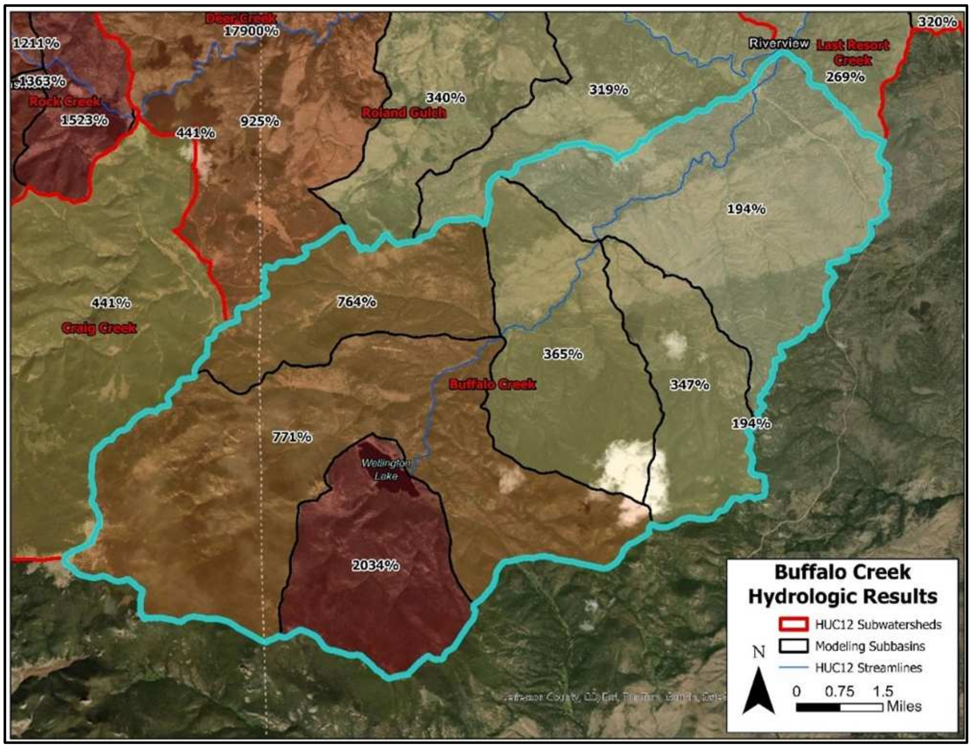


Figure C.13. Percent change in 10-year flows for each subbasin in the Buffalo Creek HUC-12 Watershed.

- **Burn severity-** Because of a recent fire in the lower watershed, the burn severity is predicted to be limited and muted. This will continue until fuels have fully recovered on the landscape. The upper watershed, which has not recently burned, is shown to experience moderate to high overall burn severity relative to the other HUC-12 subwatersheds. In particular, the Wellington Lake contributing area is predicted to suffer a very serve burn.
- **Hydrologic Response-** The contributing area of Wellington Lake and Freeman Creek in the upper watershed are characterized by higher slopes which will enhance post-fire impacts (Figure C.13). However, due to the flow length to the North Fork, it is also likely that the most severe impacts are attenuated in the watershed prior to the confluence, reducing the intensity. Wellington Lake is likely to serve as a large sink for post-fire flows and sediment, disrupting the transport downstream, but this will focus those impact on this resource.
- **Fluvial Hazards & Function** – Buffalo Creek watershed is fairly homogenous through the length of the basin. The stream and tributaries vary from confined to partially confined through the watershed with a scattering of depositional meadows. These areas could be enhanced to provide more sediment and flow attenuation. Some of the creeks include Rolling Creek, Freeman Creek, inflows to Wellington Lake, South Fork Buffalo Creek, upper portions of Redskin Creek, Morrison Creek, and Buffalo Creek just upstream of the Town. Many of the roads share corridors with the fluvial system, exposing them to increased risk during flood events. The Redskin Creek

Rd should be improved when possible to provide additional and more terrestrial access to the watershed.

- **Debris Flow Risk-** Overall debris flow risk in the basin is moderate to high with the focus of risk in the upper watershed above the Redskin Creek and South Fork Buffalo Creek confluence. The upper 1/5th of the basin is designated Roadless and Wilderness limiting risk to VARs. The high erodibility of the sediment within the basin elevates the risk of indirect impacts to the downstream portion despite the lower probability of debris flows in that portion of the basin.
- **Hillslope Erosion-** High yield areas are limited to the upper watershed within the Roadless and Wilderness areas. Because of the location and erodibility of the source material, mitigation at the source will be limited and impractical.

Deer Creek

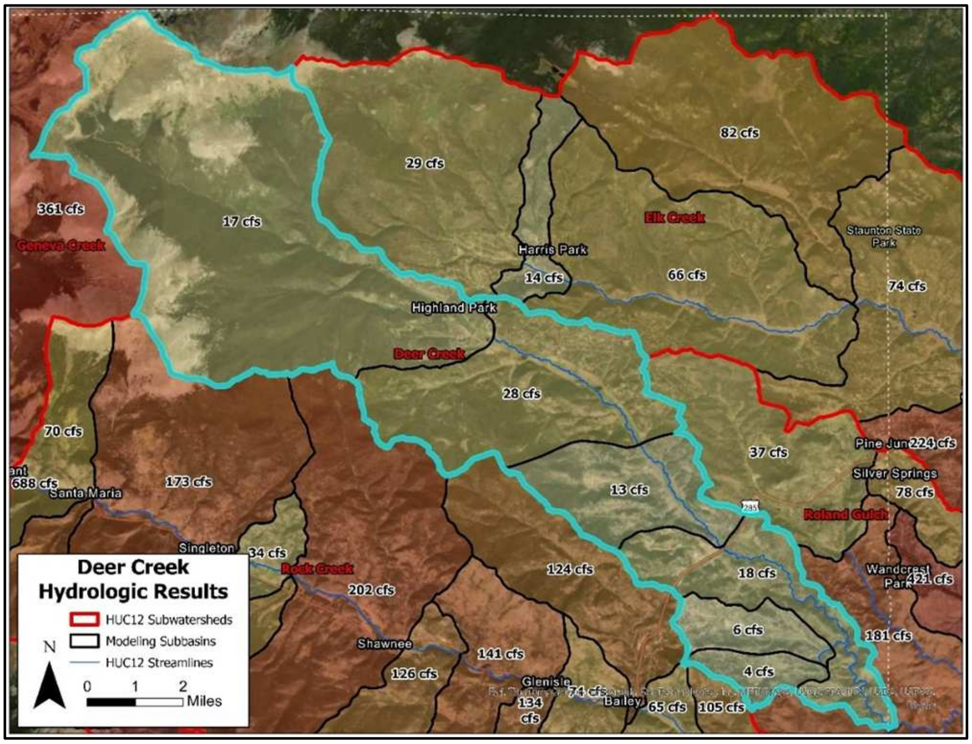


Figure C.14. Absolute change in 10-year flows for each subbasin in the Deer Creek HUC-12 Watershed.

- **Burn severity-** This basin is generally characterized by limited predicted high severity burn (<20%), but expansive moderate severity burn areas (>50%). The basins high severity burn areas are limit to the dense forests in the upper headwaters as well as the lower canyon basin. It is apparent that mechanical thinning operations have been extensive surround the population centers and this is reflected in the fire behavior predictions. Direct wildfire impacts will likely drive risk in this watershed because of the population density on the hills in this basin.
- **Hydrologic Response-** Pre-burn modeling shows very limited excess runoff from this basin due to the low basin slopes, unconfined valley, and low curve number estimates. This ability allows the watershed to naturally attenuate and store flood flows. Figure C.14 shows an absolute increase in flow rather than the percent change because a small increase from 0 is shown as a massive percent increase. Generally, any increase in flow has the potential to unravel the natural resiliency

of the watershed, and with compound agricultural modifications in the main stem valley, the areas are vulnerable to post-fire degradation that may exacerbate post-fire impacts.

- **Fluvial Hazards & Function** – The large valley along Deer Creek Road is likely a historic beaver meadow complex that has since been modified and altered for agricultural purposes. Some beaver complexes are still visible adjacent to the Saddlestring Rd crossing, and these should be protected to preserve the population. Below the Rising Sun Rd Crossings, the degradation to the valley is dramatic. Irrigation diversions, offline ponds, and conversion to a single threaded channel will limit the function and post-fire resiliency of these areas. Multiple crossings (~14) in this valley are at risk during post-fire floods. The contraction required to flow through the culverts limits the connectivity and riparian extent of the valley.
- The lower ¼ of the basin flows through a steep canyon that will transport flows and sediment with little capacity for storage or deposition. Mitigation in this area will be limited. Infrastructure in this stretch is limited aside from a community adjacent to CR-72 crossing. This will be at high risk in any post-fire flood events due to the rapid change in valley width.
- **Debris Flow Risk-** Debris flow risk in this basin is low with the exception of the lower most canyon reach. This reach could have pronounced and direct impacts to the North Fork due to its proximity, however the confined reach likely has a low sensitivity to fluvial change other than conveying sediment to downstream VARs.
- **Hillslope Erosion-** High yield areas are limited to the upper watershed within the Roadless and Wilderness areas. Hillslope erosion from these areas is likely to be attenuated in the lower valley reach, provided that the on-going degradation to the stream system is rehabilitated or limited moving forward.

Elk Creek

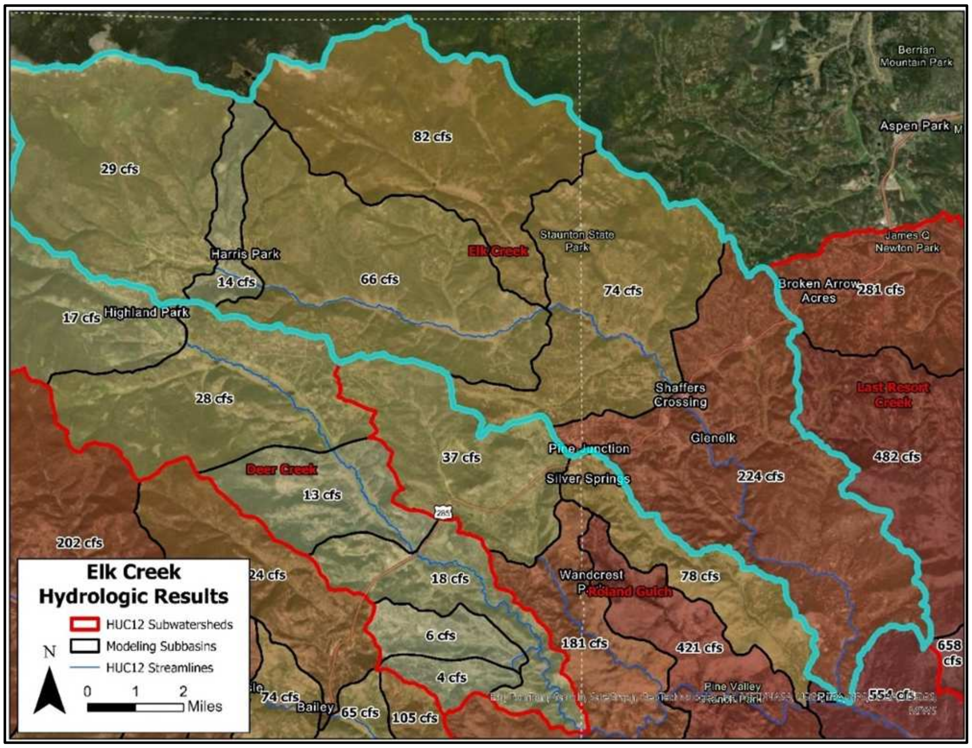


Figure C.15. Absolute change in 10-year flows for each subbasin in the Elk Creek HUC-12 Watershed.

- **Burn severity-** This basin is generally characterized by limited predicted high severity burn (<20%), but expansive moderate severity burn areas (~50%). The basin's high severity burn areas are limited to the dense forests adjacent to the watershed divide. It is apparent that mechanical thinning operations have been extensive surround the population centers and this is reflected in the fire behavior predictions. Direct wildfire impacts will likely drive risk in this watershed because of the population density on the hills in this basin.
- **Hydrologic Response-** Pre-burn modeling shows very limited excess runoff from this basin due to the low basin slopes, unconfined valley, and low curve number estimates. This ability allows the watershed to naturally attenuate and store flood flows. Figure C.15 shows an absolute increase in flow rather than the percent change because a small increase from 0 is shown as a massive percent increase. Generally, any increase in flow has the potential to unravel the natural resiliency of the watershed, and with compound agricultural modifications in the main stem valley, the areas are vulnerable to post-fire degradation that may exacerbate post-fire impacts.
- **Fluvial Hazards & Function** – Although less continuous than Deer Creek, large depositional meadows existing in the upper half of Elk Creek and the middle of North Elk Creek. No beaver complexes are visible in the basin despite some potentially viable areas along Forest Drive within Elk Creek and Ridge Rd along North Elk Creek, the degradation to the valley is dramatic. Irrigation diversions, offline ponds, and conversion to a single threaded channel will limit the function and post-fire resiliency of these areas. Multiple crossings (~4) in the valley are at risk during post-fire floods. The contraction required to flow through the culverts limits the connectivity and riparian extent of the valley.

The lower half of the basin, below Glenelk and along S. Elk Creek Rd, flows through a steep canyon that will transport flows and sediment with little capacity for storage or deposition. Mitigation in this area will be limited. This canyon is populated with many homes and private infrastructure that is at high risk to fluvial hazards. Indian Springs Village will be at high risk in any post-fire flood events due to the rapid change in valley width and density of structures and crossings.

- **Debris Flow Risk-** Debris flow risk in this basin is low to moderate except for the lower canyon reach, mentioned in the fluvial hazards. This reach is characterized by tributary channels all very prone to debris flows in the event of a high severity burn. Indian Springs Village and Sphinx Park are at acute risk in a post-fire environment.
- **Hillslope Erosion-** High yield areas are limited to the dense forests adjacent to the watershed divide. Hillslope erosion from these areas may attenuate in the middle valleys, provided that the on-going degradation to the stream system is rehabilitated or limited moving forward. The lower canyon reach has some areas of high yield, but this risk is much less pronounced than others in the reach.

Roland Gluch

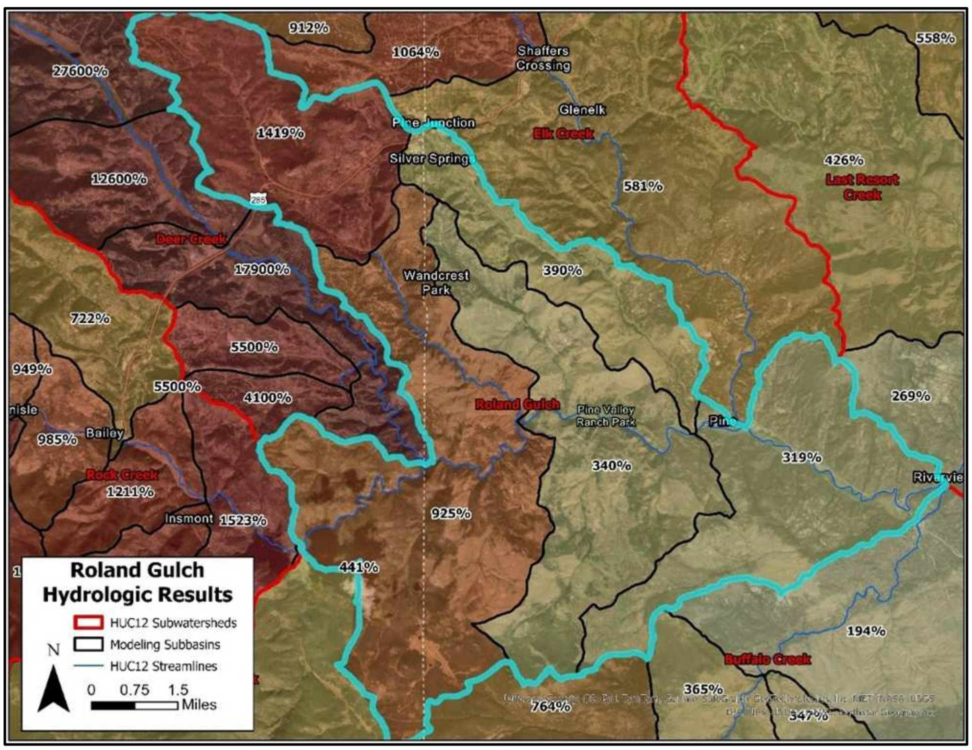


Figure C.16. Percent change in 10-year flows for each subbasin in the Roland Gulch HUC-12 Watershed.

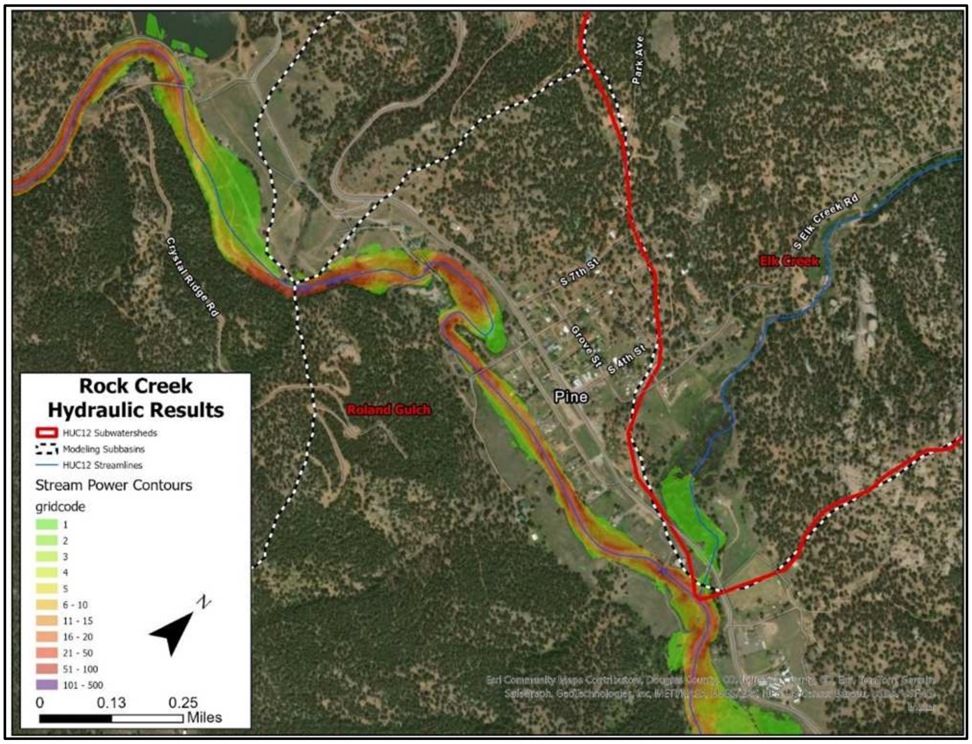


Figure C.17. 2D modeling results showing stream power in a portion of the Pine hydraulic model.

- **Burn severity**- The High Meadow Fire (2000) in the lower watershed has reduced the mature forest fuels, limiting the burn severity in the burn scar. This will continue until fuels have fully recovered on the landscape. The upper watershed and Pine Gulch Watershed, which has not recently or extensively burned, is shown to experience moderate to high overall burn severity relative to the other HUC-12 subwatersheds. In particular, the portions of Pine adjacent to the HWY-285 are predicted to severely burn which will increase post-fire hazards discuss below.
- **Hydrologic Response**- Figure C.16 shows the overall increase in post fire flows to be 5 times across the basin, but with high variability between the regions impacted by the High Meadow Fire and those that were not. The contributing area of Pine Gulch in the upper watershed is characterized by lower slopes which may dampen post-fire impacts. Upstream of Pine, the basin is characterized by small tributaries feeding the NFSPR directly. Tributaries not impacted by past fires should be considered high risk due to the proximity to the mainstem.
- **Hydraulic Insights**- A 2D hydraulic model was developed for the Pine Valley area to understand the detailed flow dynamics within the wider NFSPR valley around a more unconfined and populated community. At the top of the model, the river exits a confined canyon and enters the Pine Valley (Figure C.17). Two large tributaries, Pine Gulch and Elk Creek, confluence in this valley and will likely add to the fluvial risk in the area.

  The inundation boundary for the 10-year post-fire should be used as a high-risk zone in any pre- and post-fire planning. There are at least 50 residential structures in this high-risk zone within the analysis area. The Fluvial Hazard Zone delineation, outside of the inundation boundary, should be used to approximate a moderate risk zone in a post-fire setting. Below is a list of specific high-risk areas:

  - Just upstream of the Central Ridge Rd crossing, a pond has been built on the outside of the meander bend. This pond embankment separating the pond and river is likely to fail during a large post-fire event. The crossing here is also at risk and is the only access point for the Crystal Ridge Community (~2 houses).

  - The alluvial fan at Pine Gulch constricts the NFSPR channel to the south. This constriction is likely to backwater flows upstream while increasing erosion in the meander bend. It’s possible that flood events within Pine Gulch increase the local instability of the NFSPR.
  - The Rio Vista Rd crossing within the complex meander just upstream of the Jefferson St. crossing is also at acute risk of compounding flooding issues or failing. This could create cascading impacts for the surrounding infrastructure.
  - Downstream of the Jefferson St. crossing, a series of 14 properties on the north side of the NFPSR are within the floodplain and likely to experience issues during a large post-fire event. Elk Creek also confluences within this stretch which may increase the complex hydraulics and fluvial hazards in the area.
  - Downstream of the Elk Creek Confluence along CR-126, the stream enters a wide valley of agricultural lands with limited infrastructure. Opportunities to enhance the attenuation and storage of flows and sediment in this reach should be explored.

