Attachment #1

RESPEC

ANCHORPOINT

carollo

City of Steamboat Springs

Mount Werner Water District

FISH CREEK CRITICAL COMMUNITY WILDFIRE WATERSHED PROTECTION PLAN (CWP)²

PREPARED FOR
City of Steamboat Springs
137 10th St
Steamboat Springs, CO 80487

AND

Mount Werner Water & Sanitation District
3310 Clearwater Trail
Steamboat Springs, CO 80487

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RSI-3518

September 2019

Fish Creek Critical Community Watershed Wildfire Protection Plan (CWP)²

prepared for

City of Steamboat Springs

And

Mt Werner Water and Sanitation District

prepared by

RESPEC Consulting & Services, Inc.
Anchor Point Group, LLC.
Carollo Engineers

September 2019

EXECUTIVE SUMMARY

With the increasing frequency and severity of wildfires resulting from the cumulative impacts of climate change, overgrown forests, and pest infestations, managers of surface water supply systems in forested watersheds must address wildfire impacts when planning for water security. Steamboat Springs' water is sourced from the Fish Creek basin, a heavily forested watershed, vulnerable to wildfire. The basin provides over 90 percent of the community's drinking water; and, the direct drainage to the Fish Creek Filtration Plant (FCFP) is located entirely within Routt National Forest (RNF), with the majority in designated Roadless Areas. It is characterized by high elevation mixed conifer forests, interspersed with montane meadows and fen wetlands (groundwater supplied) in the riparian corridors, and aspen and shrublands at lower elevations.

The City of Steamboat Springs (City), Mount Werner Water and Sanitation District (District), and greater community have long been aware of the threats that wildfire poses to their water supply and have called for the development of a cross-jurisdictional plan to address these threats in numerous water, wildfire, and forest related planning documents. The Fish Creek Critical Community Watershed Wildfire Protection Plan $(CWP)^2$ represents the culmination of these previous efforts. It was conducted for the City, in partnership with the District, and funded by a grant through the Colorado Water Conservation Board (CWCB) to support objectives outlined in the State Water Plan. The primary objective of the Fish Creek $(CWP)^2$ was to develop a plan through an open and collaborative process with stakeholders to clearly define and prioritize site specific measures to implement within the water supply system and the watershed as a whole before, during, and after a wildfire event to protect critical drinking water supply, infrastructure and watershed health, as well as identify/ prioritize improvements and/or modifications to water treatment facility and/or reservoir operations to address postfire water quality impacts.

The City and District recognized from the outset that collaboration would be vital to ensure a successful wildfire mitigation planning effort. Without support from key partners, the mitigation planning effort could easily result in a "shelf document" that would not ultimately provide the value of protecting water-supply. Therefore, upon project initiation, the project leads assembled a Core Team of land/resource managers and subject matter experts to operate as an advisory committee to guide the planning effort throughout the development of the plan that included representatives from the following local, state and federal agencies/ organizations: US Forest Service (USFS), Colorado State Forest Service (CSFS), Routt County Office of Emergency Management (OEM), Routt County Environmental Health Department, Steamboat Springs Fire District, and Yampa Valley Sustainability Council (YVSC). Members of this group were actively engaged throughout the project, so it could benefit from their technical expertise and local and institutional knowledge. Feedback from the Core Team on the technical analyses, and particularly on project identification and prioritization in the context of agency priorities and constraints, has been invaluable to the development of the Fish Creek $(CWP)^2$.

The technical analyses centered on watershed risk assessment, which consisted of identifying both wildfire and postfire hazards. The wildfire hazard identification methodology employed FlamMap fire-behavior modeling, which is used by federal agencies to assess and manage fire events. The postfire hydrologic hazard identification integrated the wildfire hazard information, RNF soil survey data, watershed topography, National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation frequency datasets using US Geological Survey (USGS) debris flow models. This enabled the quantification of potential sediment delivery to water-supply reservoirs and critical infrastructure, while a high-level geomorphic assessment, pre/postfire peak flow modeling, and desktop topographic identified the most likely deposition, hydrologically problematic, and potential hydrologic/ sediment control locations throughout the watershed.

Information derived from each analysis was synthesized to produce a composite hazard index to determine the Watershed Risk Map, which identifies the areas within Steamboat Springs' water-supply drainage area most likely to contribute large sediment loads to critical infrastructure, as shown in Figure ES-1. A sensitivity analysis was conducted to determine areas where reducing the potential for a severe wildfire would have the greatest impact in reducing the resultant postfire hydrologic hazard. The identified areas were evaluated in the context of previous, ongoing, planned projects and access issues in the watershed to develop the Final Prioritized Watershed Map, shown in Figure ES-2. Water supply system infrastructure/ operational improvements involved a separate analysis of expected water quality impacts and FCFP processes. Project opportunities were identified around the following goals:

- A more wildfire resistant landscape in the watershed;
  - Recommendations include evaluating/ maintaining/ enhancing: natural features that can serve to mitigate wildfire and postfire impacts, upland forest condition and emerging silviculture strategies, existing fuels reduction projects along high use corridors (i.e. roads and trails) and recreational areas (trailheads and campgrounds), as well as accomplishing fuels treatments identified in previous CWPPs (Fish Creek Sanctuary and Burgess Creek) that can buffer the basin from fires originating in the community.
- Timely and effective implementation of postfire hydrologic/ sediment controls in the watershed if a damaging fire does occur;
  - Recommendations are focused around supporting the USFS led Burned Area Emergency Response (BAER) process, which provides emergency assessment and stabilization for burned National Forest System lands. While the majority of recommendations are for actions that would be taken after a wildfire (hence, are dependent on actual fire location/ conditions), there are actions that can be taken before a fire to support BAER (e.g. rain gauge installation, sourcing erosion control materials) and prepare for long term recovery/ restoration.
- Community and guests that are educated about where their drinking water comes from and the threat of wildfire to their water supply, and are responsible recreational users of watershed;
  - Recommendations to inform and engage the Steamboat Springs community and its guest are centered around a mounting a public relations campaign (in collaboration with partners) that will reach recreational users of Fish Creek Basin and around organizing volunteer days to accomplish projects and encourage a culture of stewardship in the watershed.
- Coordinated preemptive mitigation (including outreach), wildfire response, postfire emergency stabilization, and watershed recovery and restoration;
  - Recommendations regarding coordination/ collaboration are included to facilitate and prioritize working together with partners to achieve the goals of the $(CWP)^2$. Coordination and collaboration are foundational to accomplishing preemptive mitigation and outreach projects, and critical for ensuring a timely and effective wildfire and postfire response.
- Water supply system resiliency.
  - Recommendations to improve water supply system infrastructure/ operations are the only set that do not rely on collaboration with partners. Moreover, these directly support Steamboat Springs City Council's goal to "identify and implement strategies to promote water supply resiliency," and should be considered very high priority. Actions have been prioritized by what can be accomplished in the near, mid, and long-term and include supporting the development of water supply redundancy that is currently underway.

Specific recommendations are summarized in Table ES-1; these are described in detail in the in Plans & Projects and Infrastructure/ Operational Improvements Sections (Sections 7 and 8). The Implementation Strategy and Action Plan in (Section 9) prioritizes actions that can be taken before, during, and after wildfire occurrence, and Section 10 describes Monitoring & Evaluation procedures to track progress toward achieving (CWP)2 objectives and maintain the momentum created by this planning process as it moves into the implementation phase.