- **Fluvial Hazards & Function** – Roland Gulch watershed primarily drained directly by the NFSPR. The three main tributaries are Pine Gulch, Millers Gulch, and Buck Gulch. Each of these is confined, offering limited opportunity for enhancement in the upper watershed. In the upper watershed, a small tributary along CR-70 does host some depositional reaches that may offer some enhancement opportunities. Along the mainstem, Pine Valley Ranch Park may offer opportunities to attenuate post-fire sediment and flow, however the multiple uses at the site will be challenging.

  Any roads in these confined reaches are at risk to fluvial hazards, however the smaller watershed size limits the overall stream power and flood potential. CR-126 is at pronounced fluvial risk due to proximity to the channel in a confined reach.

- **Debris Flow Risk-** Debris flow risk is high in tributary basins that have intact mature forest. In particular, the topographic valley downstream of Pine

- **Hillslope Erosion-** High yield areas follow high severity burn predictions. Hillslope erosion is likely to directly impact larger stream systems due to the system’s limited resiliency.

Last Resort Creek

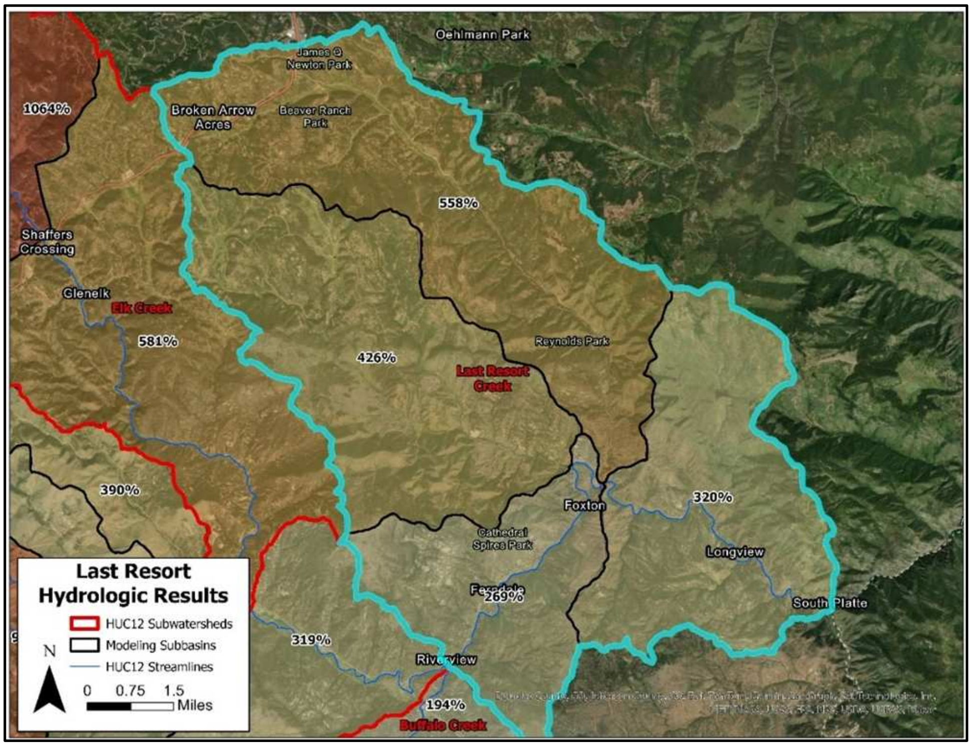


Figure C.18. Percent change in 10-year flows for each subbasin in the Last Resort Creek HUC-12 Watershed.

- **Burn severity**- This basin is generally characterized by some high severity burn (~20%), but expansive moderate severity burn areas (~60%). Predicted burn is scattered evenly and likely reduced based on limited dense forest stands and previous burn scars.
- **Hydrologic Response**- Post-fire flow increases are moderate and average four times, likely due to the limited high severity burn areas (Figure C.18). However, the landscape offers little resilience to post-fire impacts due to the confined nature of the watershed and erodible soils. The short flow lengths of tributary channels also increase the risk to the North Fork and reduces the ability of smaller channels to attenuate debris, sediment, and flood flows.
- **Fluvial Hazards & Function** – The two largest tributary channels, Last Resort Creek and Kennedy Gulch are confined in the granite canyons. There are almost no depositional zones within these systems and no evidence of active beaver habitat or recent activity. In less confined pockets, the riparian corridor is limited due to terracing and roadway encroachments. Any roads in these confined reaches are at risk to fluvial hazards, however the smaller watershed size limits the overall stream power and flood potential. CR-69 is at pronounced fluvial risk due to proximity to the channel in a confined reach.
- **Debris Flow Risk**- Debris flow risk is the highest in the study area due to the steep confined nature of the tributary channels, erodibility of the soils, and intense rainfall characteristics. Impacts to the North Fork would be direct and drastic because it is the main drainage in the HUC-12. Potential mitigation of this risk is limited.
- **Hillslope Erosion**- High yield areas follow high severity burn predictions. Hillslope erosion is likely to directly impact larger stream systems due to the system's limited resiliency.

References

Aquaveo. (2017). *WMS:SCS Lag Time Equation—XMS Wiki*. https://www.xmswiki.com/wiki/WMS:SCS_Lag_Time_Equation

Blazewicz, M., Jagt, K., and Sholtes, J. 2020. "Colorado Fluvial Hazard Zone Delineation Protocol Version 1.0". Colorado Water Conservation Board.

Bartles, M., Brauer, T., Ho, D., Fleming, M., Karlovits, G., Pak, J., Van, N., & Willis, J., 2022. *Hydrologic Modeling System HEC-HMS User's Manual v4.11*. Hydraulic Engineering Center. https://www.hec.usace.army.mil/confluence/hmsdocs/hmsum/4.11/report-documentation-page

Chapman, S.S., Griffith, G.E., Omernik, J.M., Price, A.B., Freeouf, J., and Schrupp, D.L., 2006, Ecoregions of Colorado (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey.

CWCB and DWR, 2024. CDSS Data & Tools: Stations. Colorado's Decision Support Systems. Retrieved June 27, 2024, from https://dwr.state.co.us/Tools/Home

CWCB. (2024). *Colorado Hazard Mapping & Risk MAP Portal*. https://coloradohazardmapping.com/

CWCB. (2024). *Guidance for pre- and post-fire hydrologic evaluations for wildfire ready action plans.* https://static1.squarespace.com/static/6192d196413fee2066d13575/t/66ce6648d60ee72ed39132f5/1724802643673/WRW+Hydrologic+Modeling+Fact+Sheet_v24.01.pdf

Drummond, Mark A. "Southern Rockies ecoregion." Status and trends of land change in the western United States (1973): 95-103.

Higginson, B. and Jarnecke, J., 2007. Salt Creek BAER-2007 Burned Area Emergency Response. Provo, UT: Uinta National Forest; Hydrology Specialist Report. 11 p.

Hydraulic Engineering Center, 2024a. HEC-RAS 2D User's Manual Version 6.5. https://www.hec.usace.army.mil/confluence/rasdocs/r2dum/latest

Hydraulic Engineering Center, 2022. HEC-HMS (4.11) [Computer software]. U.S. Army Corps of Engineers.

Hydraulic Engineering Center, 2024b. HEC-RAS (6.5) [Computer software]. U.S. Army Corps of Engineers.

Hydraulic Engineering Center, 2024c. Non-Newtonian Technical Reference Manual. https://www.hec.usace.army.mil/confluence/rasdocs/rasmuddebris/non-newtonian-technical-reference-manual/bulking-factor

Hydraulic Engineering Center, 2024d. Non-Newtonian User's Manual. https://www.hec.usace.army.mil/confluence/rasdocs/rasmuddebris

LandScope America, 2024. Southern Rocky Mountains Ecoregion. http://www.landscope.org/explore/natural_geographies/ecoregions/Southern%20Rocky%20Mountains/#:~:text=The%20climate%20is%20a%20temperate%20semiarid%20steppe%20regime,ecoregion%2C%20but%20reaching%2050%C2%B0F%20in%20the%20lower%20valleys.

Lind, A., 2023. "Relative Elevation Models in Global Maper." Blue Marble Geographics. Relative Elevation Models in Global Mapper - Blue Marble Geographics.

Madole, R., VanSistine, P., Michael, J., (1998). *Pleistocene Glaciation in the Upper Platte River Drainage Basins, Colorado*. Geological Investigations Series I-2644. United States Geological Survey.

Montgomery, David R., and John M. Buffington. "Channel-reach morphology in mountain drainage basins." *Geological Society of America Bulletin* 109.5 (1997): 596-611. https://doi.org/10.1130/0016-7606(1997)109<0596:CRMIMD>2.3.CO;2

Thomas C. Pierson. (2005). *Distinguishing between debris flows and floods from field evidence in small watersheds* (Fact Sheet 2004–3142; Fact Sheet). USGS.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [2024].

USGS, 2023. PeakFQ (7.4.1) [Computer software]. USGS.

USGS, 1979. Geologic Map of Colorado, https://ngmdb.usgs.gov/Prodesc/proddesc_68589.htm.

Vaill, J. E. 2000. *Analysis of the magnitude and frequency of floods in Colorado* (Water-Resources Investigations Report 99–4190). USGS. https://doi.org/10.3133/wri994190

Wohl, E., Marshall, A., Scamardo, J., White, D., and Morrison, R., (2022). *Biogeomorphic influences on river corridor resilience to wildfire disturbances in a mountain stream of the Southern Rockies, USA,* Science of The Total Environment. Volume 820. https://doi.org/10.1016/j.scitotenv.2022.153321.

Yochum, S.E., Wible, T., Ghanbari, M., and Millonig, S. (2024). Flood Potential Portal: User Manual. One Water Solutions Institute and the National Stream and Aquatic Ecology Center, Colorado State University and the U.S. Forest Service, Version 2.0.

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APPENDIX D

Susceptibility Analysis

Susceptibility Model Methodology

This section provides an outline of the overall steps that were taken to develop the susceptibility model for the North Fork WRAP.

The Colorado Wildfire Ready Watersheds Mapping and Susceptibility fact sheet was used as a reference for the model. The document can be found here: [CWCB Mapping and Susceptibility Fact Sheet]

Subwatershed Delineation

1. The first step was to identify the area that would be used for the model. Watershed boundaries were based on existing NHD HUC delineations and further divided based on the number, density, and importance of VARs. HUCs with a higher occurrence of VARs were subdivided so susceptibility rankings were more accurate for each area. Less populated HUCs, such as in the western portion of the planning area, were left as is. The figure below shows the adjusted watershed boundaries and their associated IDs.

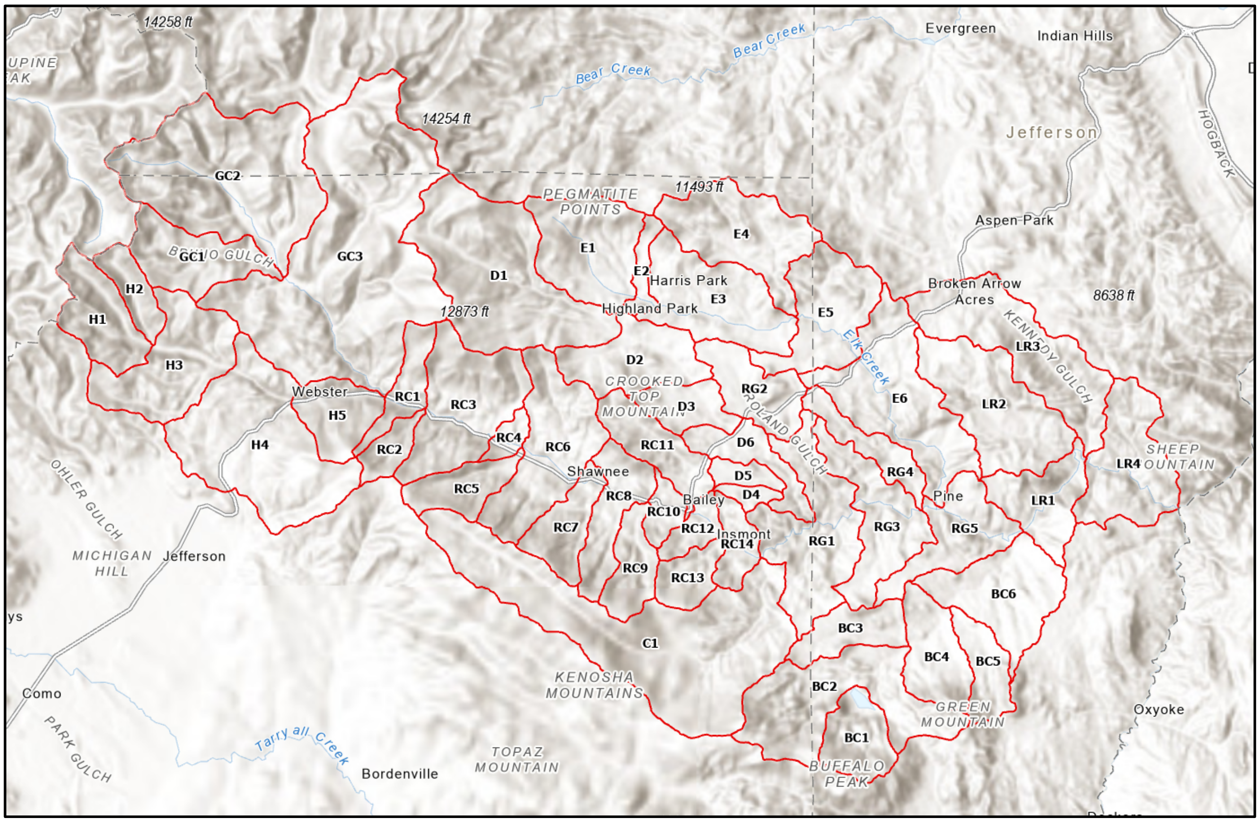

Figure D.1. Overview of delineated subwatersheds

2. The next step of the analysis was adding post-fire hazard baseline data as a basemap to the planning area. Four hazards were applied to the planning area including:
    a. Hydrologic Change
    b. Sediment Yield Change
    c. Debris Flow
    d. Fluvial Geomorphic Hazards (FGH)

This data was provided to us following completion of the hazard analysis phase (Section 4). Flooding was also added to the map originally, using FEMA floodplain mapping data. However, this was later removed as it overlapped much of the FGH data and “double counted” points of hazard-VAR intersect. The FGH data that was used resulted from the 2D HEC-RAS modeling resulting in higher resolution results that are more applicable to the project.

3. After the hazards were identified we selected the specific values-at-risk (VARs) assets to analyze. We used the framework developed by the Colorado Wildfire Ready Watersheds plan as a reference, however later decided to remove and add certain VARs as suggested by the core team.

Framework Risk Matrix		Values-at-Risk																	
		Water Infrastructure								Life and Property									
		Reservoirs (Total Storage Volume)	Built Flowlines (Total Length)	Decreed Water (Total Flow Rate)	Source Water	Aquatic Species Habitat	Natural Conveyance	Water Infrastructure (Structures, Diversions, etc)	Wetland and Riparian Areas	Buildings	Historic Buildings	Critical Infrastructure	Recreational Areas	Energy Infrastructure	Crossings	Roads	Trails	Abandoned Mining Lands	Hazardous Materials
Post-Fire Hazards	Hydrologic Change (Watershed Level Intersection)	✓	x	x	✓	✓	✓	✓	✓	x	x	x	x	✓	✓	x	x	x	x
	Flooding (Direct Intersection)	x	x	x	x	x	x	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Sediment Yield Change (Watershed Level Intersection)	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	✓	✓	x	x	✓	x
	Debris Flow (Watershed Level Intersection)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x
	Fluvial Geomorphic Hazards (Direct Intersection)	✓	✓	x	x	x	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	x	✓

Figure D.2. Framework Risk Matrix example. The final risk matrix that was used in the susceptibility analysis is shown in section 5.2 and below in figure D.3

The final list of VARs used in the susceptibility analysis include:

a. Reservoirs
b. Built Flowlines
c. Decreed Water
d. Source Water
e. Aquatic Species Habitat
f. Natural Conveyance
g. Water Infrastructure
h. Building Footprints
i. Historic Buildings
j. Critical Infrastructure
k. Recreational Areas
l. Energy Infrastructure
m. Crossings
n. Roads
o. Trials
p. Abandoned Mining Lands
q. Hazardous Materials

Some of the VAR layers were obtained from publicly available databases and others were provided by Core Team and stakeholders. Please refer to the data gap analysis in Appendix B for more detailed information. Note the red outline in the screenshot above, these are hazards/VARs that we initially used but then removed from the model. This include wetlands and riparian areas which skewed the results of the analysis by indicating there was a high degree of intersect, and therefor susceptibility in remote watersheds with few other VARs present.

4. Once all of our hazard and VAR data was added, the next step was to assign ranks to both. We used the workflow outlined by the Colorado Wildfire Ready Watersheds plan (linked in a previous step) as reference. Hazards and VARs were compiled for every sub-watershed in the project area and ranked accordingly. Below is an overview of how we ranked everything.

   a. Hazards

      – **Hydrologic Change** – values were ranked from 1 – 10.
      – **Sediment Yield Change** – identified the sum per watershed and normalized based on watershed size. Ranked from 1 – 10.

- **Debris Flow** – Volume and probability were identified per watershed, then combined and ranked from 1 – 10.
- **Fluvial Geomorphic Hazard** – Not Ranked. Instead, we identified VARs that fell within the FGH zone and ranked them instead (separately from the ranks assigned to them per watershed. For example, if a crossing fell within an FGH zone, we identified the total number of crossings that fell within the watershed AND the total number of crossings that fell within the FGZ and ranked both totals separately).

b. <u>VARs</u>

- **Reservoirs** – Total acre feet per watershed were identified and ranked from 1 – 10.
- **Built Flow Lines** – Total distance (feet) per watershed were identified and ranked form 1 – 10.
- **Decreed Water** – Total flow rate (cfs) was identified by watershed and ranked from 1 – 10.
- **Source Water** – Source water values were noted and ranked from 1 – 10.
- **Aquatic Species Habitat** – Total acres were noted per watershed and ranked from 1 – 10.
- **Natural Conveyance** – Total distance in feet were identified per watershed and ranked from 1 – 10.
- **Water Infrastructure** – Total number of water infrastructure were identified per watershed and ranked from 1 – 10.
- **Buildings** – Total number of buildings were identified per watershed and ranked from 1 – 10.
- **Historic Buildings** – Total number of historic buildings were identified per watershed and ranked from 1 – 10.
- **Critical Infrastructure** – Total number of critical infrastructure assets were identified per watershed and ranked from 1 – 10.
- **Recreational Areas** – Total number of recreational areas were identified per watershed and ranked from 1 – 10.
- **Energy Infrastructure** – We used transmission line data for this VAR, identified the total length (ft) per watershed and ranked from 1 – 10.
- **Crossings** – Total number of crossings were identified per watershed and ranked from 1 – 10.
- **Roads** – Total length of roads (ft) were noted for each watershed and ranked from 1 – 10.
- **Trails** – Total length of trails (ft) were noted for each watershed and ranked from 1 – 10.
- **Abandoned Mining Lands** – Total acreage of abandoned mining lands were noted per watershed and ranked form 1 – 10.
- **Hazardous Materials** – Total number of hazardous material sites were identified per watershed and ranked from 1 – 10.

5. Once all hazards and VARs were ranked, we performed an intersection between them. The figure below shows which hazards were intersected with each VAR. Intersect determination was based on CWCB guidance, and discussions with the Core Team. Intersect values was calculated by

multiplying ranked values of the hazards and the ranked values of the VARs (created in step 4 above).

Framework Risk Matrix	Values-at-Risk: Water Infrastructure						Values-at-Risk: Life and Property									
Post-Fire Hazards	Reservoirs (Total Storage Volume)	Built Flowlines (Total Length)	Decreed Water (Total Flow Rate)	Source Water	Natural Conveyance	Water Infrastructure (Structures, Diversions, etc)	Buildings	Historic Buildings	Critical Infrastructure	Recreational Areas	Energy Infrastructure	Crossings	Roads	Trails	Abandoned Mining Lands	Hazardous Materials
Hydrologic Change (Watershed Level Intersection)	✓	x	x	✓	✓	✓	x	x	x	x	✓	✓	x	x	x	x
Flooding (Direct Intersection)	x	x	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sediment Yield Change (Watershed Level Intersection)	✓	✓	✓	✓	✓	✓	x	x	x	x	✓	✓	x	x	✓	x
Debris Flow (Watershed Level Intersection)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x
Fluvial Geomorphic Hazards (Direct Intersection)	✓	✓	x	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	x	✓

Figure D.3. Final Framework Risk Matrix

6. Next, an overall rank was established using the intersected values. 3 total ranks were developed for a Water Infrastructure category, a Life & Property category, and an overall (all VARs) category with categories being based on VAR groupings (noted below). These ranks were identified by summing the intersected values for the specific VARs, getting an average, and ranking them from 1 – 10. Below is the breakdown of which VARs were assigned to each category.

Water Infrastructure

- Reservoirs
- Built Flowlines
- Decreed Water
- Source Water
- Aquatic Species Habitat
- Natural Conveyance
- Water Infrastructure

Life & Property

- Buildings
- Historic Buildings
- Critical Infrastructure
- Recreational Areas
- Energy Infrastructure
- Crossings
- Roads
- Trails
- Abandoned Mining Lands
- Hazardous Materials

7. Once the final ranks have been established, the next step was to create the susceptibility model visual. We started off by dividing the project area into a grid of hexagonal cells. Each cell was analyzed to see how many VARs fell within that specific area and what the total (overall) hazard rank and mean for that hexagon was. The overall hazard mean was then multiplied by the total VARs and the resulting value was then ranked from 1 – 10. This gave us the following visual:

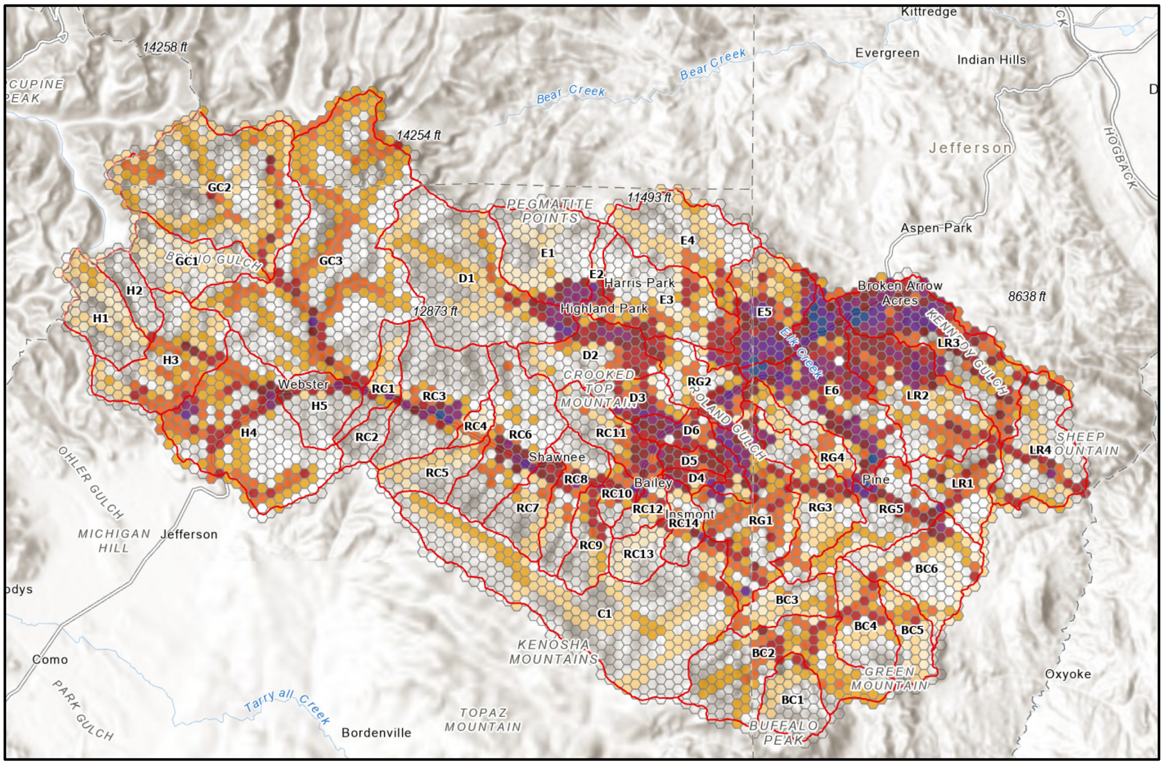

Figure D.4. Susceptibility model overall impacts ranking

This layer attempts to locate general areas that have an increased risk, based on the intersected/combined information that we've received from the number of VARs that fell within the cells and the overall hazard that overlaps them.

Susceptibility Ranking Methodology

In addition to analyzing the potential for each hazard to impact selected VARs across the full planning area, our susceptibility analysis ranked each watershed based on risk to each VAR category (water infrastructure and life and property) and based on the risk posed by each hazard. This ranking incorporated the hazard analysis results presented in Section 4. The sections below summarize the methods used to rank susceptibility in each watershed and the composite ranking.

Sediment Yield Ranking

Once the Sediment Yield Change (SYC) hazard analysis was complete (section 4), the change values for each subwatershed were summed, providing an overall watershed value. The sum values were then normalized by the acreage of each watershed. Next, all sum values we reclassified from 1 – 10 to obtain a rank with 1 being lower susceptibility and 10 being the highest. These values were then reclassified along natural breaks into “low”, “moderate”, “high”, and “extreme”.

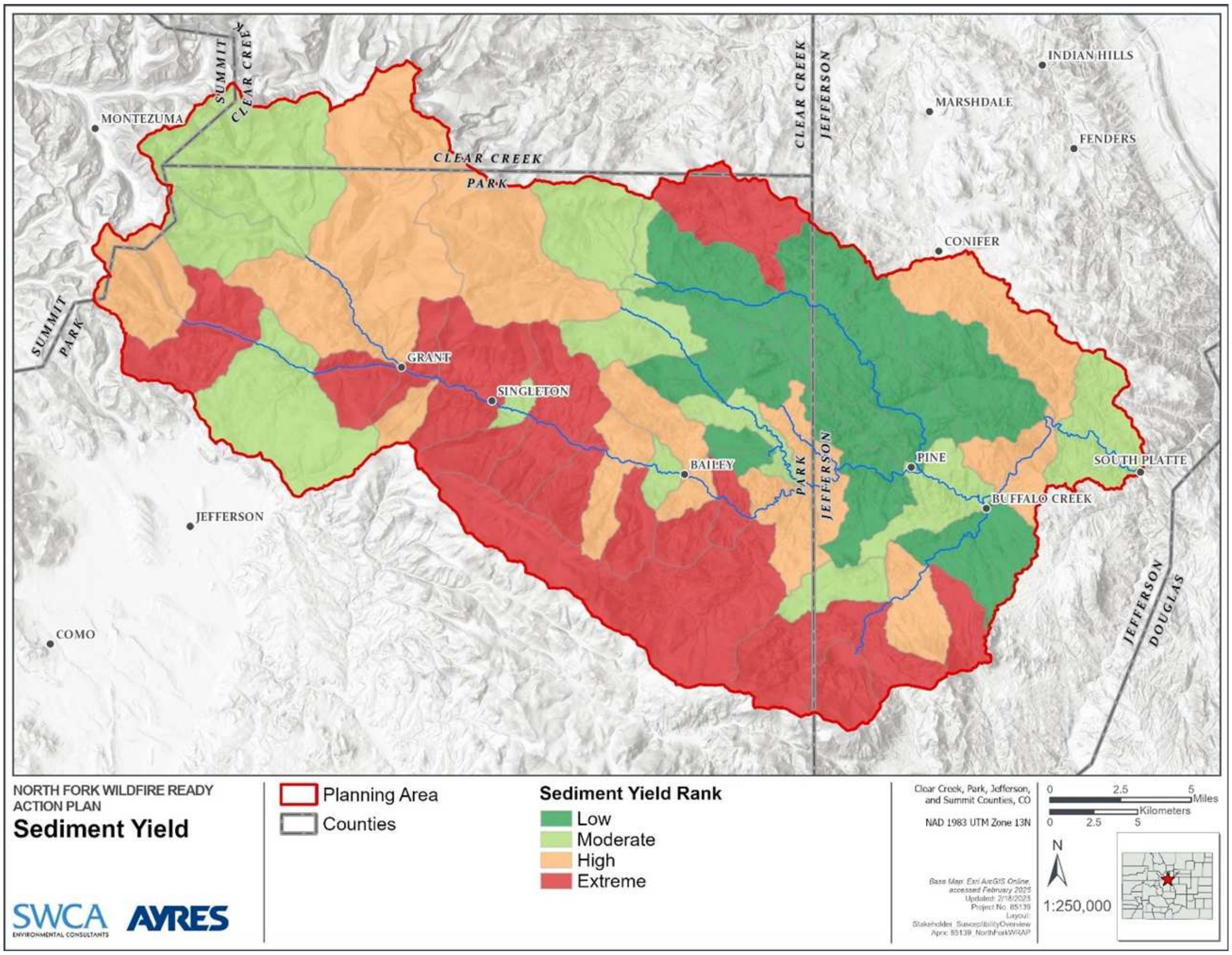

Figure D.5. Sediment yield ranking

Debris Flow Hazard Ranking

Once the debris flow analysis was complete (Section 4), the data from the analysis was used to calculate a sum debris flow volume for each watershed. Additionally, probability values for each watershed were averaged. Both the sum value for volume and the probability averages were reclassed from 1 – 10 along natural breaks. The probability and volume ranks were summed for each watershed and the resulting value was reclassed once more from 1 – 10, giving the final debris flow rank. These values were then reclassified along natural breaks into “low”, “moderate”, “high”, and “extreme” for visual representation.

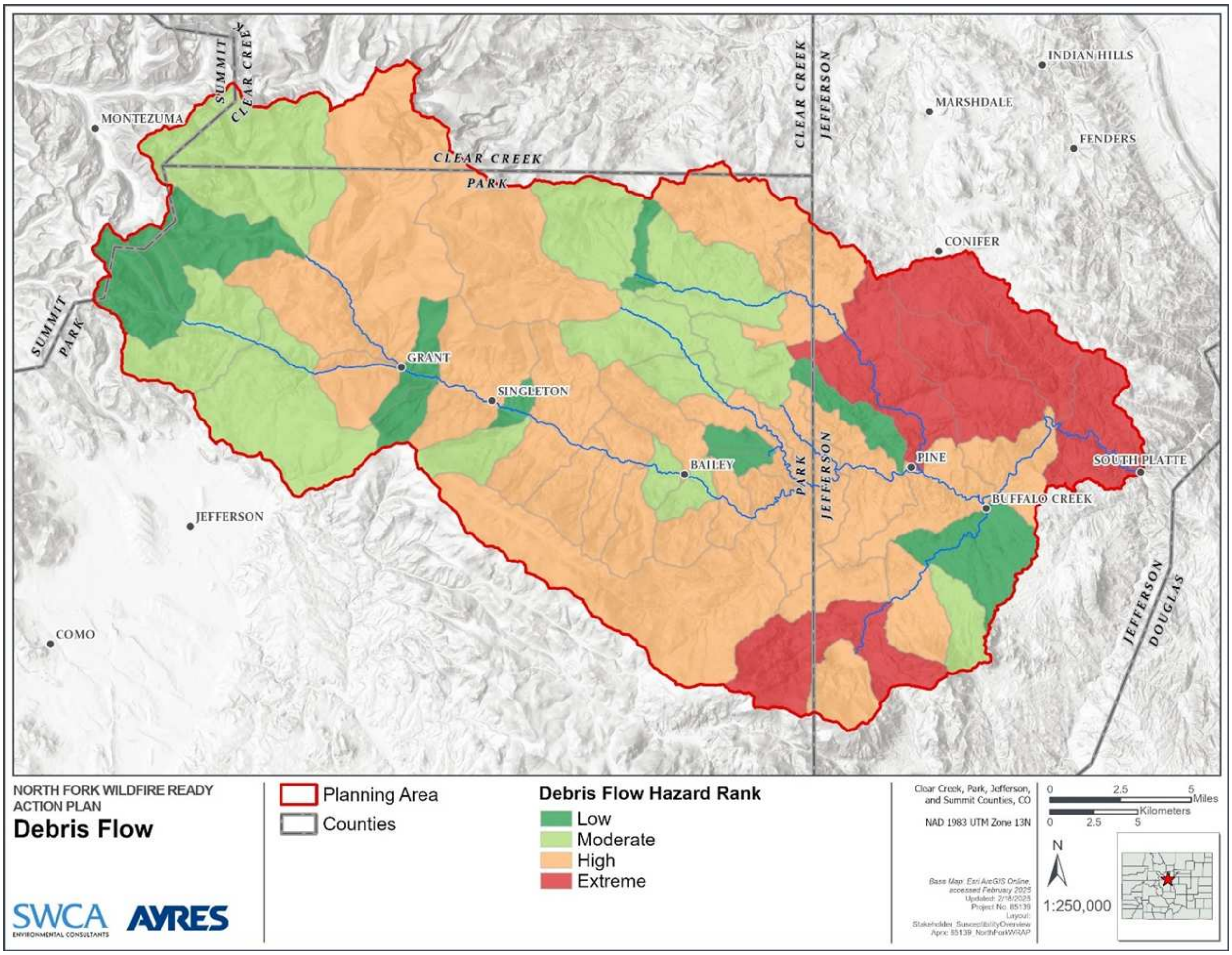

Figure D.6. Debris flow hazard ranking

Hydrologic Change Ranking

One the hydrologic change analysis was complete (Section 4), the resulting change values were summed for each watershed. These values were then reclassed from 1 – 10 along natural breaks, resulting in a rank for each watershed. These values were then reclassified along natural breaks into “low”, “moderate”, “high”, and “extreme”.

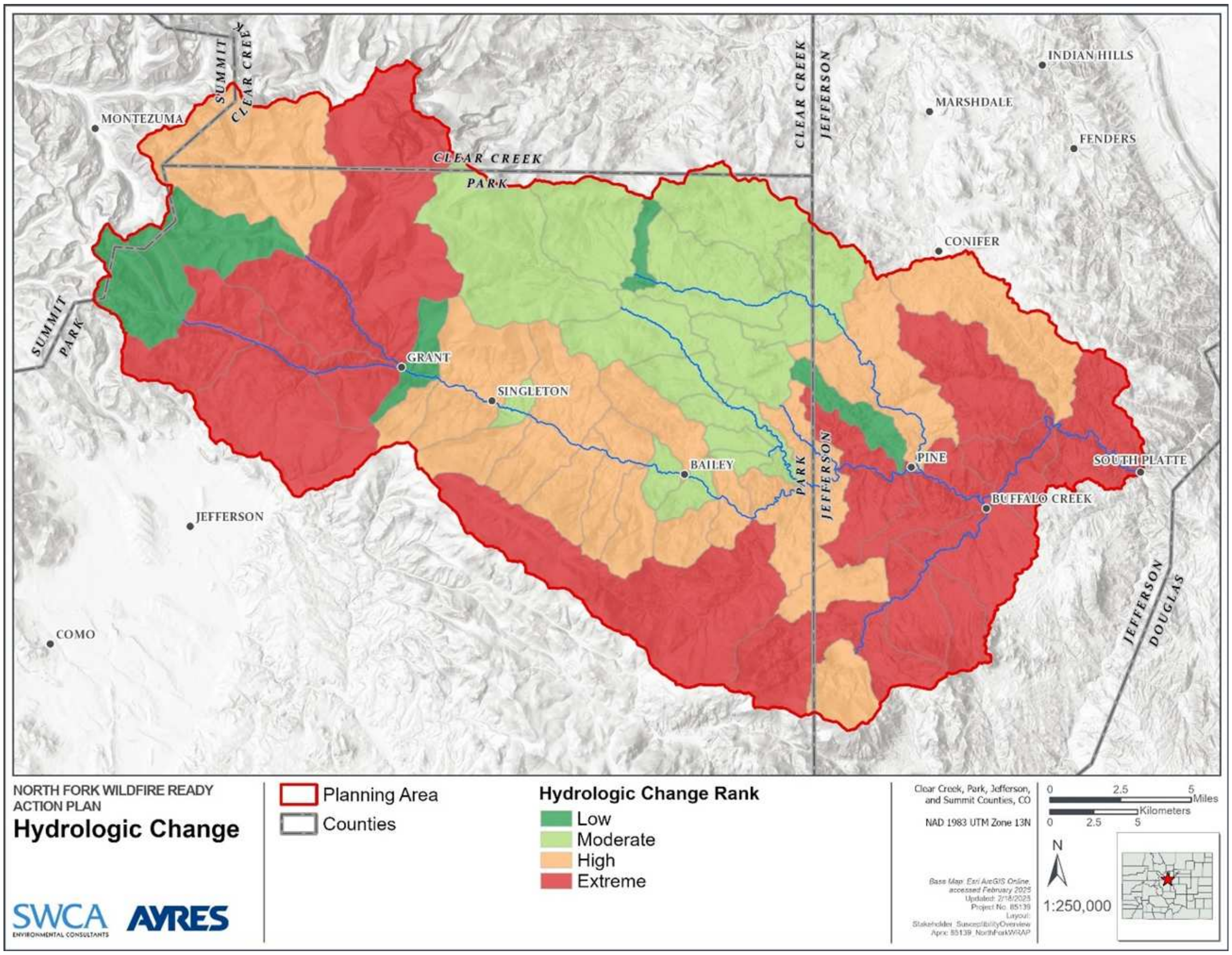

Figure D.7. Hydrologic change ranking

Fluvial Geomorphic Hazard Ranking

Once the Fluvial Geomorphic Hazard analysis was complete (Section 4), VARs that fell within a FGH zone were counted and ranked from 1 – 10. These ranks were then averaged for each watershed. Averages were then reclassed to a range of 1 – 10 along natural breaks. These values were then reclassified along natural breaks into “low”, “moderate”, “high”, and “extreme”. Because the FGH analysis was only completed along priority reaches of the North Fork, watershed rankings were only completed for watersheds that are intersected by the main stem of the North Fork river.

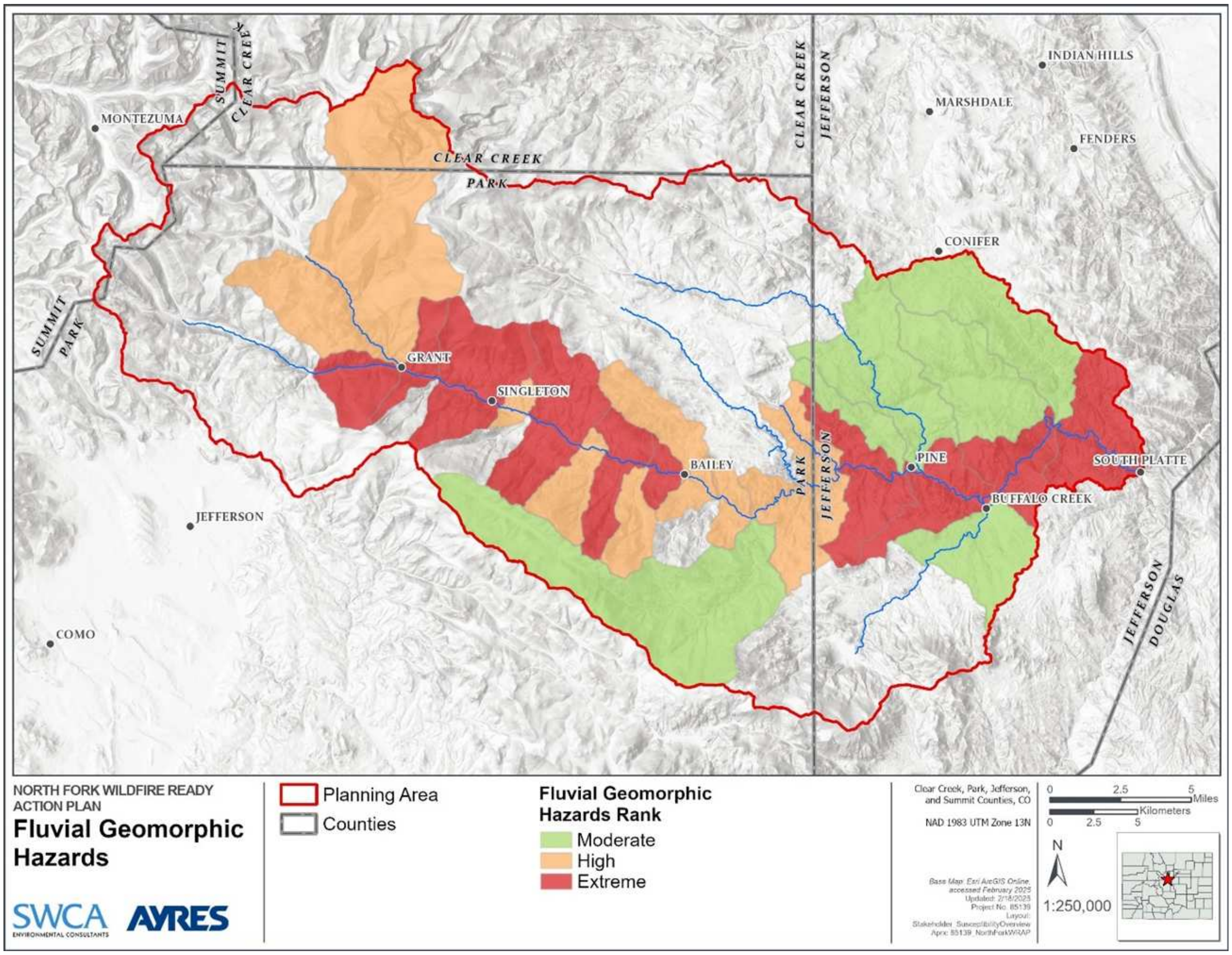

Figure D.8. Fluvial geomorphic hazard ranking

Composite Ranking

After all hazards and VARs were ranked from 1 – 10 and then intersected (multiplied). The intersected values were summed and divided by the total number of VARs that fell within the given composite category (overall, life/property, and water infrastructure). Please refer to Table 5.1 for the final risk matrix table.

All green cells (54 total) represent VARs that fell within the overall category. There are 22 green cells for the water infrastructure category, etc. Then those values were ranked from 1 – 10 to give the final score. For example:

1. Sum of all intersected values within the overall category / 54 = average
2. Average is then ranked from 1 – 10.

Or:

1. Sum of all intersected values within the water infrastructure category / 22 = average
2. Average is then ranked from 1 – 10.

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APPENDIX E

Treatment and Mitigation Methods

E.1 Project Planning Workflow Case Study

This section will review the steps to identifying an area of concern, assessing its risk, and planning pre- and post-fire tactics to mitigate wildfire risk. This approach is being presented in the context of the Harris Park Priority Area, but can be applied to any project in the planning area.

Figure E.1 Project planning considerations

With the long list of potential pre- and post-fire techniques and approaches, it can be difficult to prioritize and choose projects. This is a longer, individualized process that depends on the values and recommendations of the town, stakeholders, landowners, and consultants. This list presents some key factors that contribute to selecting actionable projects.