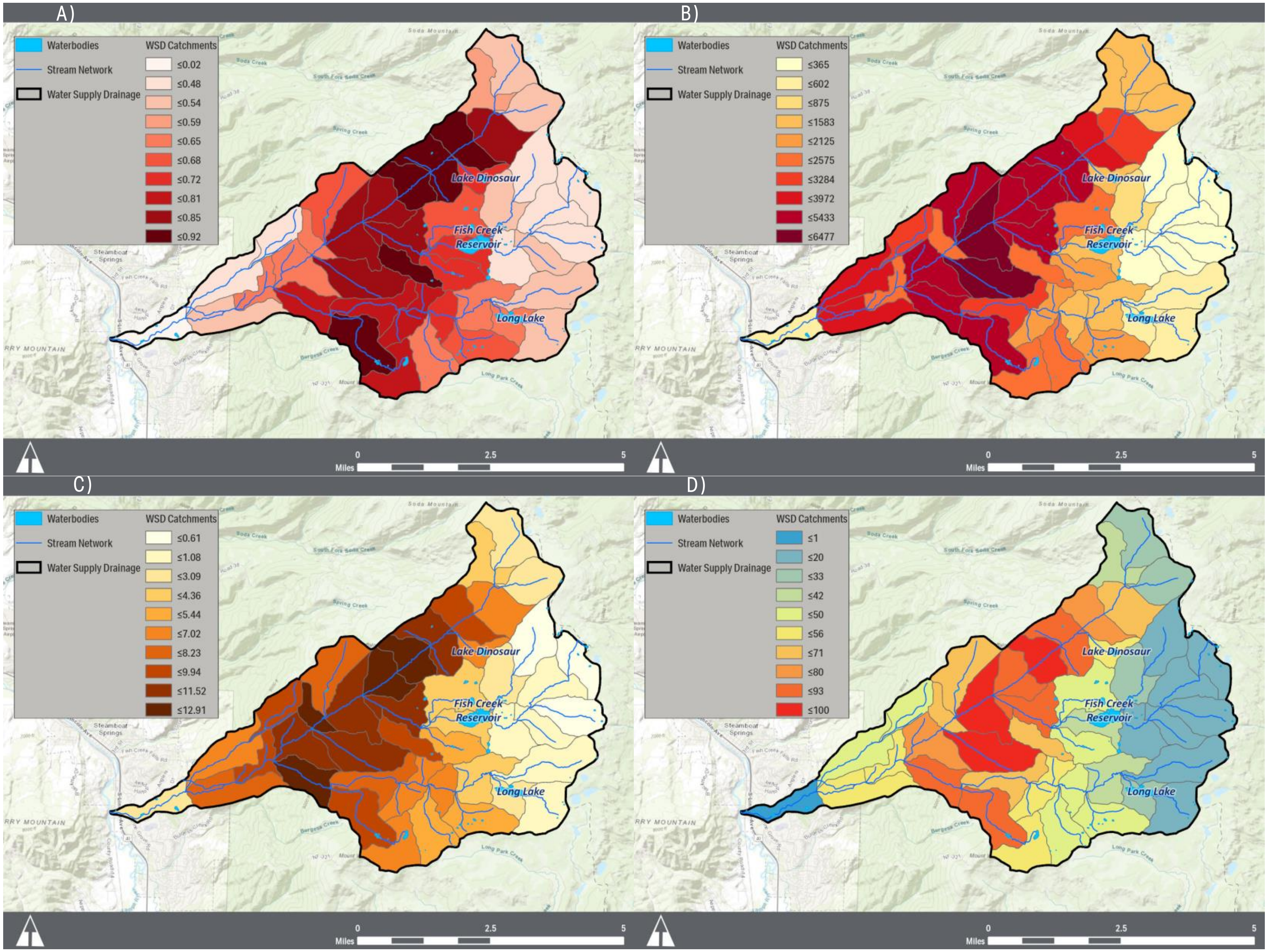

Figure ES-1. Debris Flow A) Probability (percent), B) Volume (m^3), C) Relative Mass (ton/acre), and D) Composite Hazard Index (Watershed Risk Map).

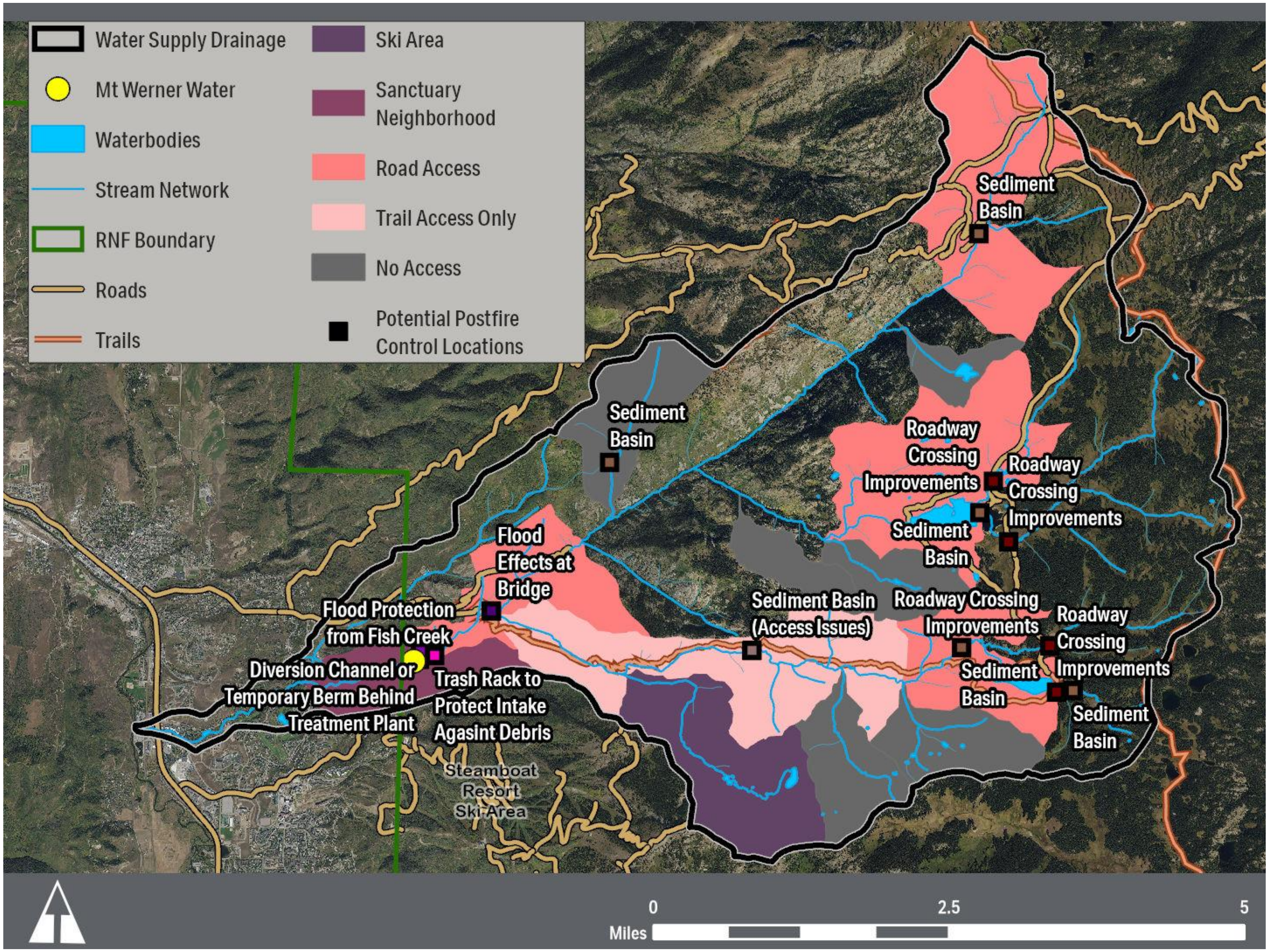

Figure ES-2 Final Watershed Prioritized Map , Overlain with Road and Trail Access.

Table ES-1. Recommendation Summary

Project/ Action Item	Description	Cost / Time Estimate
A more wildfire resistant landscape in the watershed		
Treatment Plant Protection	Create defensible space using Zone concept.	$1,000-2,000/ acre
Previous CWPP Projects	Evaluate/ complete Sanctuary and Burgess Creek CWPP recommendations; partner with Ski Resort and on Rout Co. CWPP.	$3,000-5,000/ acre
Roads, Trails. Campgrounds	Work with USFS to evaluate/ maintain fuels treatments in/ along high use areas/ corridors.	$3,000-5,000/ acre
Riparian Corridors	Assess, monitor, and maintain wetlands and riparian corridors in the upper watershed.	work with USFS
Upland Forests	Assess/ monitor upland forest condition; reconstruct basin fire history; monitor ASCC/ CSFS long-term silviculture/climate change study.	work with CSFS
Timely and effective implementation of postfire hydrologic/ sediment controls in the watershed if a fire occurs		
Rain Gauge Installation	Partner with NWS to install a rain gauge in the upper watershed.	$1,500-4,000
BAER Support	BAER rapidly evaluates the burned area and prescribe emergency stabilization treatments; it also coordinates with NRCS, other local, state, and federal agencies that aid private landowners. Steamboat can support BAER by having local suppliers of erosion control materials (wood straw, wood shred), and providing the (CWP)2 data package.	USFS funded, FEMA, and NRCS programs fund projects on private lands
Infrastructure Protection	Temporary diversion/berm at FCFP, sediment basins above reservoirs and at critical locations, roadway crossing improvements.	$9,000-$200,000
Community and guests that are educated about their drinking water source, the threat of wildfire, and responsible use		
Informational Campaign & Volunteer Days	Place informational signs in high-use areas, notices on trail web map interfaces and in hotels/resorts. Partner with Yampatika and YVSC on watershed walks and volunteer days.	$50,000
Coordinated preemptive mitigation, wildfire response, postfire emergency stabilization, and recovery/ restoration		
Routt County Wildfire Council	Continue to collaborate with key stakeholders to support integrated wildfire preparedness planning, partner on mitigation and coordinate outreach efforts; integration point for (CWP)2, with the City's Water Resource Mgr. and District's GM representing the watershed/ supply.	40-80 hours
Permitting Collaboration	Identify NEPA and HFRA requirements for projects in RNF. Secure WUI designation for Fish Creek basin.	20-60 hours
Funding Investigation	Work with partners to ensure eligibility requirements for key preemptive watershed wildfire protection and postfire watershed restoration grant programs are met. Connect with program liaisons; plan for need to secure rehabilitation & restoration funding.	20-60 hours
Water supply system resiliency		
Water Supply System Improvements	Complete near-term action items: intake protection ($30-300k), residuals management ($5k-TBD), testing equipment ($40-60k), filter improvements (<$1,000-$350,000), mobile treatment/ dewatering (TBD, establish MSA).	
	Plan for mid-size/range improvements: intake hydrocyclone (TBD), cationic polymer feed ($50-150k), non-ionic polymer feed ($50-150k), bulk alum tanks ($200-500k).	
	Evaluate and determine course of action for large-scale, long-range improvements: pre-treatment ($100k-$5M), post-filtration ($4-10M), capacity expansion (TBD).	

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1 INTRODUCTION

The City of Steamboat Springs (City) and Mount Werner Water and Sanitation District (District) operate a joint water supply and treatment system to provide drinking water to the greater Steamboat Springs area. Ninety-three percent of the raw water that supplies the City and the District comes from the 26 square mile Fish Creek Basin, and two reservoirs near the top of the watershed – Long Lake Reservoir and Fish Creek Reservoir – supply the direct diversion at Fish Creek to a conventional filtration treatment plant near the city limits, the Fish Creek Filtration Plant (FCFP). As shown in Figure 1-1, the water supply drainage defined for the Fish Creek $(CWP)^2$ includes the entire Fish Creek 12-digit Hydrologic Unit Code (HUC12) Subwatershed defined in the US Geological Survey (USGS) Watershed Boundary Dataset (WBD) to allow for the inclusion of the most downstream segments of Fish Creek basin in the risk assessment; the 25 square mile direct drainage to the FCFP is shown with a dashed line in Figure 1-1. Fish Creek basin is heavily forested, with the direct drainage to the FCFP located entirely within Routt National Forest (RNF) and the majority in designated as Roadless Areas. It is characterized by high elevation mixed conifer forests, interspersed with montane meadows and fen wetlands (groundwater supplied) in the riparian corridors, and aspen and shrublands at lower elevations.

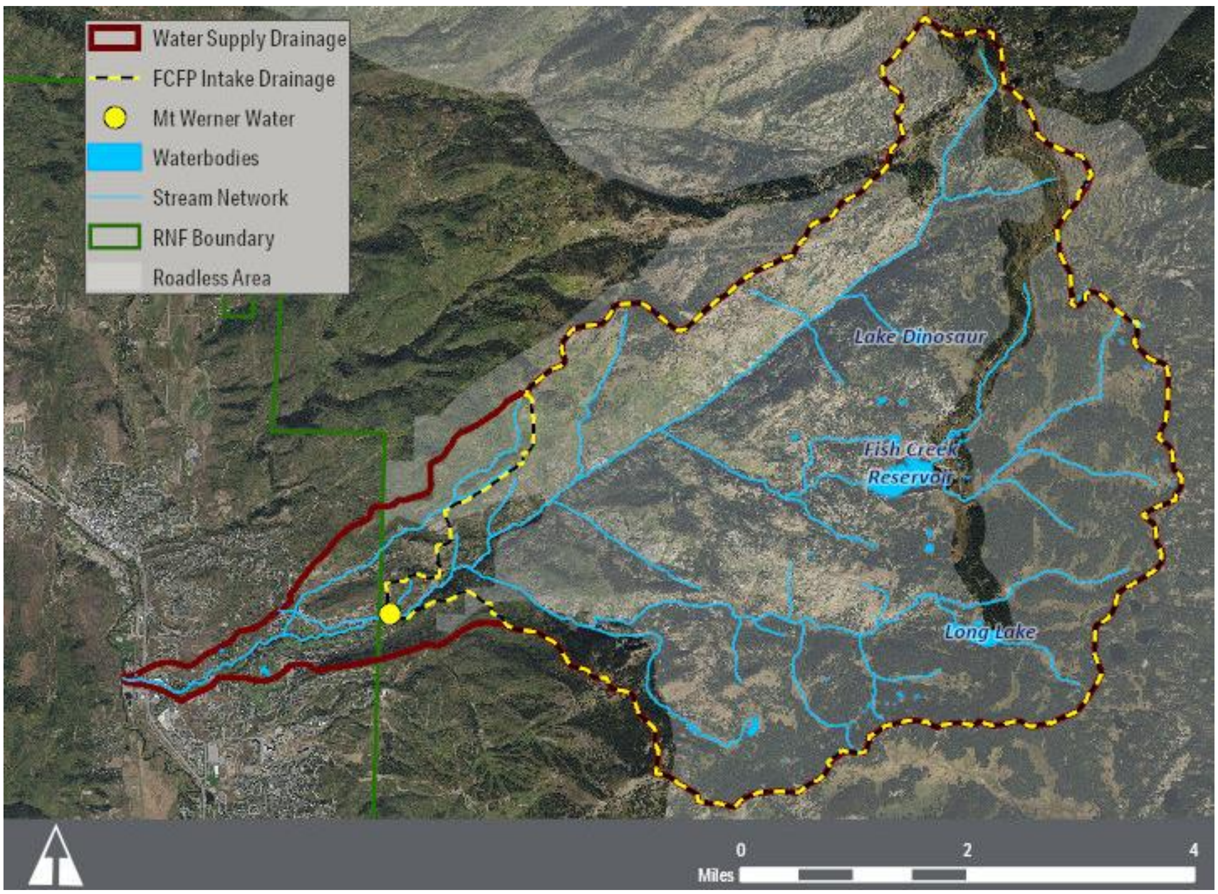

Figure 1-1. Project Area

With the increasing frequency and severity of wildfires resulting from the cumulative impacts of climate change, overgrown forests, and pest infestations, managers of surface water supply systems in forested watersheds must address wildfire impacts when planning for water security. Wildfires burn vegetation and alter soil properties, causing rainfall to run-off rather than soak in to the soil; and, with the loss of vegetation and root systems, landscapes can easily erode. Consequently, rainfall in burned watersheds often produces floods that carry debris, sediment, ash, and contaminants into water sources; this has implications for water supply. Sediment fills reservoirs, decreasing storage capacities; while debris, sediment, ash and contaminants lower water quality, making the water more difficult and expensive to treat and make safe for drinking and cause unwanted tastes and odors. After the 1996 Buffalo Creek fire and the 2002 Hayman fire located in the South Platte drainage in Colorado's Front Range, Denver Water spent over $28 million (M) to mitigate the impacts of heavy rains washing sediments from wildfire-affected lands into their reservoirs. Following the 2002 fire season, the Colorado Department of Health estimated that 26 municipal water storage facilities were shut down due to fire and post-fire impacts (CSFS, 2014). The Colorado Statewide Forest Resource Assessment (CSFS) identified 642 watersheds susceptible to damaging wildfire, and 371 forested watersheds with high to very high risk from postfire erosion. The Fish Creek basin is a critical water-supply watershed susceptible to wildfire and received the highest classification for drinking water risk in the CSFS 2017 Colorado Wildfire Risk Assessment (CO-WRA) update (Figure 1-2; CSFS, 2017). And, Colorado's 2018 fire season, with five of the 20 largest wildfires in Colorado's history, (all of which have occurred since 2010), underscores the urgency water mangers face.