The first four considerations are mostly blind to feasibility: what is the most efficient work for benefiting the watershed, ecosystem, and population? Overlapping hazards and benefits can point to areas where a single, thoughtfully designed project could have the most impact. Other times, a single asset may be valuable enough to stakeholders that a project is chosen to protect that asset alone. With these steps in mind, let's move through an example area of concern in the hopes of developing a strategy.

The last two considerations are vital to accomplishing actual risk reduction or mitigation. Throughout the project development and evaluation process, return to these factors as filters to avoid investing too much time speculating on something that might be prohibitively difficult to permit or access. Especially for pre-fire risk reduction, including process-based restoration and area treatments, it is often more important to guarantee wide spatial distribution than to focus on one specific area.

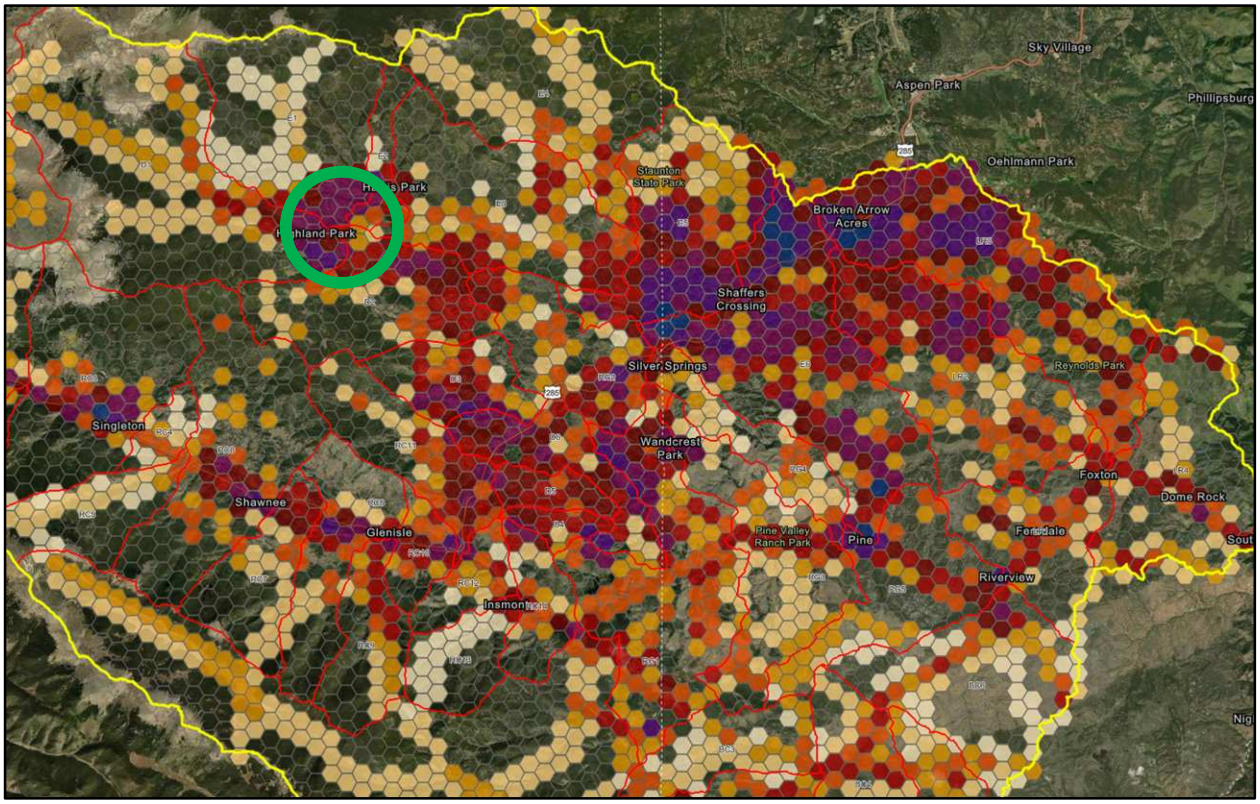


Figure E.2 Harris Park priority area with susceptibility ranking basemap

Our case study will focus on the community of Harris Park, which lies in the upper Elk Creek watershed near the border with the Deer Creek watershed. First, we will discuss why this area was selected as a priority.

Figure E.2 above shows the “Overall Impacts” layer of the North Fork WRAP Web Map. The dark purple hexagons represent the highest intersection of hazards and infrastructure, and light hexagons the lowest. The overall score was calculated by multiplying the number of Values at Risk (VARs) in the hexagon with the mean susceptibility score from different hazard types. The broad nature of the hazard risk mapping and the highly individualized aspects of VARs make it difficult to fully rely on this map for identifying areas of concern.

For example, consider a neighborhood located in a watershed that is predicted to have extremely high post-fire flood magnitudes. This will have a high Overall Impacts score due to fluvial hazard risk, but we need to look deeper. If these houses are all located on a hilltop far from fluvial hazards, and there are plentiful egress routes, then this neighborhood is not at high risk of fluvial hazards. Looking for overlapping hazard types is a good way to identify potential project locations while avoiding these false positives, since it’s hard to be resilient against all hazards at once without dutiful preparation. Community input was vital to identifying areas of concern. Harris Park stood out initially due to community input and high Overall Impact score.

Figure E.3 Aerial view of Harris Park with ingress/ egress concerns highlighted.

One glaring aspect of Harris Park immediately justified detailed evaluation as an area of concern: evacuation routes. As we can see in this map, all the exit routes first need to cross Elk Creek. The culverts are not large, but their redundancy is helpful. Then, the full egress route from Harris Park must follow CR 43 parallel to Deer Creek. If this road is damaged by fire, landslides, debris flows, or fluvial processes, it would drastically slow down evacuation and emergency response.

As called out on the map, we do see a possible second egress route along Elk Creek. This is a private farm access road that, even if temporarily opened, would likely not tolerate heavy traffic well. Nonetheless, it merits further discussion by local stakeholders and will be identified in the final project list.

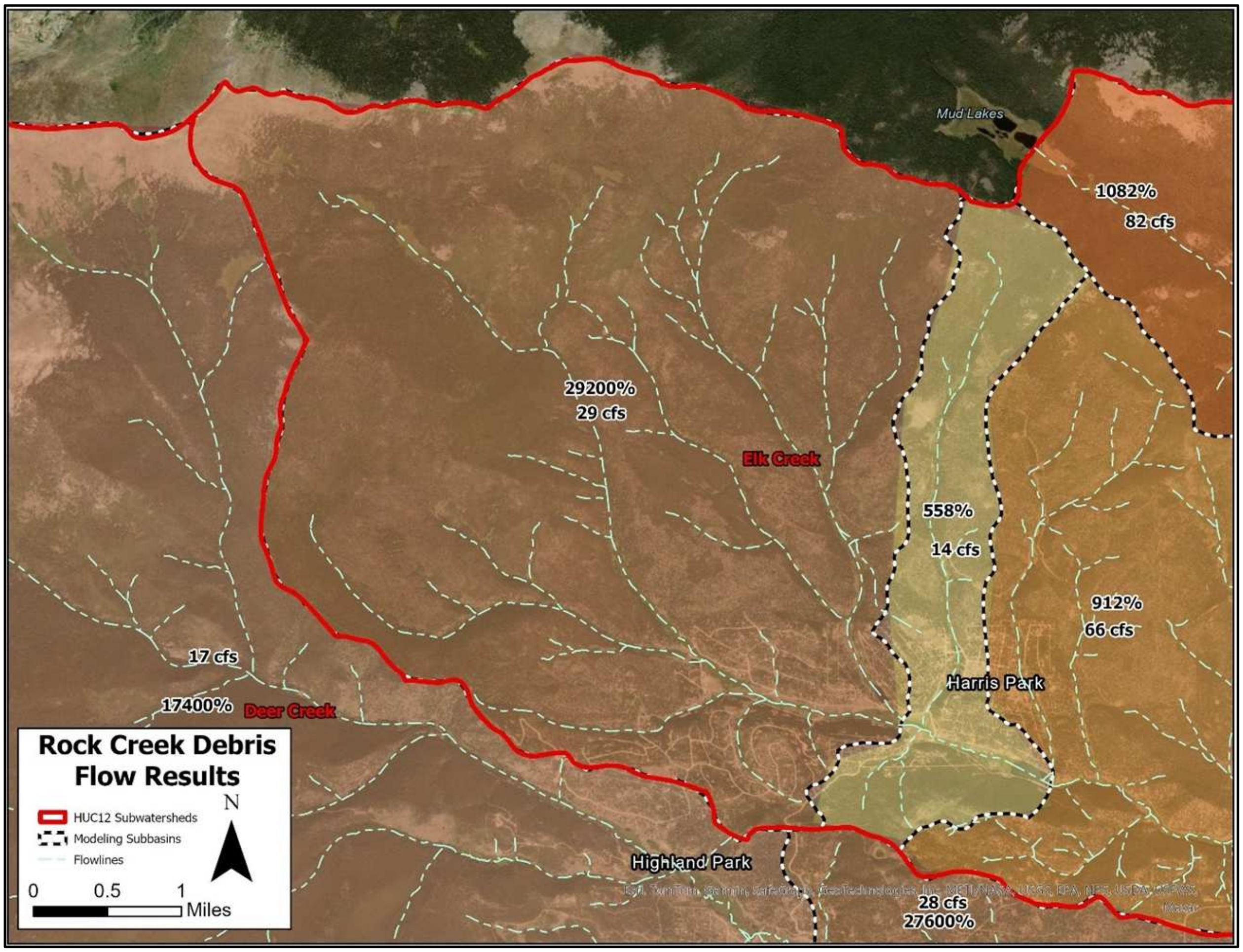


Figure E.4 Hydrologic change results for the Elk Creek watershed which contains Harris Park

After identifying the most valuable things to protect in this region – a dense population and limited evacuation routes – we'll examine risk category results to help plan mitigation tactics. First is fire-affect hydrology, which increases flows in a basin. Note that the Deer Creek watershed is also being examined throughout this process because it contains the evacuation route. We see an extremely high percentage increase in discharge, but low absolute value of increase. This poses a particular risk of overwhelming small culverts or fords that were never intended to accommodate high flow, especially combined with debris.

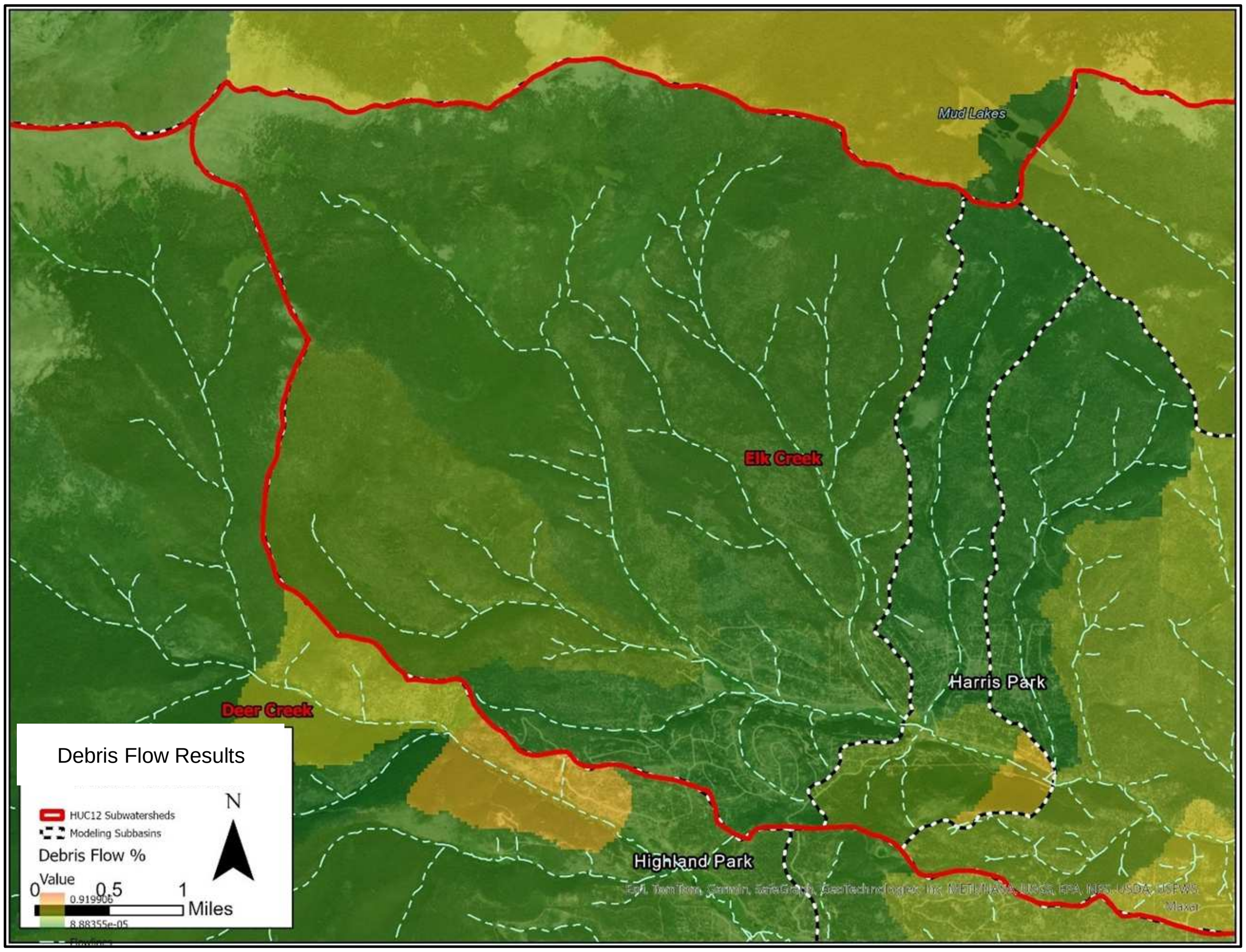


Figure E.5 Debris flow ranking for the Elk Creek watershed

Next, debris flow results will be considered. This modeling is focused on the response of small streams and gullies to a high-intensity rainfall event. The risk is quite low near and above Harris Park, likely due to few steep gullies being present. However, we see elevated risk just above Highland Park, where the Harris Park evacuation passes through. This is important to consider for pre-fire planning.

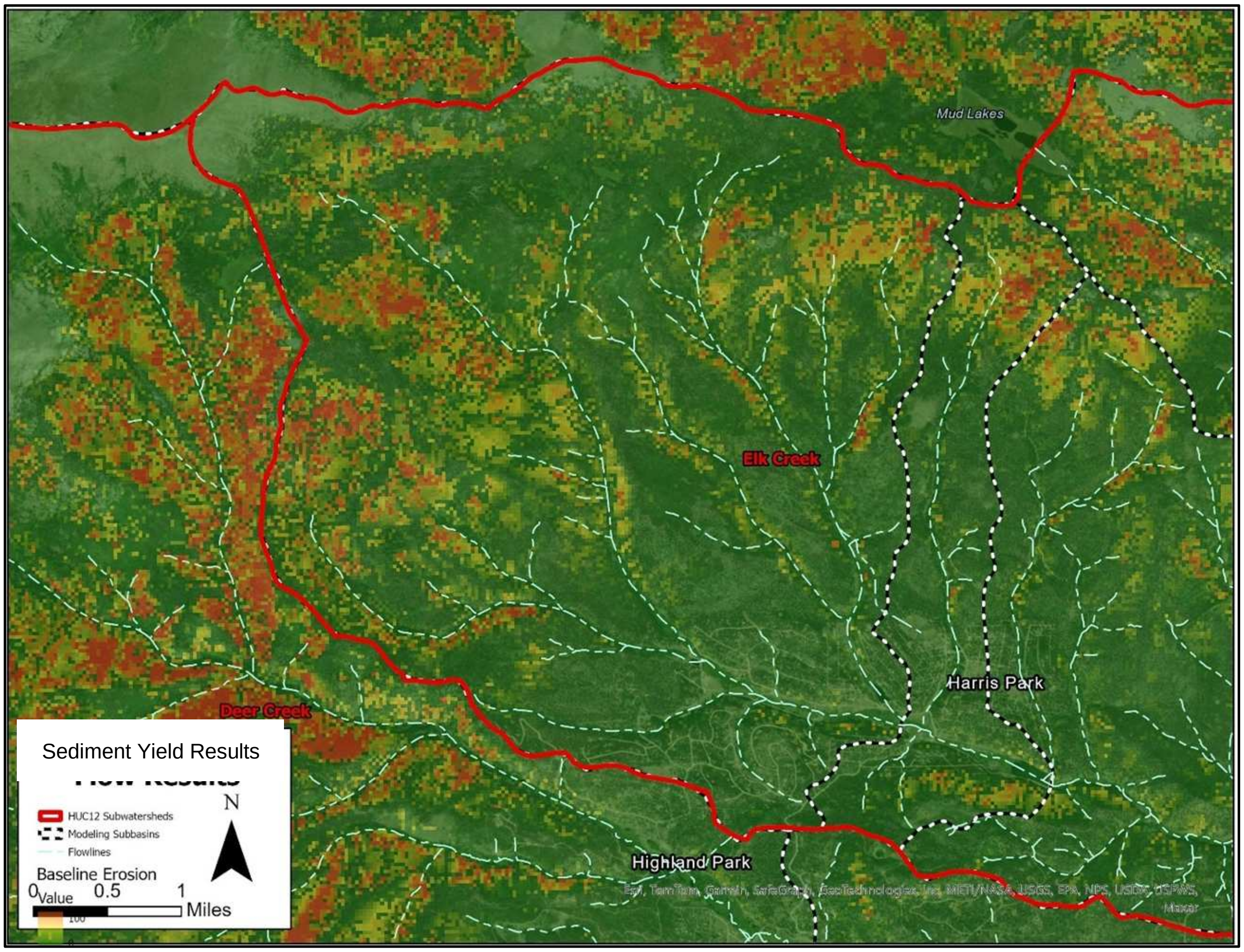


Figure E.6 Sediment yield results for the Elk Creek watershed

The sediment yield risk closely follows the debris flow risk map. Sediment supply poses more of a problem for long-term water quality, rather than immediate impacts. There are two dammed ponds in Harris Park: Regal Lake and Mt. Royal Lake. If these are used for drinking water supply, then a sediment mitigation plan should be created to protect them in case of a fire. Although sediment supply is relatively low, safe drinking water is extremely valuable.

We have identified key values at risk: population, evacuation routes, and drinking water. Next, we consulted our model results to identify hazards that threaten those assets: hydrology increases and sediment yield. Our modeling did not evaluate fire risk, but the local CWPP can be referenced for additional detail.

The next step is to create a holistic approach to preparing for a wildfire, including actions to take both pre- and post-fire. The first step of the approach is always preemptive fire mitigation. All forested areas in the North Fork of the South Platte watershed would benefit from fire mitigation such as thinning, controlled burns, and strategic fuel breaks. After preemptive fire mitigation, we consider pre- and post-fire mitigation in three categories, the first of which is infrastructure protection.

Figure E.7 Aerial image of Elk Creek through Harris Park

The above figure is looking upstream along Elk Creek – Harris Park is to the right, and Regal Lake is directly below the page cutoff. The annotations show infrastructure lying in or near the floodplain of Elk Creek, which will be at risk of flooding due to hydrological increases. Red boxes are houses, yellow lines are roads, and orange lines are culverts. The blue pond is Mt Royal Lake, which is not adjacent to Elk Creek but still requires planning for sediment supply and storage capacity.

Figure E.8 Example of hydrological change protection measures. A muscle wall protecting a home (left), and flood barrier bags to protect a roadway (right)

For some infrastructure like that highlighted in Figure E.8, which may only rarely be subjected to fluvial hazards, temporary flood protection measures may be sufficient. There is a variety of protection techniques that can be deployed post-fire to protect a home or road against the temporary post-fire discharge increases. On the left, a muscle wall protects a home. On the right, flood barrier bags add conveyance capacity to a secondary channel and protect a roadway. Additional information on temporary measures is available below in the treatments table included as Appendix E.3.

Figure E.9 Example of long-term measures that can be applied to crossing to prevent post-fire hydrology and debris flow damage. An armored ford (left), and a culvert with overtopping protection (right)

As discussed earlier, small culverts are at risk of clogging and overtopping due to post-fire debris and hydrology increases. This can damage the road repeatedly, inhibiting transportation and requiring costly reconstruction. Preemptive crossing improvements can mitigate and reduce these risks. Minor crossings on certain roads could be reconfigured into armored fords (left) that will overtop but survive some level of post-fire flooding. Other culverts could be upsized and receive overtopping protection (right).