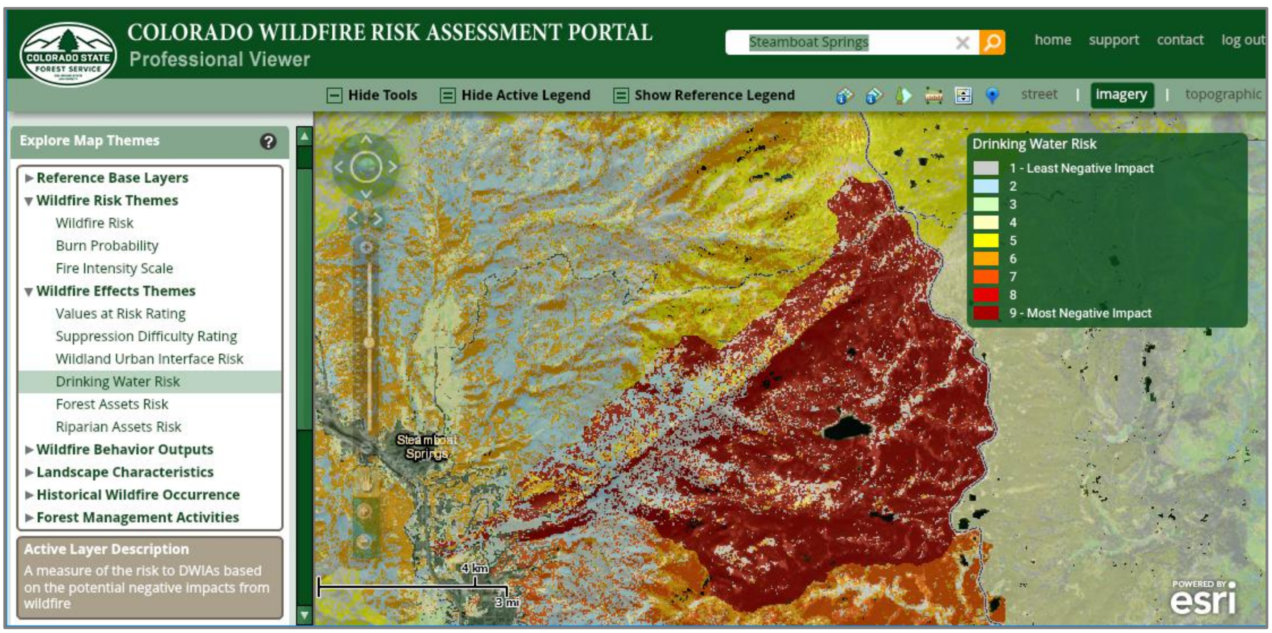

Figure 1-2. Wildfire Related Drinking Water Risk from Colorado Wildfire Risk Assessment Portal

Steamboat Springs area water, land, and resource managers and planners have long been aware of the threats that wildfire poses to their water supply. Nearly every local watershed and/or wildfire planning document acknowledges concerns of postfire erosional impacts to drinking water supply and infrastructure for the Steamboat Springs community. As the past several years of intense wildfires has amplified this message at the national level, Colorado State agencies have been incorporating watershed wildfire resiliency into statewide plans/ objectives and developing the mechanisms necessary to fund it. The Colorado Water Plan states the importance of integrated wildfire and water supply planning for communities susceptible to water quality issues that severe wildfires cause; and the Colorado Water Conservation Board (CWCB) initiated a grant program to help implement the Colorado Water Plan. This Critical Watershed Wildfire Protection Plan $(CWP)^2$, is the first project to receive a Colorado Water Plan grant to address water supply resiliency in forested, fire-prone watersheds. With its development the City, in cooperation with the District, are preemptively addressing the hazards that wildfire poses to the municipal watershed to ensure that they can continue to deliver drinking water to the community.

2 PURPOSE AND OBJECTIVES

The primary objective of the Fish Creek (CWP)² was to develop a plan through an open and collaborative process with stakeholders to clearly define and prioritize site specific measures to implement within the water supply system and the watershed as a whole before, during, and after a wildfire event to protect critical drinking water supply and infrastructure and watershed health. The (CWP)^2 also identifies improvements and/or modifications to water treatment facility and/or reservoir operations to address postfire water quality impacts.

3 THE PLANNING PROCESS

The Fish Creek (CWP)^2 was initiated and led by the City's Water Resources Manager, Kelly Romer-Heaney in partnership with the District's General Manager (GM), Frank Alfone, and the RESPEC/Anchor Point/ Carollo project team was contracted to conduct the planning process. From the outset, it was recognized that connecting and communicating with project partners was vital to ensuring a successful wildfire mitigation planning effort. Without support from key partners (including but not limited to the City, the District, Routt County, Steamboat Springs Fire District, the US Forest Service (USFS), the Colorado State Forest Service (CSFS), and the Yampa Valley Sustainability Council (YVSC), the mitigation planning effort could easily result in a "shelf document" that would not ultimately provide the value of protecting water-supply. Therefore, upon project initiation, the project leads assembled a Core Team of land/resource managers and subject matter experts to operate as an advisory committee to guide the planning effort throughout the development of the plan. Considerable emphasis was placed on effective communication to ensure that the planning process would lead to solutions and treatment recommendations that had the input and support from appropriate agencies. User-friendly engagement opportunities were employed to make the collaborative process accessible, foster long-term involvement, and encourage community participation to garner public support for project implementation.

3.1 CORE TEAM

An effective, implementable (CWP)^2 requires collaboration with and input from local land/resource managers, subject matter experts, and stakeholders. Therefore, garnering input from local, state, and federal land management agencies was crucial to the planning process. Contributions were sought from a Core Team that included representatives from the following local, state, and federal agencies/ organizations: RNF, CSFS, Routt County Office of Emergency Management (OEM), Routt County Environmental Health Department, Steamboat Springs Fire District, and Yampa River Sustainability Council. Members of this group were actively engaged to guide work conducted throughout the project, so that the (CWP)^2 could benefit from their technical expertise and local and institutional knowledge. Feedback from the Core Team on the technical analyses, and particularly on prioritization in the context of agency priorities and constraints, has been invaluable to the Fish Creek (CWP)^2, and we would like to thank the participating agencies/organizations and Core Team members for their commitment and contributions to this project, including:

- Routt National Forest
    - Liz Schnackenberg, Forest Hydrologist
    - Kevin Thompson, Fire Manager

  - Tara Umphries, District Ranger
- Colorado State Forest Service
  - Carolina Manriquez, Forester,
  - John Twitchell, District Forester
- Yampa Valley Sustainability Council
  - Sarah Jones, Executive Director
- Routt County
  - Mo DeMorat, Emergency Operations Director
  - Scott Cowman, Environmental Health Director
- City of Steamboat Springs
  - Mel Stewart, Fire Chief
  - Michelle Carr, Collection & Distribution Manager
  - Jon Snyder, Public Works Director

3.2 PROJECT MEETINGS

Three formal Core Team meetings were held at Centennial Hall in Steamboat Springs throughout the course of the project to ensure a high level of project communication, facilitate coordination and collaboration between the various agencies and stakeholders working within the basin, and ultimately lay the foundation for a coordinated implementation effort. Agendas were sent out before each of the project meetings, which typically began with a status update from the project team, then transitioned into collaborative discussion of critical issues or items for each stage of the project.

A kickoff meeting was held October 6, 2018 with the Core Team, where an overview of the technical analyses performed for the watershed risk assessment was presented and discussed. This was the first meeting to obtain input from project partners, and the project team presented the background information, study goals, task schedule, and procedures that were to be used to complete the project. Data requirements, resource concerns, problem areas, and watershed issues were discussed at this meeting

After the initial risk assessment was complete, a second Core Team meeting was held March 28, 2019, where the results of the technical analyses were presented. Problem areas within the watershed were identified and a draft risk map was discussed in the context of project identification and prioritization. The Core Team provided insight on operability constraints that could impede implementation as well as on agency wildfire and postfire response processes. Additional analyses were suggested to better understand the effectiveness of fuels treatments on the identified problem areas.

A final formal project meeting was held on June 6, 2019 to present potential project recommendations and verify these recommendations with the Core Team to ensure that the $(CWP)^2$ did not result in projects that are not desirable to stakeholders or feasible for land and resource managers to consider for implementation. Discussions included alignment with agency plans/ objectives, CWPPs, existing watershed plans, and other local efforts that could potentially be leveraged to achieve the intent of the Fish Creek $(CWP)^2$. Different types of fuels treatments and hydrologic controls were discussed in the context of their appropriateness to forest types within the basin and permitting requirements.