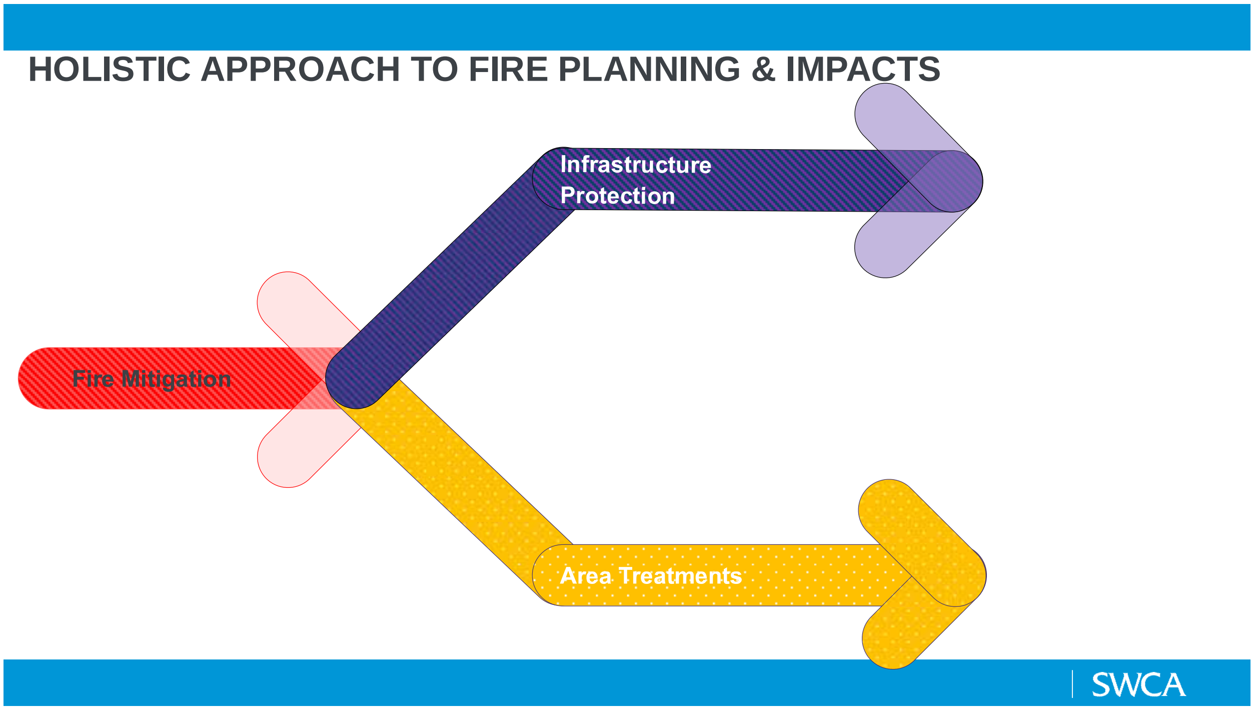


Figure E.10 Holistic planning approach to fire and post-fire impacts

The second aspect of holistic planning is area treatments, which require broad spatial application within the contributing watershed to be effective. In the pre-fire context this included prescribed burns, mechanical thinning, and forest management. In the post-fire context, the focus shifts to dampening post-fire hydrologic change and recovery. These treatments include hillslope erosion, aerial mulching, and tree felling techniques.

Figure E.11 Fuels reduction and mitigation opportunities in Harris Park

Area treatments generally focus on reducing burn severity in the pre-fire context and stabilizing burned soil post-fire, which reduces sediment supply and debris flow risk while contributing to ecosystem recovery. The treatments are very labor-intensive due to their broad spatial coverage. Figure E.11 highlights some areas that initially stood out for potential pre-fire and post-fire area treatments. The variability of the sites and areas will require a varied mitigation approach in both the pre- and post-fire context.

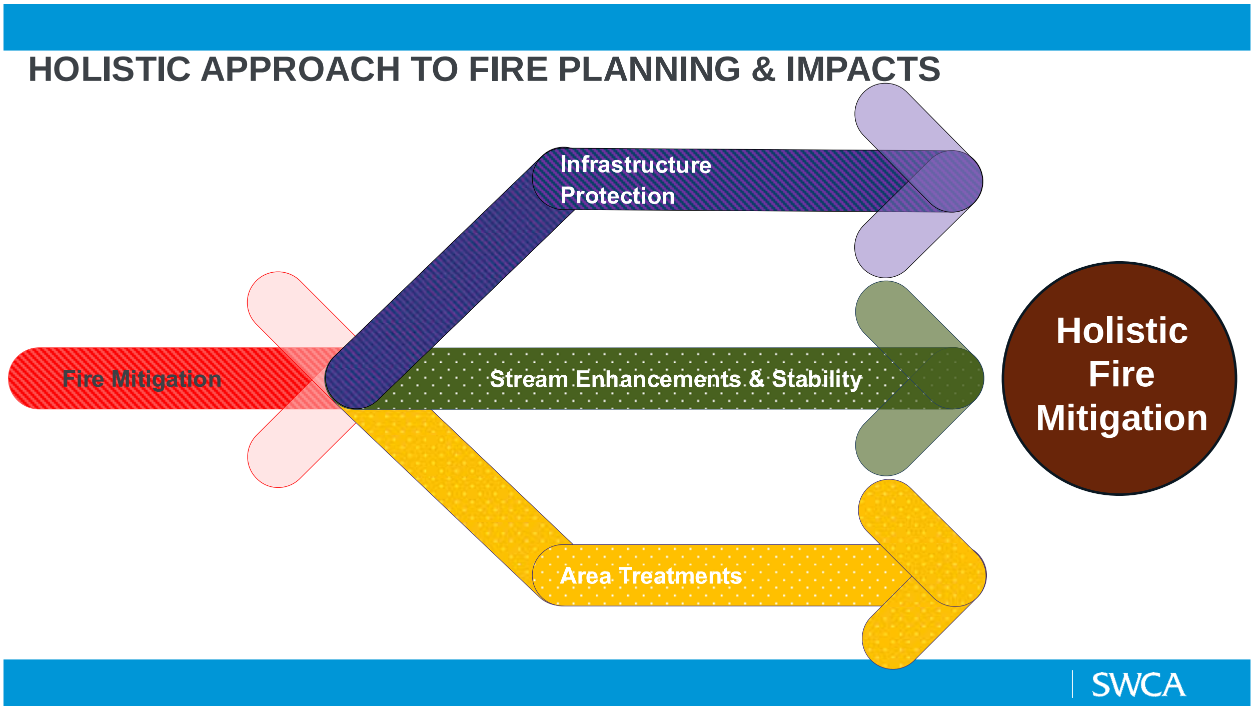


Figure E.12 Holistic planning approach to fire and post-fire impacts

The third component of a holistic fire mitigation strategy is in-stream work focused on either long-term process enhancements or stabilization. Stabilization generally refers to constructing hardened banks using riprap or other countermeasures, with the goal of limiting the natural erosive processes of the river. Sometimes, this is necessary to protect immovable infrastructure adjacent to or within rivers corridors, like essential highways in canyons. In the case of Harris Park, roads are mostly redundant or set back far enough from the stream that stabilization measures are not necessary. However, there are some potential areas for stream enhancements, as shown below.

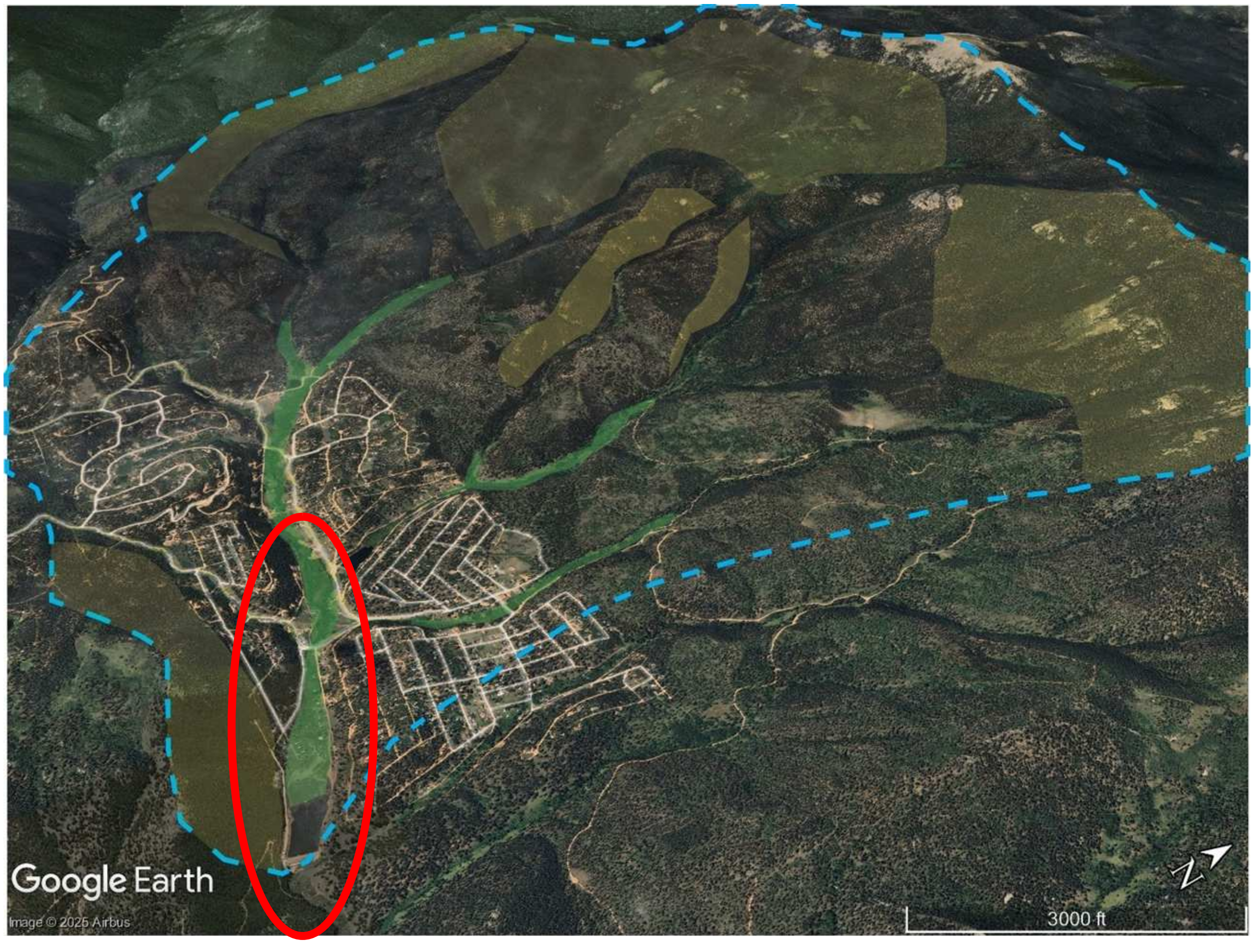


Figure E.13 Example of depositional reach with stream process enhancement opportunity

Stream process enhancements aim to restore natural stream and floodplain processes that have degraded over time due to human encroachment, artificial hydrologic control, or post-fire effects. These factors often cause stream entrenchment and floodplain disconnection, which then harm habitats and make stream corridors less resilient to future disturbance, such as wildfires.

Floodplains that receive frequent, minor inundation stay wet for longer, creating fire breaks and wildlife refuge areas during wildfires. To achieve these benefits, most process enhancement work is focused on reconnecting disconnected floodplains by adding naturalistic roughness features – like log structures and beaver dam analogues – to slow flow, retain sediment, and encourage minor bank overtopping.

In Figure E.13 above, The light green highlighted areas show flatter, depositional reaches around Harris Park that are candidates for stream process enhancement work. In these areas, encroachment and culverts have homogenized and restricted the floodplain while depriving the channel of woody material. The red circle shows the focus on the infrastructure protection in the lower portions of Harris Park.

In summary, the wildfire risk reduction and mitigation around Harris Park should be developed utilizing a series of holistic approaches:

1. Administrative Action
    - In the pre-fire context, this community needs to be informed of the risk and equipped with knowledge to better plan in the event of a wildfire.

- Properties and infrastructure that However, difficult to protect should be tagged for relocation or acquisition.
- As previously mentioned, agreements should be drafted to utilize existing egress (the private road) and establish an additional evacuation route.

2. Process-Based Restoration
   - Depositional Reaches (shown in the "PBR Initial Sites" layer provided) should be identified and prioritized to enhance natural stream function in pre-fire. In post-fire, these areas will be essential to absorb impacts and assist in recovery. Projects to rehabilitate these areas after a burn should be completed after exigent threats are addressed.
3. Stream Stabilization
   - Stabilization may be required around critical infrastructure, like the water supply reservoirs or major roadways. However, many structures along Elk Creek have encroached on floodplain and creek. These areas should not be stabilized as it is likely to mitigate the underlying issues, proximity to fluvial hazards, and will degrade the resiliency of the watershed in the process.
4. Emergency Measures for Life & Property
   - In the pre-fire context, defensible spaces should be established around structures to reduce the risk of burn during a wildfire.
   - In the post-fire context, many structures along Elk Creek will require emergency protection from flooding. This will prove costly, time consuming, and potentially inadequate so ideally other measures are used to minimize this task post-fire.
5. Roadway and Access Improvements
   - As mentioned previously, egress must be ensured within this community. The main entrance and exit, Deer Creek Rd and , later, Harris Park Rd, must be improved to increase resiliency to fluvial hazards. Crossing should be upsized and equipped to handle debris. Multi-barreled culverts should be avoided at all costs. Overtopping protection may be an adequate short-term alternative depending on the traffic. Adding emergency routes and redundancy will allow for more flexibility in planning.
6. Hillslope Erosion & Sediment Capture
   - In pre-fire, reduction of burn severity is key to reducing sediment yield in post-fire. Mechanical thinning and prescribed burned should be prioritized on steep hillslopes in dense forests.
   - Hillslope erosion treatments should be prioritized on high severity burn slopes that are direct inputs to reservoirs.
   - Sediment capture, such as forebays, may be appropriate upstream of reservoirs and crossings if optimized and funded for regular maintenance.

Stakeholder should divide and conquer according to funding, mandates, and expertise. All of these approaches should be explored and implemented into a mitigation program and strategy to ensure success and limit impacts.

E.2 Mitigation Summary Sheets

This section provides individual project fact sheets for pre and post fire recommendations.

Mitigation Approach:

Process-Based Restoration

Description, Setting, Applicability, and Limitations

Approach Description:

Process-based restoration (PBR) accounts for a riparian system's dynamic nature and disturbance-based diversity. PBR techniques promote and restore natural processes so fluvial systems can self-maintain diversity and physical complexity that leads to resiliency. Typically, structures reconnect floodplains, increasing inundation and attenuation of water and sediment across the landscape. Like natural systems, PBR projects are built over time. After structures are installed, they should be monitored and ***adaptively managed***. This is the process of updating and augmenting structures in the years after installation.

Projects can be ***labor-based*** (aka low-tech), which utilizes hand-crews supported by small machines and equipment, or ***machine-based*** (aka high-tech), which uses more traditional construction equipment and machinery.

Secondary Benefits: PBR is the best tool to enhance and rehabilitate stream processes and wetland function, which aids in biodiversity, water quality, and watershed resiliency.

Timing: Its cascading benefits for riparian corridors make it applicable in the pre- and post-fire environments.

Appropriate Settings: Depositional stream reaches with lower valley confinement relative to adjacent reaches, abandoned beaver complexes, riparian meadows, and gullies, with limited functionality.

Fire-Related Hazards Addressed:

Hazards	Directly Mitigates	Supports Mitigation
Burn Severity		X
Hydrologic Response (Flooding)	X	
Fluvial Hazards	X	
Debris Flow		X
Water Quality		X
Hillslope Erosion	X	

An image of a post-assisted log structure (PALS) in an abandoned beaver complex. This labor-based PBR feature is well suited for small perennial streams in highly burned watershed as it leverages the high sediment yields and flows to reverse some incision and improve floodplain connectivity.

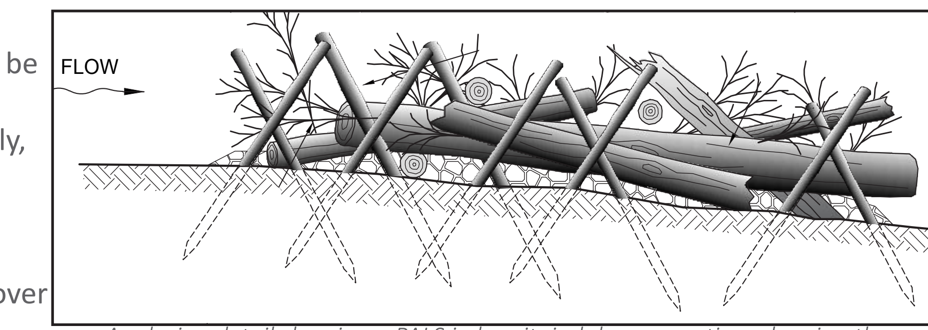
An image of a ballasted log structure in a simplified river valley downstream of a significant burn. The machine-based installation is large enough to resist yearly peaks while increasing roughness in the channel which in turn increases floodplain connectivity, shallow groundwater elevations, physical complexity, and riparian extent.

Prioritization: Pre-fire, this should be high priority for natural resource focused stakeholders in areas of concern. Post-fire, PBR is a part of long-term recovery which takes place after exigent protection and mitigation occurs.

Limitations:

1. ***Conflicts:*** The processes that PBR works to enhance can often create conflict with nearby when countermeasures are not considered.
2. ***Scale:*** Current science and conceptual models indicate that massive amounts of features are required to create measurable change at a the watershed-scale. PBR projects will be needed in all tributary channels within the appropriate systems. Accessing the required extent of remote watershed is often difficult and not practical.
3. ***Quantifiable:*** Without robust monitoring, it can be difficult to quantify impacts and return on investments (ROI).
4. ***Flood Type:*** PBR, unless deployed at the scales mentioned above, should not be expected to mitigate hazards from large storm events, such as debris flows.

Next Steps: Proposed_PBR.shp should be evaluated and shared with partners to generate a list of future projects. Ideally, the projects developed should vary in ownership, funding, and permitting requirements to create a "hopper" of future project that can be completed over time.



An design detail showing a PALS in longituindal cross-section, showing the types of material, stabilization, and blockage of the channel.

Stakeholders

Funding Sources

- Federal Grants: (NRCS), (USFS).
- State Grants: Colorado Water Conservation Board (CWCB).

Partner Organizations

- Non-Profits: National Forest Foundation (NFF), Trout Unlimited (TU).
- United States Forest Service (USFS).
- Local Municipalities: Park & Jefferson County, Towns & Cities.

Potential Permitting & Approvals

- FEMA Floodplains, USACE (404 permitting), USFS (Approvals and Wilderness), Land Owner Approvals.

Scale of Implementation

	Min — Max
Summary of Overall Effort	
Design & Permitting Effort	
Construction Time & Impact	
Maintenance Required (Scale & Frequency)	
Rough Cost Magnitude	

Mitigation Approach:

Stream Stabilization

SWCA ENVIRONMENTAL CONSULTANTS AYRES

Description, Setting, Applicability, and Limitations

Approach Description:

Stream stabilization reduces fluvial hazards by armoring a stream banks and bed against high energy flows that occur more commonly post-fire. **Fire-affected hydrology increases flow in streams which causes widening**, or erosion on the banks and bed, to accommodate the additional water. Occasionally flow is disrupted by debris or at a road crossing, causing rapid deposition and channel realignment. Armor is used to help mitigate widening and ensure efficient conveyance of flood waters.

Armoring of the channel boundaries to reducing widening and bank erosion involves using large, typically imported, rock to resist erosion and protect the underlying soils. **Armoring of the channel bed to reduce incision** involves constructing rock drops, or "checks", to dissipate energy while protecting bed sediment. Flow can also be redirected using bendway weirs or spurs when applicable.

Secondary Benefits: Stream stabilization can be used to increase long-term flood resiliency in confined systems when vital infrastructure has encroached on a stream within a valley or canyon.

Timing: Stream stabilization may take place in pre- or post-fire planning.

Appropriate Settings: **Stream stabilization should be used to protect infrastructure that cannot be relocated out of fluvial hazard zones.** Despite historical precedence, stabilization should not be used to confine the stream to allow for continued or new floodplain development.

Prioritization: In pre-fire, this should be priority for transportation and municipal stakeholders in areas of concern, when relocation is not possible. Relocation of private transportation routes and structures away from fluvial hazard areas should be encouraged as its the most sustainable to protecting life and property from fluvial hazards.

Fire-Related Hazards Addressed:

Hazards	Directly Mitigates	Supports Mitigation
Burn Severity		
Hydrologic Response (Flooding)	X	
Fluvial Hazards	X	
Debris Flow		
Water Quality		X
Hillslope Erosion	X	

(Left) An image of stream widening that occurred during a post-fire flood event. (Center) A lower impact mitigation method appropriate to support private infrastructure using large native boulders and willow staking to support bank stability at this location. (Right) A large-scale mitigation project within the Big Thompson Canyon to restore the streambank after the 2013 floods. This stream stabilization was installed to improve long-term resilience of a vital transportation corridor in the face of future flood events, including those presented by wildfire.

Limitations:

1. ***Conflicts:*** Armoring focuses stream flow within the channel which can disconnect valuable floodplains and degrade healthy stream processes. Modifications to streams has downstream impacts.
2. ***False Mitigation:*** Stream stabilization is extremely costly to design and install. It can be difficult to fully account for flood forces which ultimate lead to failures. These mitigation features can provide a false sense of security to communities about the long-term risk.

Next Steps: The Fluvial Hazard Zone, Inundation Boundaries from the 2D models, and Debris Flow modeling has been used to identify structures at varying levels of risk. These VARs should be prioritized based on their utility, ability to relocate, and hazard risk. After prioritization, stream stabilization should be a considered mitigation for the most valuable, vulnerable, and immovable. Some additional roadways at risk from fluvial processes, particularly lateral migration and erosion, have been identified for evaluation for Stream Stabilization (Proposed_Stream_Stab.shp).

Three different types of vertical stabilization, or grade control features, from less impactful and resistant(log structure: left) to more imapctful (native rock check: middle), and even more resistant with large boulders. They reduce erosion of the streambed, incision, through armoring.

Stakeholders

Funding Sources

- Federal Grants: Emergency Watereshed Protection (EWP) Program (NRCS), (USFS)
- State Grants: Colorado Water Conservation Board (CWCB)

Partner Organizations

- Non-Profits: National Forest Foundation (NFF), Trout Unlimited (TU)
- United States Forest Service (USFS)
- Local Municipalities: Park & Jefferson County, Towns & Cities.

Potential Permitting & Approvals

- FEMA Floodplains, USACE (404 permitting), USFS (Approvals and Wilderness), Land Owner Approvals.

Scale of Implementation

	Min … Max
Summary of Overall Effort	
Design & Permitting Effort	
Construction Time & Impact	
Maintenance Required (Scale & Frequency)	
Rough Cost Magnitude	

Mitigation Approach:

Roadway & Access Improvements

SWCA ENVIRONMENTAL CONSULTANTS AYRES

Description, Setting, Applicability, and Limitations

Approach Description:

Roadways are critical to evacuate people from impacted areas prior to or during extreme events and to get support in to impacted areas. Additionally, all other mitigation efforts typically require access. Access supports all mitigation and requires mitigation. It is not uncommon to need to improve roadway conditions to make post-fire PBR practical. **Fire-affected hydrology creates floods that cause stream widening**, or erosion on the banks and bed, to accommodate the additional water. This widening can impact roadways that share a confined valley or that have encroached on the stream. Undersized crossings, particularly culverts, create a flow disruption, reducing sediment transport capacities locally and rapidly. This causes deposition, burying, over-topping, and potentially failure of the crossing. Debris, which is ubiquitous with post-fire flows, exacerbates these processes.

Longitudinal roadway issues should ideally be resolved through relocation to upper terraces when possible, but in many cases this not possible. Stream stabilization mitigation should be referenced and utilized. General drainage of the road should also be improved through the maintenance or installation of rolling dips and drainage ditches. Impacts to crossings can be resolved 3 ways: (1) replace the structure with a ford, (2) prepare the structure for controlled overtopping, or (3) upsize the structure to convey fire-affected flow and debris.

Secondary Benefits: Upsizing structures, especially culverts, to accommodate more stream processes will improve stream processes and that are essential to riparian health and resilience.

Timing: Once critical and immovable crossings have been identified, improvements may be performed pre- or post-fire.

Appropriate Settings: Crossings that cannot be relocated should be improved according to their usage. Private and rural crossings should be prepared for repeated overtopping of flow when they inevitably become overwhelmed during flood events while more vital bridges or culverts should be upsized to convey at least the 10-year post-fire flows with debris and bulking. Other stakeholders or funding opportunities may require higher design standards.

Fire-Related Hazards Addressed:

Hazards	Directly Mitigates	Supports Mitigation
Burn Severity		X
Hydrologic Response (Flooding)	X	
Fluvial Hazards	X	
Debris Flow		X
Water Quality		X
Hillslope Erosion	X	

Examples of the three mitigation options for crossings within a fire-impacted watershed: (Left) a conversion of a culvert to a stream ford which reduces the flow disruption, (middle) an upsized culvert that has also been prepared to overtop using matrix riprap on the downstream side, and (right) a replacement of a culvert to an adequate size with a live-bottom to better allow for the conveyance of flow, sediment, and wood.

Prioritization: Pre-fire, this should be priority for transportation and municipal stakeholders when crossings are regularly replaced and for key access routes. Post-fire, maintaining and improving key access routes is vital. Access to individual properties can be extremely onerous and often other administrative options are less costly in the near- and long-term.

Limitations:

1. ***Effort:*** Improving stream crossings is an intensive effort and post-fire flooding is unforgiving on culverts even when designed for overtopping. Careful consideration must be made to each crossings value. Proper planning of access and redundancy can help manage costs.
2. ***Scale:*** Because fire-affected hydrology impacts are most pronounced within gullies small perennial stream, and hillslopes, small culverts that are usually adequate are extremely vulnerable and unlikely to be addressed pre-fire. The number of these within the North Fork is vast and likely under counted.

Next Steps: Some critical crossings have been identified and prioritized (Priority_Access.shp). Some additional roadways at risk from fluvial processes, particularly lateral migration and erosion, have been identified for evaluation for Stream Stabilization (Proposed_Stream_Stab.shp). These should be analyzed by stakeholders and improved if appropriate.

An example of an extremely vulnerable culvert alogn CR-64 within Bailey, CO. This structure is undersized and vulnerable to racking large wood.

Stakeholders

Funding Sources

- Federal Grants: Emergency Watershed Protection (EWP) Program (NRCS), (USFS)
- State Grants: Colorado Department of Transportation (CDOT)

Partner Organizations

- Non-Profits: National Forest Foundation (NFF), Trout Unlimited (TU)
- United States Forest Service (USFS)
- Local Municipalities: Park & Jefferson County, Towns & Cities.

Potential Permitting & Approvals

- FEMA Floodplains, USACE (404 permitting), USFS (Approvals and Wilderness), CDOT, Land Owner Approvals.

Scale of Implementation

	Min — Max
Summary of Overall Effort	
Design & Permitting Effort	
Construction Time & Impact	
Maintenance Required (Scale & Frequency)	
Rough Cost Magnitude	

Mitigation Approach:

Hillslope Erosion & Sediment Capture

SWCA ENVIRONMENTAL CONSULTANTS AYRES

Description, Setting, Applicability, and Limitations

Approach Description:

Hillslope erosion and sediment control techniques aim to reduce the supply of sediment leaving a watershed post-fire. Hydrophobic soil without living vegetation is highly susceptible to erosion through rain impact, sheet flow, and rill formation. The resulting increase in sediment supply negatively impacts aquatic organism health and drinking water quality while disrupting normal riverine erosion and deposition patterns. Hillslope erosion mitigation techniques increase the bare soil's resistance to erosion using mulch, fabric, or vegetation. These measures are effective and speed soil recovery, but require very broad application across the burned area.

Sediment Capture features work to slow flows and encourage deposition in an easily accessible area that can be continuously maintained, like sediment forebays, sediment basins, and culvert clean-outs. These features are often deployed to support other infrastructure, like culverts or roadways, consolidating sediment and simplifying regular maintenance.

Secondary Benefits: Mitigating hillslope erosion allows vegetation to reestablish quicker after a fire, which then provides self-sustaining erosion mitigation.

Timing: Most hillslope erosion and sediment mitigation measures are only useful post-fire, but some preparation can be done pre-fire.

Appropriate Settings: To see measurable water quality improvement, erosion and sediment mitigation must be performed on vulnerable hillslopes across most of the burned watershed. Prioritize hillslopes with moderate slope (20-50 degrees), low vegetation (<25%), low rock coverage, and high sun exposure. Point-based sediment capture technologies, like bales and ponds, should be placed in naturally deposition areas as high up in the watershed as topography and access constraints allow.

Fire-Related Hazards Addressed:

Hazards	*Directly Mitigates*	*Supports Mitigation*
Burn Severity		
Hydrologic Response (Flooding)		X
Fluvial Hazards		X
Debris Flow		X
Water Quality	X	
Hillslope Erosion	X	

Examples of hillslope erosion mitigation and sediment capture measures. (Left) Mulched wood chips are dropped across a burned watershed, targeting erosion-prone hillslopes. While expensive, this method can quickly treat vulnerable areas quickly. Unfortunately, scientific results have not been able to verify statistically significant reductions in flow or sediment supply from treated watersheds. (Middle) Biodegradable wattles with weed-free filling are applied to burned hillslopes. They catch sediment and prevented rill formation, but require significant labor and fill quickly. (Right) Wood strand bales detail to capture sediment in a depositional reach, concentrating deposition for potential removal.

Prioritization: Pre-fire, hillslope erosion is likely limited to sediment capture features along existing nusiance areas. Post-fire, hillslopes surrounding vulnerable infastructure, like reservoirs, vital roadways, and other water resource infastructure should prioritized intially.

Limitations:

1. ***Conflicts:*** Broad application of hillslope erosion mitigation measures requires approval from different landowners while respecting their interests. **These features must utilize biodegradable weed-free materials to avoid creating long-term trash and weed issues to solve a short-term sediment issue.**
2. ***Scale:*** Hillslope erosion mitigation requires broad application to see quantifiable benefits.
3. ***Maintenance:*** Sediment capture features require regular maintenance to remove the sediment.

Next Steps: The Strontia Sediment Management Plan, developed with SWCA and Denver Water, was used to identify sediment issues in a pre-fire settling. The projects developed from this study should continue to be persued (Strontia_Sed.shp). Additional areas for potential sediment basins in a post-fire setting have been identified based on geomorphic considerations not administrative considerations Coordinate with CDOT or local transportation departments to establish a plan for deploying post-fire hillslope stabilization near key roads. Contact USFS, parks, and large landowners to select preferred mitigation techniques.

A sediment basin filled with post-fire sediment. Large facilities are expensive and required significant permitting, design, and maintenance. These facilities are not included in the scale ranking below.

Stakeholders

Funding Sources

- Federal Grants: (NRCS), BAER (USFS)
- State Grants: Colorado Water Conservation Board (CWCB)

Partner Organizations

- Non-Profits: United Way
- United States Forest Service (USFS)
- Local Municipalities: Park & Jefferson County, Towns & Cities.

Potential Permitting & Approvals

- USFS (Approvals and Wilderness), Land Owner Approvals.

Scale of Implementation

	Min — *Max*
Summary of Overall Effort	
Design & Permitting Effort	
Construction Time & Impact	
Maintenance Required (Scale & Frequency)	
Rough Cost Magnitude	

Mitigation Approach:

SWCA ENVIRONMENTAL CONSULTANTS AYRES

Emergency Measures for Life & Property

Description, Setting, Applicability, and Limitations

Approach Description:

Emergency Measures are focused on reducing inundation and exposure to fluvial hazards of structures and utilities. Techniques can focus on **enabling more conveyance in appropriate locations**, like the channel, **creating new conveyance networks**, like developing swales on overbank areas, or **diverting and deflecting flows aways from a Valuable Asset at Risk (VAR)**. Usually, these three approaches are combined in a project area to build redundancy. Typically, due to costs, time, and stakeholder constraints, these features are designed to handle higher recurrence events, from typical nuisance flooding from summer thunderstorms to a 10-year post-fire event. In additional to these measures, structure should reduce wildfire risk by creating defensible spaces and reducing fuels on properties. These are the focus of other planning efforts (CWPPs) that should be referenced for specific recommendations and actions.

Secondary Benefits: There are no secondary benefits to infrastructure protection.

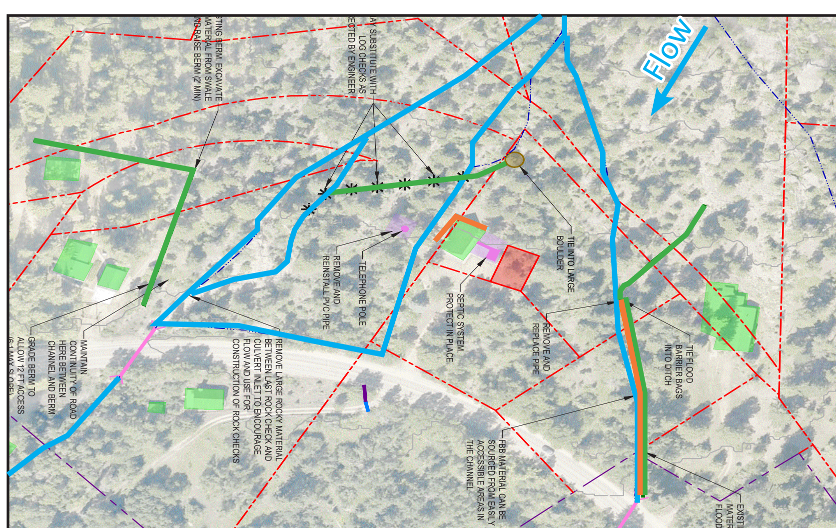
Timing: This type of work is typically only tolerated in response to a exigent threat, like post-fire or after post-fire flooding has occurred.

Appropriate Settings: Emergency measures are required to protect life and property in response to risk, which is dramatically elevated in a post-fire environment. This mitigation category should be considered a last resort. If other actions are taken pre-fire, as described in other approaches, the need for these installations can be reduced.

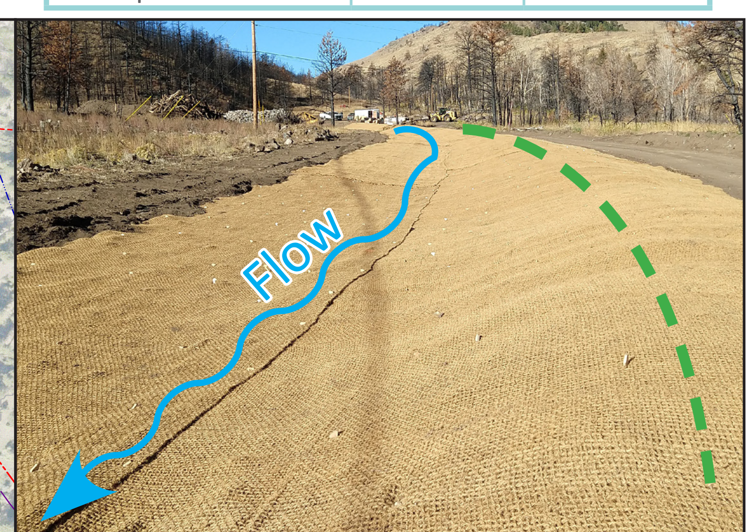
Prioritization: Post-fire, this is a high priority for most local governments and the NRCS through the Emergency Watershed Protection (EWP) Program. Funding aimed at mitigating risk to life and property will utilize these techniques, but maybe be flexible enough to support these installations alongside other approaches.

Fire-Related Hazards Addressed:

Hazards	Directly Mitigates	Supports Mitigation
Burn Severity		
Hydrologic Response (Flooding)	X	
Fluvial Hazards	X	
Debris Flow		X
Water Quality		
Hillslope Erosion		



An infrastructure protection planset in a post-fire watershed that combines flood barriers (orange lines) and creation of overbank conveyance networks using diversion berms (green lines) to control uncertain flooding (blue lines). This design was only targeting annual peak thunderstorm flooding and was overwhelmed during a large events.



An image of a diversion berm which provides new conveyance networks by creating a swale for flow (blue line). The excavated material is used to create a berm on the downhill side (green dashed line), which provides more conveyance capacity for the swale and protects vulverable infastructure.

Limitations:

1. ***Conflicts:*** Features that prioritize conveyance and consolidate water to prevent flooding are likely to degrade riparian habitat over the long-term. The flood walls, including barrier bags and muscle wall, should be removed from the floodplain, but funding for removal is limited after fire-risk has subsided.
2. ***False Mitigation:*** Infrastructure protection, especially for individual private properties, is not a long-term solution to the underlying issues for valuable-assets in high risk locations. These mitigation features provide can provide a false sense of security to communities with near-term and long-term risk, even when communication is developed around that risk. Relocation or buy-out are often the only way to truly reduce long-term post-fire risk to a vulnerable location.
3. ***Flood Type:*** Infrastructure protection is typically not designed to handle catastrophic post-fire events (~100-year post-fire floods) due to costs, impacts, and site feasibility. These events can overwhelm mitigation features and planned mitigation efforts.

Next Steps: The Fluvial Hazard Zone, Inundation Boundaries from the 2D models, and Debris Flow modeling has been used to identify structures at varying levels of risk. These VARs should be prioritized based on their utility, ability to relocate, and hazard risk. VARs identified in the WRAP should be prioritized and other pre-fire mitigation approaches, particularly Administrative Actions, should be used to reduce risk.

An image (left) of Flood Barrier Bags, a product that is just to protection structure during more frequent flood events. The flood wall shown is designed to divert flow away and around the vulnerable structure. It will not protect the structure from all inundation, but will reduce exposure to fluvial hazards.

Stakeholders

Funding Sources

- Federal Grants: Emergency Watershed Protection (EWP) Program (NRCS)
- State Agencies: Colorado Water Conservation Board (CWCB)

Partner Organizations

- Non-Profits: United Way, Local Community Support Groups
- Department Homeland Security
- Local Municipalities: Park & Jefferson County, Towns & Cities.

Potential Permitting & Approvals

- FEMA Floodplains, USACE (404 permitting), Land Owner Approvals.

Scale of Implementation

	Min — Max
Summary of Overall Effort	
Design & Permitting Effort	
Construction Time & Impact	
Maintenance Required (Scale & Frequency)	
Rough Cost Magnitude	

Mitigation Approach:

Administrative Actions

SWCA ENVIRONMENTAL CONSULTANTS AYRES

Description, Setting, Applicability, and Limitations

Approach Description:

Administrative Actions are defined as processes that work to improve the long-term interactions between infrastructure and natural landscapes. Over time these landscapes are dynamic and sometimes hazardous. Systems, information, codes, and laws have been set up to limit the interactions or to better prepare residents & managers for potential risk. **Regulatory programs define standards for development that ensure risk mitigation techniques are broadly applied.** Although localities can enact their own regulations, most programs are defined at the state or federal level, such as FEMA Floodplains, Colorado's Fluvial Hazard Mapping Program, and transportation design standards. Local governments have more initiative over non-regulatory actions. These generally focus on informing residents about and managing land use to mitigate area-specific risks. It is well documented that individuals and societies struggle to quantify risk on time-scales larger than a few decades. Communities must be reminded of the past flooding and their own responsibilities. The 21st century has seen a high-level of monetary investment, with inadequate insurance, into high-risk communities. Some example locally-driven administrative actions are listed below, but there are many creative solutions to specific hazards.

1. **Communication & Information** - Farmer's market booths, individual community meetings, informational brochures, open houses, and community events are some great ways to share valuable information and foster better decision-making.
2. **Hazard Boundary Development** - Hazard boundaries are useful communication and regulaty tools, depending on the boundary types. Fluvial Hazard Zones (FHZs) are being delineated across the state to assist communities in determining long-term risk associated with flooding, including post-fire hazards. Recurrence-based floodplain boundaries, like FEMA's Special Flood Hazard Area (SFHA), are familiar, but are likely to underestimate fire-related risks.
3. **Alert Gages** - Post-fire hazards frequently overwhelm site and funding constraints making mitigation beyond yearly nuisance flooding difficult. In these cases, the most appropriate path forward may be improving response time for the local community by developing a local alert system or bolstering a existing system.
4. **Relocation Support or Buy-Outs** - The only way to eliminate long-term risk to fluvial hazards is to relocate or remove infrastructure from the fluvial process space (areas created and utilized by a river system over geologic time). In some cases, a relatively small relocation is all that is required to reduce risk, as shown by the hazard models developed within the WRAP. Sometimes, due to poor planning or landscape shifts, a VAR (value at risk) is determined to be less valuable than the mitigation required to protect it. A buy-out should be proposed in these instances.

Timing: This should be an ongoing process in communities of high post-fire risk. Trust and relationships are required to change behaviors, especially in rural areas. While a disaster is often a catalyst for discussion and change in a community, relationships built prior are essential to the sucess of post-fire outreach.

Prioritization: Effective administrative actions make all other mitigation possible. Setting up a persistent risk management and staffing system is essential to making any long-term change happen.

Fire-Related Hazards Addressed:

Hazards	Directly Mitigates	Supports Mitigation
Burn Severity		X
Hydrologic Response (Flooding)		X
Fluvial Hazards		X
Debris Flow		X
Water Quality		X
Hillslope Erosion		X

An image of the aftermath of a post-fire debris flow within the Cameron Peak Fire burn scar. This event resulted in 4 lives and 8 structures lost. This community is undergoing a combination of mitigation, stabilization, and buy-outs.

Limitations:

1. ***Staffing:*** Outside of disaster response and recovery, funding for permanent staffing is challenging. Leaning on partners and stakeholders is essential to building awareness and trust.
2. ***Communication:*** Convincing stakeholders and community members of the risk is challenging because it forces tough decisions and often requires faith in complex science. Information from CWCB is extremely valuable. Individual testimony from other fire recovery areas is also extremely useful.

Next Steps: Project Areas identified in the WRAP should be prioritized and outreach should begin to inform the community of risk. Specific communiities and needs have been idendtified in Proposed_Admin.shp. Partners and stakeholders should develop a multi-year plan for outreach within these areas. Properties and infrastructure appropriate for relocation or buy-outs have been identified at a high level. Existing community organizations, like HOAs, roadway associations, and recreation groups, should be leveraged as partners and communication hubs.

(Left) An informational workshop on process-based restoration for post-fire mitigation. (Right) Permanent signage to inform risk to travelers.

Stakeholders

Funding Sources

- Federal Grants: Emergency Watershed Protection (EWP) Program (NRCS)
- State Grants: Colorado Water Conservation Board (CWCB)

Partner Organizations & Informational Assistance

- Non-Profits: United Way, Upper South Platte Watershed Coalition
- Colorado Water Conservation Board (CWCB)
- United States Forest Service (USFS)
- Local Municipalities: Park & Jefferson County, Towns & Cities.
- Federal Emergency Management Agency (FEMA)

Scale of Implementation

	Min — Max
Summary of Overall Effort	
Design & Permitting Effort	
Construction Time & Impact	
Maintenance Required (Scale & Frequency)	
Rough Cost Magnitude	

E.3 Treatment Table

This section provides a comprehensive table of pre- and post- fire treatment options that can be implemented in different locations across the North Fork WRAP planning area.