Additionally, members of the Core Team participated in individual calls and meetings focused on key aspects of the project, specifically related to their subject matter expertise and their agencies' knowledge and needs. Members of this group were contacted regularly throughout the project to obtain feedback, so that the project could benefit from their expertise. The multiple interactions with and between these team members directly contributed to the successful outcome of this project.

3.3 STAKEHOLDER ENGAGEMENT & PUBLIC OUTREACH

The planning process also involved engaging key stakeholders and the greater Steamboat Springs community with the understanding that garnering public support for the (CWP)^2 is crucial for successful implementation. A webpage was created for the Fish Creek (CWP)^2 on the City's website, with a link provided to this page on the District's website, to allow for public access to project documents, presentations, and updates (special thanks to the City's communication director, Mike Lane); and, a public outreach brochure was developed and distributed at the Routt County Wildfire Mitigation Roundtable and Conference, which was held May 10-11th in Steamboat Springs (Figure 3-1). Both the website and tri-fold brochure included an overview of the City and District's joint water supply system, wildfire impacts to water supply, and (CWP)^2 objectives, listed contact information for project leads, and contained an announcement for an open house where the public could learn more about the project.

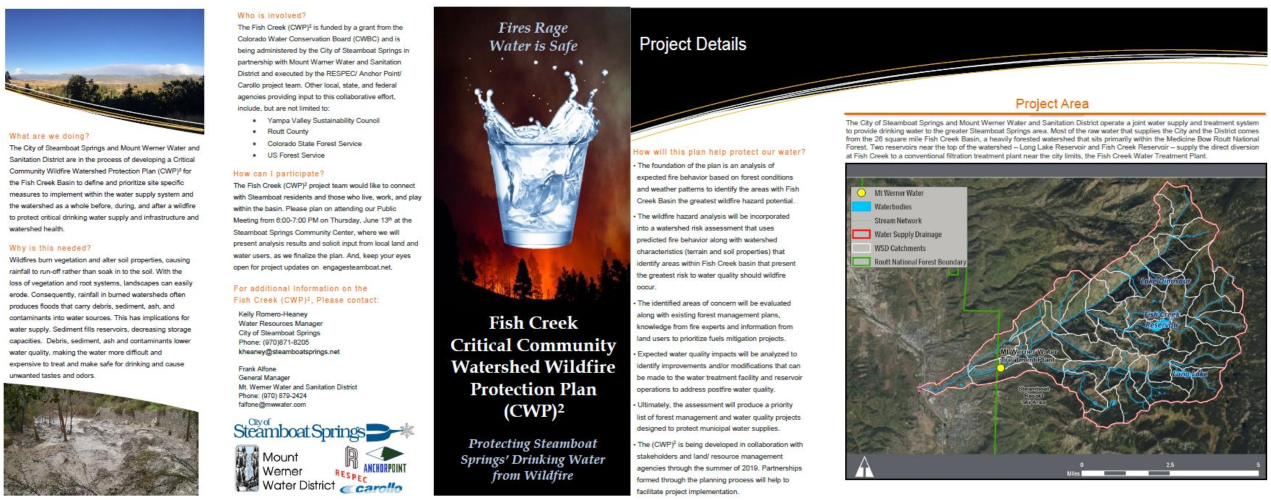

Figure 3-1. Tri-fold Brochure Created to Advertise the Fish Creek (CWP)^2

A public meeting was held on June 13th at the Steamboat Springs Community Center to encourage community participation and foster long term involvement. The meeting was advertised at the Routt County Wildfire Conference, on the project webpage, and the City's and the District's community calendars. The project also benefited established communication routinely used by the Core Team's agencies/ organizations, and many team members posted the meeting announcement on their social media pages and websites. Additionally, direct email invitations were sent to key stakeholders. The open house style public meeting began with presentation that summarized the technical analysis and findings of risk assessment and prioritization process and identified potential project opportunities. This was followed by a question and answer session and collaborative discussion. Attendance included representatives from the Core Team, Mt Werner Water Board, Fish Creek Sanctuary neighborhood, and the Steamboat Pilot & Today newspaper.

4 SUMMARY OF BACKGROUND INFORMATION

The first task in developing the $(CWP)^2$ was to gather and review all available reports, datasets, and geospatial layers pertinent to the project, so that it could build on, rather than duplicate, previous efforts in the study area. Existing background information was identified by the project leads at the project outset to include pertinent forest- and hydrology-related reports and datasets, and specifically, the Upper Yampa Watershed Plan, the Routt County Community Wildfire Protection Plan (CWPP), and the Fish Creek – Sanctuary CWPP. Key points from these documents as they relate to the Fish Creek $(CWP)^2$ are summarized below:

- Upper Yampa Watershed Plan (May 2016), and its precursor, the Upper Yampa River State of the Watershed Report (May 2014).
  - The Upper Yampa River Watershed (UYRW) Group developed a State of the Watershed Report (SOWR) in 2014 that summarizes information on watershed characteristics, water quality parameters, and natural and human influences on water quality within the watershed and provides area-specific overviews of water quality and watershed characteristics for the five major sub-basins, including Fish Creek.
  - The intention of this non-regulatory watershed plan is to increase local partnerships and their capacity to protect and enhance water quality, promote water conservation, and sustain and improve the present health of the watershed. Stakeholders worked together both to define objectives for watershed health and to prioritize projects aimed at meeting those objectives.
  - "Fish Creek Reservoir wildfire preparedness" a secondary objective identified in the UYRW Plan's Potential Project List. The development of the Fisk Creek $(CWP)^2$ is the first step in meeting that objective.
  - Several other priority objectives from the UYRW Plan may dovetail with the Fish Creek $(CWP)^2$, such as: Outreach & Education, Riparian Health Assessments, Critical Wetlands Identification & Mapping, and Water Quality Monitoring.
- Routt County CWPP (September 2010)
  - The Routt County CWPP notes that the Steamboat Springs Area, which consists of the City of Steamboat Springs and the Steamboat Springs Rural Fire Protection District, and surrounding area comprise the greatest amount of value at risk within the county. One of the CWPP's five goals is to "maintain healthy watersheds".
  - The CWPP synthesizes and expands upon several community CWPPs within the county, including the Fish Creek Sanctuary CWPP (discussed below) and the Burgess Creek CWPP (the Burgess Creek drainage borders the Fish Creek basin to the south and contains the Steamboat Ski Resort).
  - Completed projects from the community CWPPs are listed, including two from the Fish Creek CWPP: Sanctuary Fuels Treatment Project in 2007 which leveraged grant money to create a 1.5 mile shaded fuel break behind 23 lots, and a 2009 grant related project that involved removing the beetle kill and other deadwood along Fish Creek and replanting.
  - Several new or planned projects are within the Steamboat Springs Area are identified, including: the USFS Steamboat Front Fuels Project, Routt County Road Hazard Project, USFS Road Hazard Project.
- Fish Creek – Sanctuary CWPP (May 2007)
  - The Sanctuary CWPP states, "Preserving the Fish Creek watershed is invaluable. Fish Creek alone provides the sole water source for the majority of Steamboat Springs' residents, all of the families within the Sanctuary and nearly all people in the surrounding developments." The development of the Fish Creek $(CWP)^2$ directly addresses that concern.

- The Fish Creek Sanctuary neighborhood borders Mount Werner Water to the north, the Rollingstone (formerly Sheraton) Golf Course to the west, and RNF to the south and east. It notes extensive beetle induced tree loss and available hazardous fuel substrate among the conifers abundant on the south ridge preservation area and along the banks of Fish Creek. New beetle activity was identified just upstream from the land surrounding Mt. Werner Water and Sanitation District on the north side of Fish Creek.
- The plan notes that seasonal alpine thunderstorms, high levels of bicycle and pedestrian trail use during spring and summer, occasional unauthorized campfires, and the ongoing residential building activity within the area all have potential to increase wildfire risk.
- Finally, the CWP states that, "to be truly effective, treatment and fire mitigation must be considered a very long-term endeavor." The Sanctuary CWPP outlined several projects, many of which have been accomplished. However, some of the Sanctuary CWPP project recommendations have not yet been implemented. Rejuvenation of this long-term endeavor would be beneficial for protecting the watershed.