Treatment Name	Treatment Description	Appropriate Applications	Targeting Hazards	Timing	Labor- or Machine-Based Implementation	Scale of Feature (Cost, Impacts, Permitting, Design)	Order of Magnitude Cost Range
Process-Based Restoration							
Post Assisted Log Structures (PALS)	PALS and BDAs accomplish similar objectives but are often used in different settings. The intention is to slow water flow and create opportunities for sediment and debris collection. PALs require less migration room but are likely to influence geomorphology and hydrology. In general, BDAs are designed to alter baseflows while PALS are designed to affect bankfull flows. Materials consist of wood posts with woody debris woven in and biodegradable filter fabric.	These structures increase in channel roughness and complexity to reduce sediment transport capacity, floodplain connectivity, and wood retention. Works well in wood starved areas (if wood is imported).	Burn Severity Flooding Sediment Yield	Both (Pre-Fire & Post-Fire)	Labor- or Machine-Based	Level 2 or 3	$2,000 - $5,000 per feature
Engineered Log Jam	Structure that recreates historically occurring log structures and channel structural diversity. Can be anchored mid-stream or to the bank. Generally constructed to address a specific issue or protect an ecological value. Requires pre-planning to account for hydrology, sediment, and structural stability	These structures increase in channel roughness and complexity to reduce sediment transport capacity, floodplain connectivity, and wood retention. Works well in wood starved areas (if wood is imported). For use in larger systems and when longer life spans are desired.	Burn Severity Flooding Sediment Yield	Both (Pre-Fire & Post-Fire)	Machine-Based	Level 3	$10,000 - $30,000 per feature

Strategic Tree Felling	Strategic felling is intended to increase channel complexity, attenuate (trap) sediment, and retain woody debris. This approach involves felling large woody material (full trees), often burned trees, into the channel to provide the ingredients for the stream to create log jams during large flows. This can also be done on alluvial fans to decrease channelization and sediment transport.	Upper watersheds in remote areas that are at high risk to debris flows and post-fire flooding (high burn severity and steep slopes.	Flooding Sediment Yield	Both (Pre-Fire & Post-Fire)	Labor-Based	Level 1	\$100 - \$500 per feature
Riparian Buffers	Revegetation practice to preserve or expand a buffer zone between the stream and adjacent land use (in wildfire setting -> erodible slopes and gullies). Requires setting development restrictions and nay require planting to expand and revegetate designated buffer zones. Buffer width should be based on drainage area.	Stream reaches with abundant development and high VAR occurrence. Areas with high sedimentation rates .	Flooding Sediment Yield Erosion	Pre-fire	Labor-Based	Level 1	\$500 - \$10,000 per feature
Floodplain Grading	Removal of material to expedite the floodplain formation process within an incised stream. This can be vital to allow for more "floodplain connectivity" in entrenched and incised reaches by building a floodplain between the channel and the terrace.	Useful in regulated floodplains. Potentially useful in removing sediment sources.	Flooding Sediment Yield Erosion	Both (Pre-Fire & Post-Fire)	Machine-Based	Level 3	\$50 - \$200 per cubic yard
Willow Wattle	These features help to prevent erosion and assist in vegetation recovery in wetlands. They are made from harvested willow stakes and branches.	Useful in low energy environments in willow dominated systems.	Erosion Sediment Yield	Both (Pre-Fire & Post-Fire)	Labor-Based	Level 1	\$500 - \$2,000 per feature

Beaver Dam Analog (BDA)	BDAs are generally channel spanning structures that create pooling and sediment capture. BDAs are often used in broader areas with less confinement and medium energy potential. In general, BDAs are designed to alter baseflows while PALS are designed to affect bankfull flows. Materials consist of wood posts with woody debris woven in and biodegradable filter fabric.	Useful in pre-fire, low energy environments to halt and potentially reverse incision. Should be maintained and enhanced overtime.	FloodingSediment YieldErosion	Both (Pre-Fire & Post-Fire)	Labor-Based	Level 2	$1,000 - $5,000per feature
Roadway & Access Improvements							
Turnout sediment traps	Used on road turnouts and downslope of roads that are not able to be closed. The traps will be constructed from sediment piles and shored up with wood or straw bales for stability and filtration. Channels waters and sediment downslope from road to disperse in forested areas	On roadways where minor sediment and flood impacts are expected to prevent road closure/ damage. Requires suitable outlet/ storage area agent to roadway.	Erosion Flooding	Post-Fire	Machine-Based	Level 3	$5,000 - $10,000 per feature
Outsloping and Rolling Dips	Altering road or trail surface to disperse water and reduce rilling, gullies, and high erosion rates	Low to moderate sloped roads (<10%) in moderate and high burn severity areas	Erosion Flooding	Both (Pre-Fire & Post-Fire)	Machine-Based	Level 3	$2,000 - $5,000 per feature
Stream Fords or Armored Crossings	Intended to protect road infrastructure without diverting water from its channel. Can be implemented following culvert failure or anticipated failure. Typically slopes road down to channel elevation or allows a means for water to overtop a section of the road in high flow conditions. These can be	Roads often overtopped by mild flooding. Roads crossing ephemeral channels. Road crossings with anticipated culvert failure or plugging. Road crossings where high sediment delivery is anticipated	Erosion Flooding	Both (Pre-Fire & Post-Fire)	Machine-Based	Level 3B	$30,000 - $80,000 per feature

	designed to accommodate aquatic passage						
Culvert Improvements (Upsizing)	Generally, involves upsizing an existing culvert or crossing to accommodate anticipated or experienced increased runoff, debris, and sediment loads	High burn severity catchments or watersheds undersized culverts roads where maintaining access is critical	Erosion Flooding	Both (Pre-Fire & Post-Fire)	Machine-Based	Level 3C	$50,000 - $1,000,000 per feature
Debris Rack or Deflector	Structure intended to protect culverts from plugging with debris. The size of the culvert and anticipated debris size will influence the choice between a deflector or rack. Debris deflectors are used to route debris away from a culvert (used for medium to large debris). Debris racks are placed on culvert inlet to capture debris (used for small debris).	Vulnerable culverts at high risk from plugging. Areas with high occurrence of downstream infrastructure.	Flooding	Both (Pre-Fire & Post-Fire)	Machine-Based	Level 3C	$10,000 - $50,000 per feature
Stream Stabilization							
Native Rock Stabilization (Check)	Prevent channel incising and downcutting by hardening a segment of the stream. The goals is to simulate a cascade to disperse energy over hardened rock.	Area with adequate rock sources. Channels that are already incised or with a headcut in close proximity.	Erosion Flooding	Post-Fire	Machine-Based	Level 3A	$5,000 - $20,000 per feature
Large Wood Stabilization (Check)	A wood wall that is created in a channel vulnerable to incision from downstream headcutting.	Areas with limited rock sauces but adequate trees. Ideal for channels that are vulnerable to headcutting but not directly threatened.	Erosion Flooding	Post-Fire	Machine-Based	Level 3A	$2,000 - $10,000 per feature

Erosion Control Mat	Provides temporary soil stability while seeded or planted vegetation regrows. Requires manual instillation of organic matting materials staked into soil. To be used on overly steepened banks and slopes that threaten infrastructure.	Useful on streambanks, slopes, and areas with concentrated runoff where burn severity or soil loss is high. For useful in focused areas not over large areas.	Erosion Flooding	Post-fire	Labor-Based	Level 2	$1,000 - $10,000 per feature
Wood Apron	Woods placed parallel to flow to create a series of steps, dispersing energy and reducing scour.	Best for use in low energy environments (wetlands) unless heavy equipment and pinning is involved.	Erosion Flooding	Both (Pre-Fire & Post-Fire)	Labor-Based	Level 2	$500 - $5,000per feature
Bank Stabilization	Armoring an eroding bank with resistance material. Generally, this term is used to describe imported rock, but wood (especially at the toe) can be used and vegetation (typically willow staking) can be used depending on the scale and distance to VAR. Costs is wide ranging and depending on the stabilization level and stream size.	Should only be used with infrastructure is directly impacted. If anticipated migration of a channel is a concern, then the armoring material can be buried adjacent to infrastructure or soft approach can be used (wood or vegetation).	Erosion Flooding	Both (Pre-Fire & Post-Fire)	Labor- or Machine-Based	Level 3	$50 - $1,000 per linear foot
Hillslope Erosion & Sediment Issues							
Dry Mulch/ Slash Spreading	Reduces surface erosion and peak flows as well as improving conditions for seeds by securing soil and creating ideal moisture and temperature conditions. Includes spreading straw, woodchips, biochar, or fibrous materials on hillslopes and unvegetated soils. Can be completed through ground or aerial applications.	Soils with moderate to high burn severity/ areas with high erosion potential. Useful on slopes up to 65% grade. Most useful where other mitigation options are limited and erosion is	Erosion	Post-fire	Labor- or Machine-Based	Level 1	$2,000 - $10,000 per acre

Fiber Rolls and Wattles	Similar to directional felling, fiber rolls or wattles slow overland flow and erosion by shortening the slope length, reducing the velocity and quantity of water and sediment reaching the main channel. Rolls may be made or purchased and composed of straw or woody materials wrapped in netting. May also be constructed with live willow stakes to promote riparian vegetation growth. These should be weed-free and made of biodegradable materials to reduce the risk of leaving trash on the landscape.	Areas of high or moderate burn severity. Slopes between 20 and 40%. Areas with significant ground cover loss	Erosion	Post-fire	Labor-Based	Level 1	\$200 - \$500 per feature
Sediment & Debris Basins	Emergency structure that stores runoff and sediment. Often used as last resort to protect life and property or in areas where control over runoff is lost. Expensive to design and build. Long time frame for design and construction	Moderate to high burn severity areas. Ares where debris flow hazard has been identified before a fire. Areas with VARs and resources are imminently at risk. Sites with capacity to capture anticipated debris volume . Sites with good construction and maintenance access	Erosion	Post-Fire	Machine-Based	Level 3A	\$50,000 - >\$1,000,000 per feature
Hydromulching	Involves the use of a hydromulcher to spray a mix of soil stabilizer and seed mix on disturbed areas. Useful in stabilizing soil and seeding native species. Restricted to road-adjacent areas accessible for a driven or towed hydromulcher	Slopes between 20% and 50% with limited soil cover. Areas adjacent to roadways with high potential for invasive intrusion	Erosion	Post-fire	Machine-Based	Level 3	\$2,000 - \$20,000 per acre

Debris Flow Barrier	A large fence structure that is installed and founded to bedrock. This device catches, slows and stores debris flow material.	Very expensive mitigation tool. To be used only in high risk areas with lots of conflict with infrastructure. Buy-outs are typically cheaper and better long-term solutions.	Erosion	Post-fire	Machine-Based	Level 3	$250,000 - >$1,000,000 per feature
Emergency Measures to Protect Life & Property							
Diversion Berm	These features block and guide water away from valuable infrastructure. They are typical used when stream are highly unstable and dynamic. They can protect large areas downstream. They also produce less impact and will blend into the landscape after they are re-vegetated.	Useful to protect downstream of alluvial fan and in areas with high flow path uncertainty.	Flooding	Post-fire	Machine-Based	Level 3A	$100 - $300 per linear foot
Drainage Swale	Development of a channel to intercept and convey flow away from infrastructure.	Cost effective, but usually provides limited conveyance.	Flooding	Post-fire	Machine-Based	Level 3A	$50 - $200 per linear foot
Earthen Berm	These features block and guide water away from valuable infrastructure. They can be used to keep water from spilling out of a channel or to divert water around structures. The surface should be stabilized with erosion control mats.	Cost effective but not designed to be removed. Vulnerable to erosion if overtopped. Can be used to direct flow away or add capacity to channels.	Flooding	Post-fire	Machine-Based	Level 3A	$50 - $200 per linear foot
Flood Barrier Bags	These features block and guide water away from valuable infrastructure. They can be used to keep water from spilling out of a channel or to divert water around structures. Adding a berm, when space allows, means they will last longer, blend in more, and have more	Cost effective, but difficult to remove. Can be used to direct flow away or add capacity to channels.	Flooding	Post-fire	Machine-Based	Level 3B	$100 - $250 per linear foot

	resistance to erosion than an earthen berm						
Muscle Wall	These features block and guide water away from valuable infrastructure. They can be used to keep water from spill out of a channel or to divert water around structures. They are lighter and easier to move than Flood Barrier Bags but are more expensive. You can drain and reuse them after five years when the flood risk dissipates.	Most expensive option, but must easier to remove. Can be used to direct flow away or add capacity to channels.	Flooding	Post-fire	Machine-Based	Level 3B	$300 - $800 per linear foot

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APPENDIX F

Potential Funding Opportunities

Funding Sources

The following section provides information on federal, state, and private funding opportunities for conducting wildfire mitigation, stream resilience, and restoration and recovery projects. It should be noted that matched funding is often a requirement of funding, specifically from federal sources. Please note that programs may change requirements or close depending on their funding allocation and agency specific guidance. Since the development of this list, administrative changes may have impacted some programs. Please refer to each funding agencies website for the most up-to-date information on each program.

Local and Private Funding Information

Source: **National Forest Foundation:** NFF is a federally chartered organization that supports forest stewardship, conservation, and community engagement related to national forest land. Their primary goal is the continued health of national forest and grasslands achieved through uniting communities around protection, restoration, and thoughtful recreation on public lands. As part of this mission, the NFF manages multiple grant programs derived from federal dollars. Listed below are relevant NFF program details.

Website: https://www.nationalforests.org/grant-programs

The Matching Awards Program is the NFF flagship funding program which is intended to support community engagement and local stewardship efforts. Engaging the community is a primary focus of the program and should center around volunteering events, trainings and workshops, and community science projects. The objective of submitted projects should be to involve the public in National Forest stewardship or restoration activities such as trail maintenance, clean up events, invasive control, and forest and watershed restoration, among other eligible activities.

The Collaborative Capacity Program for Forests & Communities Program supports efforts by collaborative teams to improve forests and grasslands managed by the Forest Service. Efforts funded through this program must show thought and planning toward long-term stewardship with clearly defined outcomes. Funds may be used to support capacity building, skill development and technical services, planning, team development and engagement.

Agency: Patagonia

Website: https://www.patagonia.com/how-we-fund/

Description: Patagonia supports innovative work that addresses the root causes of the environmental crisis and seeks to protect both the environment and affected communities. Patagonia focuses on places where they have built connections through outdoor recreation and through their network of retail stores, nationally and internationally.

Source: **U.S. Endowment for Forestry and Communities**

Agency: U.S. Environmental Protection Agency, Natural Resources Conservation Service (NRCS), U.S. Forest Service, U.S. Department of Defense, U.S. Economic Development Agency

Website: https://www.usendowment.org/

Description: As the nation’s largest public charity dedicated to keeping our working forests working and ensuring their bounty for current and future generations, the Endowment deploys the creativity and power of markets to advance their mission: The Endowment works collaboratively with partners in the public and private sectors to advance systemic, transformative and sustainable change for the health and vitality of the nation's working forests and forest-reliant communities.

Source: **State Foresters Appropriations**

Agency: National Association of State Foresters

Website: https://www.stateforesters.org/appropriations/

Description: The National Association of State Foresters supports both federal (USDA) and State and Private Forestry programs. Funding allocations and points of contact are clearly displayed in the program fact sheets created by the National Association of State Foresters. Programs supported by NASF range across federal agencies including the EPA, USFS, and NRCS. Individual state Forest Action Plans provide guidance for how each state will prioritize funding allocation of these programs. Programs supported by NASF in 2024 include:

The Forest Stewardship Program specifically targets private landowners with forested lands. The program provides technical assistance and active management efforts t improve the health of forested lands that are privately held.

The State Fire Assistance and Volunteer Fire Assistance Programs provides financial and technical assistance to state and local fire departments to improve wildfire mitigation and response capabilities. The program will fund hazardous fuel management or technical capacity building to complete on the ground mitigation efforts.

The Urban and Community Forestry Program funds management of forests and trees within communities and urban settings. The program helps communities and cities maintain healthy green infrastructure through active management and research as well as disaster planning and recovery.

The Landscape Scale Restoration Program is intended to aid state foresters in implementing priority collaborative restoration and conservation efforts across boundaries and jurisdictions. The program aims to improve cooperative forest management and increase the scale of restoration and forest health projects.

The Forest Health Management on Cooperative Lands Program funds efforts to improve the management and resilience of forest lands, specifically targeting invasive species, pests, and disease. The desired outcome is a reduction in tree mortality and improved forest resilience to protect against intense forest fires and the long term impacts.

The Forest Legacy Program assists private landowners, state agencies, and conservation groups in acquiring land for conservation and implementing easements to protect and restore diverse forest lands.

The Section 319 Non-point Source Grant Program provides funds to implement best management practices during and after silviculture operations to protect water resources.

State Funding Information

Source: **Colorado State Forest Service Grants & Funding Assistance**

Agency: Colorado State Forest Service

Website: https://csfs.colostate.edu/grants/

Description: The Colorado State Forest Service manages multiple funding programs to assist private and public landowners in managing forested lands to mitigate the risk of wildfire and steward forests for ecological, economic, and social value. A list of current programs is provided here with links to respective program sites:

Public Programs

- Forest Restoration & Wildfire Risk Mitigation: https://csfs.colostate.edu/grants/forest-restoration-wildfire-risk-mitigation/
- Colorado IRA Urban and Community Forestry: https://csfs.colostate.edu/grants/ira-ucf/
- Wildfire Mitigation Incentives for Local Government: https://csfs.colostate.edu/grants/wildfire-mitigation-incentives-for-local-government/
- Wildfire Mitigation Outreach Grant Program: https://csfs.colostate.edu/grants/wildfire-mitigation-resources-best-practices-grant-program/

Private Landowner Programs

- Forest Ag Program: https://csfs.colostate.edu/forest-ag-program/
- Forest Legacy Program: https://csfs.colostate.edu/forest-legacy-program/
- Forest Stewardship Program: https://csfs.colostate.edu/forest-stewardship-program/
- Tree Farm Program: https://csfs.colostate.edu/tree-farm/

Business Programs

- Timber, Forest Health &Wildfire Mitigation Industries Workforce Development Program: https://csfs.colostate.edu/cowood/workforce-development/
- Wildfire risk Mitigation Loan Fund: https://csfs.colostate.edu/cowood/wildfire-risk-mitigation-loan-fund/

Source: **Colorado Strategic Wildfire Action Program**

Agency: Colorado Department of Natural Resources

Website: https://dnr.colorado.gov/divisions/forestry/co-strategic-wildfire-action-program

Description: In 2021, Senate Bill 21-258 was signed into law and established the Colorado Strategic Wildfire Action Program. This program is intended to bolster wildland firefighter capabilities by expanding workforce development, providing additional funds to hire more crew members, and helping state wildland inmate fire teams (SWIFT), find long term employment post-incarceration. This funding opportunity is intended to strategically address focal landscapes and concern areas through expanded mitigation and response capacity.

Source: **GOCO Planning and Capacity**

Agency: Great Outdoors Colorado

Website: https://goco.org/programs-projects/grant-programs/planning-and-capacity

Description: The Planning and Capacity grant program will fund projects related to planning, capacity building, research, and opportunity pathway development in the areas of outdoor recreation, access, stewardship, and conservation. Capacity building and education related projects should improve the ability of the applicant to make informed, actionable decisions. Research and information sharing is also fundable through this opportunity. Potential applicants should consult with their region program officer to discuss project relevance and scope.

Additional funding programs are available through GOCO such as the stewardship impact program and the RESTORE Colorado program, which is jointly managed by GOCO and NFWF, discussed below in federal funding.

Source: **Colorado Watershed Restoration Program**

Agency: Colorado Water Conservation Board

Website: https://cwcb.colorado.gov/watershed-grants

Description: This funding program is specifically targeted to produce Wildfire Ready Action Plans and implement projects intended to mitigate post-fire watershed impacts. Funding can be used for planning, engineering designs, and implementing projects that protects values from the potential impacts of post-wildfire watershed impacts.

Source: **Colorado Water Plans Grant**

Agency: Colorado Water Conservation Board

Website: https://cwcb.colorado.gov/watershed-grants

Description: The Water Plan Grant Program was created to support the implementation of goals and objectives of the 2023 Colorado Water Plan. Each potential project team must contact the local CWCB staff member that is responsible for the watershed in which work is planned. Efforts funded by this program can include water storage and sharing, conservation and land use planning, public engagement and innovation, agricultural improvements, and watershed health. Projects may involve planning, design, and implementation.

Source: **Project bill Grants**

Agency: Colorado Water Conservation Board

Website: https://cwcb.colorado.gov/watershed-grants

Description: The Project Bill Grants is a general investment fund that can be invested in watershed projects that may not fall within other CWCB funding programs. Projects are assessed and approved on a case-by-case basis depending on current geographic needs. Notably, the program will fund river and floodplain restoration and management. Projects must have an economic nexus and improve or maintain a valuable industry in the state such as agriculture.

Source: **Colorado Healthy Rivers Fund**

Agency: Colorado Watershed Assembly

Website: https://www.coloradowater.org/colorado-healthy-rivers-fund-1

Description: The Healthy River Fund is dedicated to supporting collaborative efforts in watersheds that protect and restore watershed health and function. The program will fund planning and project implementation. This can include implementing TMLs, best management practices, channel stability and riparian restoration, flood prevention, habitat improvements, and monitoring activities.

Other Colorado Watershed Assembly Funding Programs: CWA regularly updates their website with funding opportunities from agencies and private entities. The objective and eligibility of these listings varies so please visit the below link for the latest information on watershed funding opportunities: https://www.coloradowater.org/funding-opportunities

Federal Funding Information

Please note that some funding sources, specifically FEMA funds may be specific to post-disaster

Source: **Tribal Lands Landscape Scale Restoration Grants**

Agency: First Nations Development Institute

Website: https://www.firstnations.org/projects/landscape-scale-restoration/

Description: For more than 41 years, First Nations Development Institute (First Nations), a Native-led 501(c)(3) nonprofit organization, has worked to strengthen American Indian economies to support healthy Native communities by investing in and creating innovative institutions and models that strengthen asset control and support economic development for American Indian people and their communities. FNDI supports a series of grants focused on controlling and protecting food systems, water, languages, traditional ecological knowledge, and land. They support landscape restoration grants funded through the USDA Forest Service to support priority forest landscapes at a high wildfire risk.

Source: **Innovative Finance for National forests**

Agency: U.S. Department of Agriculture

Website: **https://www.usendowment.org/ifnf/**

Description: The Innovative Finance for National Forests Grant Program aims to bring in non-USFS funds to increase forest resilience. There are three main topics for funding: wildfire resilience and recovery, sustainable recreation access and infrastructure, and watershed health. In addition, three types of projects are funded: pilot programs with on-the-ground implementation, scaling projects to deliver backlogs of unfunded work, and research and development to provide to new forest information.

Source: **Building Resilient Infrastructure and Communities (BRIC) Grant Program**

Agency: Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA)

Website: https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

Description: BRIC will support states, local communities, tribes, and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. The BRIC program guiding principles are supporting communities through capability- and capacity-building; encouraging and enabling innovation; promoting partnerships; enabling large projects; maintaining flexibility; and providing consistency.

Source: **Hazard Mitigation Grant Program (HMGP)**

Agency: FEMA

Website: https://www.fema.gov/grants/mitigation/hazard-mitigation

Description: The HMGP provides funding to state, local, tribal, or territorial governments (and individuals or businesses if the community applies on their behalf) to rebuild with the intentions to mitigate future losses due to potential disasters. This grant program is available after a presidentially declared disaster.

Source: **Hazard Mitigation Grant Program (HMGP) – Post Fire**

Agency: FEMA

Website: https://www.fema.gov/grants/mitigation/post-fire

Description: The HMGP Post Fire grant program provides assistance to communities for the purpose of implementing hazard mitigation measures following a wildfire. Mitigation measures may include:

- Soil stabilization
- Flood diversion
- Reforestation

The program is intended to reduce the potential impacts of flooding, erosion, and sedimentation that may occur on post fire landscapes and directly impact infrastructure, watersheds, and recovery efforts.

Source: **Flood Mitigation Assistance (FMA) Grant**

Agency: FEMA

Website: https://www.fema.gov/grants/mitigation/floods

Description: The Flood Mitigation Assistance Program is a competitive grant program that provides funding to states, local communities, federally recognized tribes, and territories. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program. FEMA chooses recipients based on the applicant's ranking of the project and the eligibility and cost-effectiveness of the project.

Source: **Emergency Management Performance Grant (EMPG)**

Agency: FEMA

Website: https://www.fema.gov/grants/preparedness/emergency-management-performance

Description: The EMPG program provides funding to state, local, tribal, and territorial emergency management agencies with the overall goal of creating a safe and resilient nation. The two main objectives of the program are 1) closing capability gaps that are identified in the state or territory's most recent Stakeholder Preparedness Review (SPR); and 2) building or sustaining those capabilities that are identified as high priority through the Threat and Hazard Identification and Risk Assessment (THIRA)/SPR process and other relevant information sources. The grant recipient and Regional Administrator must come to an agreement on program priorities, which are crafted based on National, State, and regional priorities.

Source: **Regional Catastrophic Preparedness (RCP) Grants**

Agency: FEMA

Website: https://www.fema.gov/grants/preparedness/regional-catastrophic

Description: The Regional Catastrophic Preparedness Grant program provides funding to increase collaboration and capacity in regard to catastrophic incident response and preparation. The program will fund planning, capacity building, outreach and education campaigns, and local studies. The objective of proposed project must be to improve community resilience to natural disasters in regard to housing and community safety, response and recovery, and long-term sustainability and preparedness.

Source: **Emergency Forest Restoration Program (EFRP)**

Agency: USDA Farm Service Agency (FSA)

Website: https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/emergency-forest-restoration/indexprogram/emergency-forest-restoration/index

Description: The Emergency Forest Restoration Program (EFRP) helps the owners of non-industrial private forests restore forest health damaged by natural disasters. The EFRP does this by authorizing payments to owners of private forests to restore disaster damaged forests. The local FSA County Committee implements EFRP for all disasters with the exceptions of drought and insect infestations. Eligible practices may include debris removal, such as down or damaged trees; site preparation, planting materials, and labor to replant forest stand; restoration of forestland roads, fire lanes, fuel breaks, or erosion-control structures; fencing, tree shelters; wildlife enhancement. To be eligible for EFRP, the land must have existing tree cover; and be owned by any nonindustrial private individual, group, association, corporation, or other private legal entity.

Source: **Emergency Conservation Program (ECP)**

Agency: USDA Farm Service Agency (FSA)

Website: https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/indexconservation/index

Description: The Emergency Conservation Program (ECP) helps farmers and ranchers to repair damage to farmlands caused by natural disasters and to help put in place methods for water conservation during severe drought. The ECP does this by giving ranchers and farmers funding and assistance to repair the damaged farmland or to install methods for water conservation. The grant could be used for restoring conservation structures (waterways, diversion ditches, buried irrigation mainlines, and permanently installed ditching system).

Source: **Environmental Quality Incentives Program (EQIP)**

Agency: National Resource Conservation Service (NRCS)

Website: https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives

Description: The Environmental Quality Incentives Program (EQIP) is a voluntary program authorized under the Agricultural Act of 2014 (2014 Farm Bill) that helps producers install measures to protect soil, water, plant, wildlife, and other natural resources while ensuring sustainable production on their farms, ranches, and forest lands. Funds can be used to improve water quality and system function, reduce erosion and sedimentation, and mitigate against volatile weather amongst other activities. Forest and wildlife resource focused lands are eligible for funding in addition to traditional agricultural operations.

Source: **Emergency Watershed Protection (EWP) Program**

Agency: National Resource Conservation Service (NRCS)

Website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

Description: The program offers technical and financial assistance to help local communities relieve imminent threats to life and property caused by floods, fires, windstorms, and other natural disasters that impair a watershed. The program requires that a local watershed emergency be declared by the state NRCS conservationist and that activities are supported by a local sponsor.

Eligible sponsors include cities, counties, towns, conservation districts, or any federally recognized Native American tribe or tribal organization. Interested public and private landowners can apply for EWP Program recovery assistance through one of those sponsors.

EWP Program covers the following activities.

- Debris removal from stream channels, road culverts, and bridges
- Reshape and protect eroded streambanks
- Correct damaged drainage facilities
- Establish vegetative cover on critically eroded lands
- Repair levees and structures
- Repair conservation practices

Source: **Tribal Environmental General Assistance Program (GAP)**

Agency: Environmental Protection Agency (EPA)

Website: https://www.epa.gov/tribal/region-8-tribal-affairs-branch#FON

Description: Funding under this program is used to aid Native American tribes in establishing and implementing their own reservation-specific environmental protection programs. To find out more about this funding opportunity please contact Tribal Branch Manager, Kimberly Varilek, at varilek.kimberly@epa.gov.

Source: Specific EPA Grant Programs

Agency: Environmental Protection Agency (EPA)

Website: https://www.epa.gov/grants/region-8-grants-information

Description: Various grant programs are listed under this site. Listed below are examples of grants offered:

- Multipurpose Grants to States and Tribes: https://www.epa.gov/grants/multipurpose-grants-states-and-tribes
- Environmental Education Grants: https://www.epa.gov/education/grants
- Environmental Justice Grants: https://www.epa.gov/environmentaljustice/environmental-justice-grants-funding-and-technical-assistance

Source: **Conservation Innovation Grants (CIG)**

Agency: National Resource Conservation Service

Website: https://www.nrcs.usda.gov/programs-initiatives/cig-conservation-innovation-grants

Description: CIG State Component. CIG is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program (EQIP) funds are used to award competitive grants to non-federal governmental or nongovernmental organizations, tribes, or individuals. CIG enables the Natural Resources Conservation Service (NRCS) to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with federal, state, and local regulations. The NRCS administers the CIG program. The CIG requires a 50/50 match between the agency and the applicant. The CIG has two funding components: national and state. Funding sources are available for water resources, soil resources, atmospheric resources, and grazing land and forest health.

Source: **Urban and Community Forestry Program, National Urban and Community Forestry Challenge Cost Share Grant Program**

Agency: U.S. Forest Service

Website: https://www.fs.usda.gov/managing-land/urban-forests/ucf

Description: U.S. Forest Service funding will provide for Urban and Community Forestry Programs that work with local communities to establish climate-resilient tree species to promote long-term forest health. The other initiative behind this program is to promote and carry out disaster risk mitigation activities, with priority given to environmental justice communities. The primary goals of the program change annually and are based on the National Ten Year Urban and Community Forestry Action Plan. The current cycles goals are 1: increase biodiversity, health, and resilience of community forests, and 2: support the use of more locally grown, regionally adapted, insect and pest resistant, and diverse native or site-appropriate species.

Source: **Catalog of Federal Funding Sources; Land Resources**

Agency: Multiple

Website: https://ofmpub.epa.gov/apex/wfc/f?p=165:512:6483383318137:::512::

Description: The Land Finance Clearing House is a catalogue of Federal funding sources for all things land related.

Examples of the types of grants found at this site are:

- Forest and Woodlands Resource Management Grant: https://sam.gov/fal/3258dad2c3d247a9a8fcdedb398e3195/view
- Environmental Education Grant: https://www.epa.gov/education/grants
- Public Assistance Grant Program: https://www.fema.gov/assistance/public
- Hazard Mitigation Grant: https://www.fema.gov/grants/mitigation/hazard-mitigation

Source: **Catalog of Federal Funding Sources; Water Resources**

Agency: Multiple

Website: https://ofmpub.epa.gov/apex/wfc/f?p=165:12:6483383318137:::12::

Description: The Water Finance Clearing House is a catalogue of Federal funding sources for all things water related. One example is the WaterSMART Water and Energy Efficiency Grant: https://www.usbr.gov/watersmart/weeg/.

Source: **Firewise Communities**

Agency: Multiple

Website: http://www.firewise.org

Description: Many different Firewise Communities activities are available to help homes and whole neighborhoods become safer from wildfire without significant expense. Community cleanup days, awareness events, and other cooperative activities can often be successfully accomplished through partnerships among neighbors, local businesses, and local fire departments at little or no cost. The kind of help you need will depend on who you are, where you are, and what you want to do. Among the different activities that individuals and neighborhoods can undertake, the following often benefit from seed funding or additional assistance from an outside source:

- Thinning/pruning/tree removal/clearing on private property—particularly on large, densely wooded properties
- Retrofit of home roofing or siding to non-combustible materials
- Managing private forest
- Community slash pickup or chipping
- Creation or improvement of access/egress roads
- Improvement of water supply for firefighting
- Public education activities throughout the community or region

Source: **The National Fire Plan (NFP)**

Agency: DOI & USDA

Website: https://www.forestsandrangelands.gov/resources/communities/index.shtml

Description: Many states are using funds from the NFP to provide funds through a cost-share with residents to help them reduce the wildfire risk to their private property. These actions are usually in the form of thinning or pruning trees, shrubs, and other vegetation and/or clearing the slash and debris from this kind of work. Opportunities are available for rural, state, and volunteer fire assistance.

Source: **GSA-Federal Excess Property Auctions**

Agency: USFS

Website: https://gsaauctions.gov/auctions/home

Description: The Federal Excess Property Auction is a way for federally owned equipment to be auctioned to public owners. Most of the property originally belonged to the Department of Defense (DoD). The platforms allows for online bidding on equipment ranging from fire trucks, boats, heavy equipment, and other items.

Source: **Inflation Reduction Act (IRA): Landowner Assistance Programs**

Agency: USDA

Website: https://www.fs.usda.gov/about-agency/state-private-forestry/coop-forestry/ira-forest-landowner-support

Description: The Inflation Reduction Act (IRA) Forest Landowner Support Programs, operating under the Cooperative Forestry Assistance Act of 1978 and aligning with the Landscape Scale Restoration (LSR) program guidelines, provide crucial financial support to underserved and small-acreage forest landowners. Launched formally on August 22, 2023, this initiative welcomes proposals from diverse entities, including tribes, nonprofits, and governments. It specifically targets non-industrial private land in rural areas, extending support to a range of underserved landowners, including beginners, those in poverty areas, tribes, limited resource producers, and veterans. The identification of geographic locations utilizes tools such as the Climate and Economic Justice Screening Tool and USDA Economic Research Service measures. By fostering climate solutions, the IRA Landowner Assistance Programs play a pivotal role in overcoming historical barriers to the participation of underserved communities in climate mitigation and forest resilience efforts.

Source: **Landscape Scale Restoration (LSR)**

Agency: USFS

Website: https://www.fs.usda.gov/managing-land/private-land/landscape-scale-restoration

Description: The Landscape Scale Restoration (LSR) program is a competitive grant initiative promoting collaborative, science-based restoration of priority forest landscapes. It allocates funds to projects across multiple jurisdictions, addressing issues like wildfire risk, watershed protection, and invasive species. Projects result in on-the-ground impacts through stakeholder collaboration. Eligibility is extended to state forestry agencies, local government units, Indian Tribes, non-profits, universities, and Alaska Native Corporations. They can request funds between $25,000 and $300,000 with a three-year project life. Funds are dedicated to rural nonindustrial private forest or state forest land outside urbanized areas. The program operates with a 1:1 match requirement, awarding funds through competitive grants and cooperative agreements. For non-Tribal applications, states can submit up to five proposals annually through forestrygrants.org. The Western Forestry Leadership Coalition manages the process, with a review team evaluating submissions in western states and Pacific Island territories.

Source: **Forest Stewardship Program (FSP)**

Agency: USFS

Website: https://www.fs.usda.gov/managing-land/private-land/forest-stewardship

Description: The Forest Stewardship Program (FSP) collaborates with state forestry agencies, cooperative extension, and conservation districts to equip private landowners with tools for effective forest management. Actively managed private forests provide timber, fuel wood, wildlife habitat, watershed protection, and recreational opportunities, benefiting both landowners and adjacent National Forest System lands. Through the capacity grants to state forestry agencies, the FSP supports private forest landowners in maintaining the productivity and health of their forests. These grants aim to enhance economic and environmental benefits, ensuring the sustainability of privately owned forests.

Source: **Wood Innovations Funding Opportunity Program/Wood Innovations Grant Program**

Agency: USDA

Website: https://www.fs.usda.gov/science-technology/energy-forest-products/wood-innovation

Description: The Wood Innovations Grant Program, under the Bipartisan Infrastructure Law and Inflation Reduction Act (IRA), allocates $20 million to support projects expanding traditional wood use. The program aims to reduce hazardous fuels, enhance forest health, lower forest management costs, and foster economically and environmentally healthy communities. Eligible applicants include for-profit and non-profit entities, government bodies, tribes, educational institutions, communities, and special purpose districts. Priority is given to proposals creating or expanding markets for wood from forest health projects, supporting domestic timber development, involving wood industry partnerships, promoting innovative wood products in commercial building markets, addressing wood energy projects, and projects benefiting underserved communities.

Source: **Habitat Restoration and Enhancement Funding**

Agency: National Fish and wildlife Foundation

Website: https://www.nfwf.org/apply-grant

Description: The National Fish and wildlife Foundation is a congressionally chartered private conservation foundation that works on public and private lands to protect fish, wildlife, and plant species and restore requisite habitats for specific species or to accomplish broader ecosystem specific objectives. Funds are provided through federal allotments and corporate contributions. Below are some of the current NFWF programs that fund work related to forest management, wildfire mitigation, stream restoration, and forest rehabilitation:

The America The Beautiful Challenge began as a result of funds from the Infrastructure Investment and Jobs Act to broadly address the need for ecosystem restoration across the country. The program prioritizes efforts from collaborative project teams working across large landscapes or improving conditions in historically underserved areas. Fundable projects are those that conserve or restore rivers, coasts, wetlands, forests, grasslands, and other systems, improving habitat connectivity, improving community resilience to climate related threats, and expanding outdoor access.

The RESTORE Colorado Program is intended to fund large scale habitat restoration and stewardship efforts on public and private lands. Projects must benefit wildlife and or local community resilience. Work through this program can be completed in river corridors, wetlands, forested lands, grasslands, and sagebrush habitats.

Source: **Community Wildfire Defense Grant**

Agency: USFS

Website: https://www.fs.usda.gov/managing-land/fire/grants

Description: The Community Wildfire Defense Grant is intended to help communities with a high wildfire risk plan and implement the goals of the National Cohesive Wildland Fire Management Strategy. These goals include restoring and maintaining landscapes, creating fire adapted communities, and improving wildfire response. Funds are available to develop or update community wildfire protection plans and to implement projects listed in CWPPs that are less than 10 years old. At risk communities are those positioned in fire prone areas, low-income communities, and those that have been impacted by a severe disaster.

Source: **Forest Legacy Program (FLP)**

Agency: USDA Forest Service

Website: https://www.fs.usda.gov/managing-land/private-land/forest-legacy

Description: The Forest Legacy Program (FLP) is a conservation initiative administered by the USDA Forest Service in collaboration with state agencies. Operating since 1990, FLP aims to identify and conserve environmentally and economically significant forested areas facing the threat of conversion to non-forest uses. FLP incentivizes landowners to maintain their forests, securing public benefits such as water quality, fish and wildlife habitat, and supporting forest product industries. Funded by the Land and Water Conservation Fund (LWCF), which receives earnings from offshore oil and gas leasing, FLP plays a crucial role in protecting privately owned managed forest lands. This is achieved through conservation easements (CEs) or land purchases, allowing landowners to either sell their property outright or retain ownership while selling development rights. The perpetual legal agreement of a CE ensures private ownership while preserving environmental values.

Source: **Wildland Urban Interface Grant Program**

Agency: Council of Western State Foresters/ USFS

Website: https://www.westernforesters.org/wui-grants

Description: The Wildland Urban Interface Grant Program is intended to address hazardous fuels in the WUI, information and education, assessment and planning, and monitoring activities. With funds from the USFS, the CWSF administers the WUI program to prioritize actions that directly reduce hazardous fuels in the interface, improve community preparedness knowledge, and develop or update a CWPP. Interested applicants must contact their state forester to discuss the project and funding needs. Projects that emphasis cross boundary or landscape scale work will be prioritized. Hazardous fuel reduction projects will receive 70% of funding. Fundable projects include defensible space improvements, thinning and fuel breaks, education material development and events, firewise or other programs, CWPP planning, and other similar projects.

Source: **Action, Implementation, & Mitigation Grant**

Agency: Coalitions and Collaboratives/ USFS

Website: https://co-co.org/get-involved/grants/aim-grant/

Description: The program is intended to increase community resilience, restore fire adapted ecosystems, and create safer conditions for residents and fire fighters. A variety of projects are funded that support wildfire risk reduction to communities with an existing or planned CWPP. Projects can include planning and or implementation in communities with moderate to high wildfire risk. Projects must demonstrate multi agency coordination and efforts toward landscape scale resilience.

Funding Sources for Homeowners

Source: **Colorado Wildfire Resilient Home Grant**

Agency: Colorado Division of Fire Prevention and Control

Website: https://nocofireshed.org/colorado-wildfire-resilient-homes-grant-program-now-accepting-applications/

The Wildfire Resilient Home Grant was developed in 2023 through House Bill 23-1273 and allocate $100,000 annually to fund retrofitting of homes to reduce structural ignitability. The grant will fund materials replacement (roofing, fencing, windows, etc.), landscaping improvements, and other defensible space and home ignition retrofits that reduce the likelihood of home ignition and spread. Homeowners must apply individually and submit a home ignition zone survey as part of the application. Funds are issued as reimbursements once work is completed.

Source: **Forest Legacy Program**

Agency: Colorado State Forest Service

Website: https://csfs.colostate.edu/forest-legacy-program/

The Forest Legacy Program is a federally funded initiative to assist in the acquisition or designation of conservation easements on privately owned forest land. The program was established to permanently protect portions of Colorado's forests that contribute to the state's ecological and scenic value while maintaining sustainable uses of forest resources such as recreation. Funds are primarily provided by the federal government with matching funds required by state funders or conservation organizations to purchase or secure forested lands. Conserved lands can be kept under private ownership or opened to public access through this easement program.

Source: **Wildfire Mitigation Resources & Best Practices Grant Program**

Agency: Colorado State Forest Service

Website: https://csfs.colostate.edu/grants/wildfire-mitigation-resources-best-practices-grant-program/

The Colorado Legislature established the Wildfire Mitigation Resources & Best Practices Grant Program in 2022. This program provides state support to conduct outreach among landowners in high wildfire hazard areas. To be eligible, a recipient must be an agency of local government, a county, municipality, special district, a tribal agency or program, or a nonprofit organization. The Colorado State Forest Service has $300,000 available for grant awards through this program.

Source: **Homesite Assessments**

Agency: Colorado State Forest Service

Website: https://csfs.colostate.edu/homeowners-landowners/homesite-assessments/

CSFS foresters are available to assist homeowners and landowners through homesite assessments. A forester will visit your land and examine your trees for disease, wildland fire defensible space, and overall health. They can make recommendations for disposing of diseased trees, safeguarding your trees, keeping your trees healthy and reducing their risk of disease, and mitigating the risk of catastrophic wildfire. For more information or to schedule a homesite assessment, contact a local CSFS Field Office.

Other Funding Information

The following resources may also provide helpful information for funding opportunities:

- Western Forestry Leadership Coalition: https://www.thewflc.org/
- USDA Information Center: https://www.nal.usda.gov/main/information-centers
- Forest Service Fire Management website: https://www.fs.usda.gov/science-technology/fire
- Insurance Services Office Mitigation Online (town fire ratings): http://www.isomitigation.com/
- National Fire Protection Association: http://www.nfpa.org
- National Interagency Fire Center, Wildland Fire Prevention/Education: https://www.nifc.gov/fire-information/fire-prevention-education-mitigation
- Department of Homeland Security U.S. Fire Administration: https://www.usfa.fema.gov/index.html

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