/ Burgess Creek CWPP (2004)

- The Burgess Creek CWPP is also included in this list, because two projects identified in this CWPP that would directly benefit the Fish Creek basin. Given that it has been fifteen years since this CWPP was developed, it may be appropriate to revisit these projects to determine 1) if they've been accomplished and 2) if maintenance is required. Descriptions are as follows:
- Develop a fuelbreak 100 to 150 feet (or more) wide, with crown closures less than forty percent, between the conifers on the north slope and the oak, aspen, and the associated shrub clumps on the south slope along the top of the primary ridge, between Burgess Creek and Fish Creek, the north boundary line of the Burgess Creek community. Hand cutting, mowing and use of a hydro ax can accomplish this. This fuelbreak will not only help protect Burgess Creek it will provide protection benefits to the other associated communities nearby.
- In Fish Creek, south of the Sanctuary residences at the base of the steep conifer covered steep ridge separating Burgess Creek and Fish Creek, thin to achieve a 40 percent tree canopy cover, prune up to 15 feet above the ground and removing slash, forest debris, and anything flammable to reduce potential wildfire momentum and rate of spread at the bottom of the ridge leading up to the north side of Burgess Creek drainage.

Several other reports and planning documents were gathered and reviewed to support the Fish Creek (CWP)^2 and these have been compiled to form a digital library of reference materials. All will be provided as part of this project and are organized according to the developing agency/ organization including:

/ The City of Steamboat Springs

- Engineering Standards: Drainage Criteria (2007, currently being updated)
- Citywide Stormwater Master Plan (2013)
- Water and Wastewater Master Plan Updates (2009)
- Yampa River Health Assessment and Streamflow Management Plan (2018)
- Steamboat Springs, Colorado Water Conservation Plan II (2011, developed in collaboration with the District and currently being updated).
- A Strategic Plan by Steamboat Springs Fire Rescue September (2018)

/ Mt Werner Water and Sanitation District

- Fish Creek Filtration Plant Operation and Maintenance Manual (Updated 2011)
- MWW 10-year Capital Improvement Plan (2019)
- 2017 Year End - Mount Werner Water District Water & Wastewater Capacity Analysis (2018)

- / United States Forest Service
  - Routt National Forest
    - Routt National Forest - Land and Resource Management Plan (1998)
    - Medicine Bow Routt National Forest and Thunder Basin National Grassland Fire Management Plan (2013)
    - Travel Analysis Report (TAR) for the Hahns Peak/Bears Ears Ranger District (2015)
    - Fish Creek Reservoir Expansion Environmental Impact Statement (EIS) (1994)
    - Buffalo Pass Trails Project Environmental Assessment and Finding of No Significant Impact (2016)
    - Steamboat Ski Area Draft EIS and Record of Decision (ROD) (2018)
    - Mad Rabbit Trails Project Newsletter (2018)
  - Burned Area Emergency Response (BAER) Guidance
    - Forest Service Manual 2500 - Watershed and Air Management, Chapter 2520 - Watershed Protection and Management, Section 2523 - Emergency Stabilization - Burned-Area Emergency Response (BAER)
    - Burned Area Emergency Response Treatments Catalog (2006)
    - A synthesis of postfire road treatments for BAER teams: methods, treatment effectiveness, and decision making tools for rehabilitation. (2009)
    - Post-fire treatment effectiveness for hillslope stabilization (2010)
- / Colorado State Forest Service
  - Statewide Forest Resource Assessment (2009)
  - Colorado Wildfire Risk Assessment Report (CO-WRA) (2013, User Manual for Web-Map Interface), Colorado Wildfire Risk Assessment Project (2013), and 2017 Colorado Wildfire Risk Assessment Update (2017)
  - 2016 Report on the Health of Colorado's Forests - Fire and Water (2016)
  - Forest Management to Protect Colorado's Water Resources (2017)
  - 2018 Report on the Health of Colorado's Forests – Protecting Our Communities (2018)
- / Routt County
  - Wildland Fire Management Tactical Operations Plan (2018)
  - Routt County Multi-Hazard Mitigation Plan (2010, currently being updated)
- / Steamboat Ski Resort Master Development Plan Amendment (2011)

Additionally, several reports and journal articles from scientific literature were compiled to support the risk assessment, and these are referenced in the report and included in the digital library. And, multiple geospatial datasets were compiled to support the risk assessment. All geospatial data obtained to support and developed through technical analyses for this project are provided in a geodatabase, including:

- / National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation frequency datasets
- / Natural Resources Conservation Service (NRCS) Web Soil Survey (WSS) and State Soil Geographic (STATSGO)
- / RNF Soil Survey (provided by Core Team)
- / LANDFIRE 1.4 40 Scott and Burgan Fire Behavior Fuel Model (FBFM40) and Existing Vegetation Type (EVT) datasets
- / United States Geological Survey 3D Elevation Program (3DEP) Digital Elevation Model (DEM)

Finally, postfire water quality predictions were required to support the recommendations for the FCFP. Data availability was investigated for sources for precipitation, streamflow and water quality data specific to the Fish Creek basin to determine whether it would be more appropriate to model water quality impact scenarios or conduct a literature review to determine scaling factors for water quality constituents of concern. This information would be needed to support the development of continuous (i.e. baseflow in addition to storm event) hydrologic and/or a water quality model. The findings are as follows:

- The nearest real-time precipitation gage is Dry Lake Remote Automated Weather Station (RAWS, station #050207), located approximately 2 miles north of the Fish Creek Basin boundary. This station provides precipitation, wind speed, temperature, and relative humidity at an hourly time-step. While it would be ideal to have a station in the basin, this location would suffice to support modeling efforts. However, for postfire conditions, an hourly time-step is too course for predictive modeling of hydrology and water quality, because that is within the time of concentration for the Fish Creek Basin. Moreover, if a fire were to occur in the watershed a one-hour time-step would be too course to support an early warning system for the FCFP and downstream residents.
- One active USGS streamgage is located in the watershed (09238900); it measures gage height and streamflow at a 15-minute time-step, dating back to 1986 (with daily data available for 1966-1972). Data is available for six additional inactive streamgages previously located on tributaries to Fish Creek and Long Lake Reservoirs; most have daily data available from 1984-1995. These data supplemented with reservoir information (volume and release records) are sufficient to support modeling. Locations are show in Figure 4-1.
- The final requirement to model quality is the water quality data itself. This is required for model calibration and is essentially unavailable in the watershed, with the exception of routine sampling at the FCFP intake. A Sampling and Analysis Plan (SAP) was developed to obtain water quality samples at reservoir outlets to support WTP recommendations.

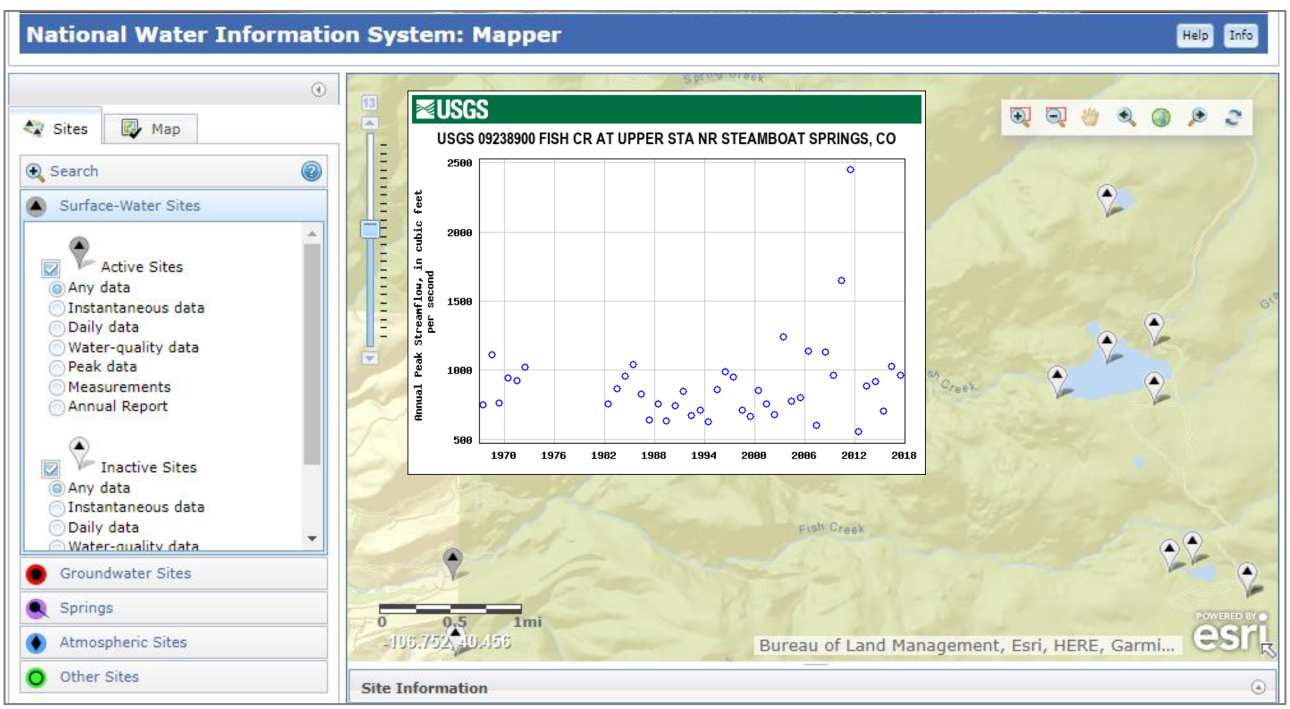

Figure 4-1. USGS Streamgage Locations and Annual Peak Flow Graphic for the Active Station Located Just Below the WTP.

Due to water quality data availability constraints, it was determined that impact scenarios would be determined through literature review of expected water quality impacts applied to measured concentrations from samples collected at the reservoir outlets. An extensive review of postfire water quality and water treatment was conducted to determine scaling factors for the water quality constituents of concern. Several journal articles and guidance documents were reviewed, including many on postfire water quality impacts from wildfires in CO (Buffalo Creek, Fourmile Canyon, Hayden, High Park, Waldo Canyon, Zirkel, and 416); these are included in the digital library for reference. The postfire water quality impact predictions relied most heavily on the following three guidance documents and journal articles:

- Wildfire effects on water quality in forest catchments: A review with implications for water supply (Smith et al., 2011)
- Post-fire water-quality response in the western United States (Rust, et al., 2018)
- Wildfire Impacts on Drinking Water Treatment Process Performance - Development of Evaluation Protocols and Management Practices (Hohner, et al., 2018)

Each provides a comprehensive summary of postfire water quality impacts from different perspectives relevant to the goals of this project: Smith conducted a comprehensive review of the literature for a wide range of physical and chemical constituents including many constituents not often measured or reported on (e.g., ash, trace metals, and polycyclic aromatic hydrocarbons (PAHs)); Rust summarized Data from 159 fires in 153 burned watersheds to identify common water-quality response during the first 5 years after a fire and included pre/post fire comparisons and percent change; and Hohner analyzed postfire water quality in the context of water treatment and conducted bench-scale experiments using leachate from soils burned in different treatment processes.

In the event of a wildfire in Fish Creek Basin, the City and District will need to understand the expected changes in stream chemistry to make any necessary adjustments to FCFP operations or investments in capital improvements to continue to supply high quality drinking water to their customers. The potential water quality impacts of a wildfire in the municipal watershed were evaluated in relation to current water treatment facility conditions and operations to inform recommendations for the water supply system (see Section 8). Scaling factors were developed based on reported values from the literature review and applied to measured concentrations from water quality samples collected at the reservoir outlets in October 2018. The full literature review summary and scaling factors are included in the digital library, and the key takeaways include:

- Water quality impacts are most severe in the first year following a fire and often remain elevated for several years as the watershed recovers. Expect increases in the range of two to three order of magnitude for suspended sediment and sediment-associated contaminants (particularly trace metals) and one order of magnitude for turbidity, nutrients and organic carbon.
- In response, water treatment by coagulation and filtration to remove flocculated particles may be required. Notably, for most toxic metals, elevated concentrations may reflect high sediment concentrations, which once removed would greatly reduce levels of these contaminants.
- At very high TSS/turbidity levels, treatment problems may be encountered that reduce the rate of water processing, potentially causing difficulties in maintaining a continuous supply of potable water. In the absence of adequate treatment facilities, water supplies may be vulnerable to more prolonged disruption from large postfire increases in suspended sediment flux.
- Elevated turbidity levels may also necessitate increased disinfection and oxidation of metals or organics using various disinfectants/oxidants such as chlorine, ozone or hydrogen peroxide. This may result in the increased formation of disinfection by-products.

5 WATERSHED RISK ASSESSMENT

The watershed risk assessment consisted of analyzing both wildfire and postfire hazards. The wildfire hazard identification methodology employed FlamMap fire-behavior modeling, which is used by federal agencies to assess and manage fire events. The postfire hydrologic hazard analysis used USGS debris flow models to integrate the wildfire hazard information, RNF soil survey data, and NOAA precipitation atlas design storms. This enabled the quantification of potential sediment delivery to water-supply reservoirs and critical infrastructure. Information derived from these analyses was synthesized to produce a composite hazard index, which was used to identify areas within the Fish Creek basin most likely to contribute large sediment loads to critical infrastructure were the watershed to experience a high-severity fire. Methods and results for each hazard analysis are summarized below.

5.1 WILDFIRE HAZARD

A risk-analysis methodology that evaluates the likelihood a fire will occur, along with fire severity predictions from fire-behavior modeling was employed to determine the wildfire hazard. This information was done using an industry-standard, federally-provided and used fire-behavior modeling package called FlamMap (v5) (Finney, 2006). FlamMap uses maps of fuel characteristics and topography, along with information about past weather patterns to predict what would happen in the event of a wildfire. The following sections provide specific information about the FlamMap modeling system as well as the data and parameters that were used to predict fire behavior.

5.1.1 MODEL BACKGROUND AND LIMITATIONS

FlamMap draws heavily on calculations from the BEHAVE fire-behavior prediction and fuel modeling system [Andrews et al., 2008]. BEHAVE is a nationally-recognized set of calculations used to estimate a surface fire's intensity and rate of spread given topographical, fuel, and weather information.

The BEHAVE modeling system has been used for a variety of applications, including current fire predictions, prescribed fire planning, fuel hazard assessment, initial attack dispatch, and fire-prevention planning and training. Predictions of wildland surface fire behavior in BEHAVE are made for a single point in time and space given user-defined fuels, weather, and topography.

The following are standard assumptions of BEHAVE:

- The fire is predicted at the flaming front. (Fire behavior is not modeled for the time after the flaming front of the fire has passed.)
- The fire is free burning (uncontrolled by suppression efforts).
- The behavior is heavily weighted toward the fine fuels (grasses and small-diameter wood).
- The fuels are continuous and uniform.
- The fires are considered to be surface fires. (Crown fire activity is modeled separately).

BEHAVE makes calculations at a single point. To make calculations for an entire landscape (important for preplanning for the effects of a wildfire at the community, district, or county scale), fire behavior is modeled using FlamMap, which models surface fire predictions, potential for crown fire development, and burn probability (Van Wagner, 1977).

The following are standard assumptions of FlamMap:

- Each calculation in each area is independent of calculations in any other area. The fire is not modeled dynamically across the landscape but statically as a series of individual calculations.
- Weather inputs such as wind and fuel moistures do not change over time.
- Fire-behavior modeling calculations are performed in a series of uniform squares (or "pixels") across the landscape. These pixels determine the level of detail, and nothing smaller than a pixel (30 meters × 30 meters, in this case) is explicitly addressed in the modeling.

The model also includes the following limitations:

- Crown fire is not calculated for shrub fuel models. The best method for determining the probability of crown fire in shrubs is to look at the flame length outputs and assume that if the flame length is greater than half the height of the plant, it will likely torch and/or crown.
- The surface fire model does not calculate the probability that a wildfire will occur–but it assumes that a fire will burn everywhere (an ignition in every 30-meter × 30-meter cell). These calculations may be conservative (overpredict) compared to observed fire behavior.
- Weather conditions are extremely variable, and all possible combinations cannot be accounted for. Outputs are best used for preplanning and not as a stand-alone product for tactical planning. Whenever possible, fire-behavior calculations should be made with actual weather observations during the fire. The most current Energy Release Component (ERC) values should also be calculated and distributed during the fire season to be used as a guideline for fire-behavior potential. The ERC is a National Fire Danger Rating System index related to how hot a fire could burn. ERC is defined as the potential available energy per square foot of flaming fire at the head of the fire and is expressed in units of British Thermal Units (BTU) per square foot.
- This evaluation is a prediction of likely fire behavior given a standardized set of conditions and a single point source ignition in every 30 meters of pixel inside the area of interest. The evaluation does not consider cumulative impacts of increased fire intensity over time and space.

5.1.2 FLAMMAP MODELING PROCEDURE

The study area was broken down into grid cells with dimensions of 30 meters × 30 meters; fire behavior was predicted for each cell based on input topographic, fuel, and weather information. Data from the LANDFIRE 1.4 dataset provided the topographic (aspect, slope, and elevation) and fuel (surface fuels, canopy closure [CC], canopy height [CH], canopy base height [CBH], and canopy bulk density [CBD]) information that is required for the FlamMap model to run (Wildland Fire Leadership Council, 2016). While the topographic inputs are straightforward, the fuel inputs are less intuitive and are, therefore, described in Section 5.1.3. Reference weather and fuel moisture information were obtained from a Remote Automated Weather Station (RAWS) site as described in Section 5.1.4.

5.1.3 FUELS

In the context of fire-behavior modeling, fuel models are a set of numbers that describe fuels in terms that the fire-behavior modeling equations can use directly. Seven characteristics are used to categorize fuel models: fuel loading, size and shape, compactness, vertical arrangement, horizontal continuity, moisture content, and chemical content. Different vegetation classes are categorized according to these characteristics into fuels models that represent how they will respond to fire. The 40 Scott and Burgan Fire Behavior Fuel Model (FBFM40) layer was obtained from the LANDFIRE 1.4 dataset and represents distinct distributions of fuel loading found among surface fuel components, size classes, and fuel types; this layer served as the baseline for the fuels inputs to FlamMap. In Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with

Rothermel's Surface Fire Spread Model, a national standard guide to fuel modeling (Scott and Burgan, 2005), Scott and Burgan describe 40 fuel models in the following six groups: non-burnable (NB), grass (GR), grass/shrub (GS), shrub (SH), timber understory (TU), and timber litter (TL). Table 5-1 shows the primary fuel models (FM) found in the project area. Table 5-2 provides a narrative describing each of these FM categories.

Table 5-1. Fuel Models Found in the Study Area[(a)]

Grass Fuel Models		Shrub Fuel Models	Timber Fuel Models	Non-burnable
FM101 (GR1)		FM147 (SH7)	FM161 (TU1)	FM91 (NB1)
FM102 (GR2)			FM165 (TL5)	FM99 (NB9)
FM121 (GS1)				
FM122 (GS2)				

(a) Some fuel other models may exist but not in quantities sufficient to significantly influence fire behavior across the landscape.

Table 5-2. Description of Fuel Model Categories

Grass Fuel (GR) Type Models	The primary carrier of fire in the GR fuel models is grass. Grass fuels can vary from heavily grazed grass stubble or sparse natural grass to dense grass (more than six feet tall). Fire behavior varies from moderate spread rate and low flame length in the sparse grass to extreme spread rate and flame length in the tall grass models.
Grass/Shrub (GS) Fuel Type Models	The primary carrier of fire in the GS fuel models is grass and shrubs combined; both components are important in determining fire behavior.
Shrub (SH) Fuel Type Models	The primary carrier of fire in the SH fuel models is live and dead shrub twigs and foliage in combination with dead and down shrub litter. A small amount of herbaceous fuel may be present.
Timber Understory (TU) Fuel Type Models	The primary carrier of fire in the TU fuel models is forest litter in combination with herbaceous or shrub fuels.
Timber Litter (TL) Fuel Type Models	The primary fire carrier in the TL FM is dead and down woody fuel. Live fuel, if present, has little effect on fire behavior.

Anchor Point recently assisted CSFS in conducting the "Fuels Calibration Project;" this new assessment is the most accurate state level assessment of fuels and was used to refine the FBFM40 layer. To achieve even more accuracy, Anchor Point conducted a field assessment and consulted with RNF's Fire Manager to calibrate the fuels profile to represent local conditions. The raw LANDFIRE FBFM40 layer and the final Fuel Model inputs to FlamMap are shown in Figure 5-1. The baseline FBFM40 layer was modified to reflect conditions observed in the field. Using the LANDFIRE Existing Vegetation Type (EVT) layer, all fuel model TU1 and TL1 were assigned to TU5 inside EVT 3055 (Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland), and all EVT 3061 (Aspen) were assigned to TU1. Digitization from aerial photography was used to re-assign the fuel model of meadows (GR1), grass/shrub areas (121), water (NB8), bare ground (NB9), and "islands" of heavy timber (TU5). Finally, Canopy Bulk Density values were multiplied by 1.5 to achieve a better balance of torching to active crown fire in the final outputs.

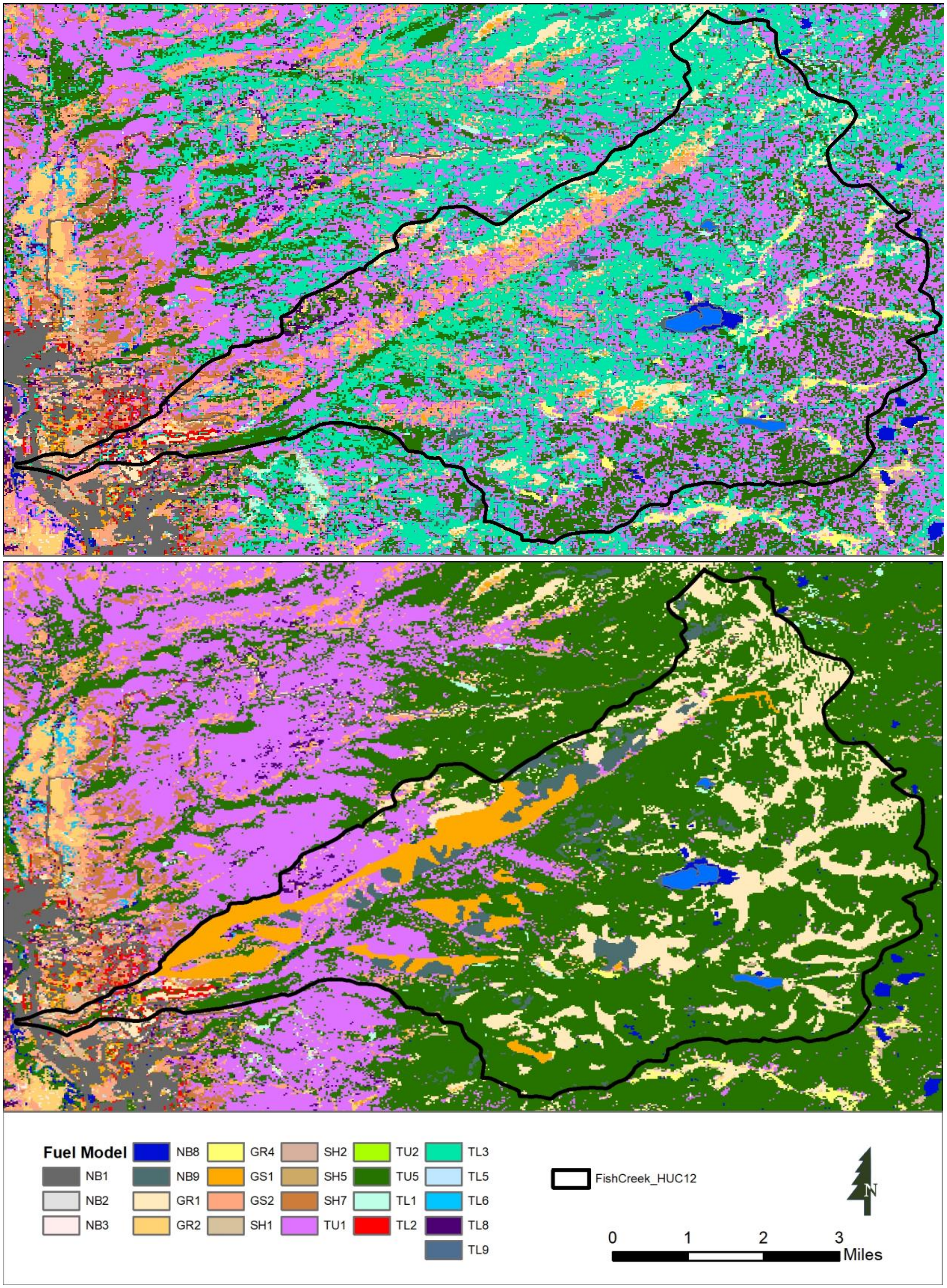

Figure 5-1. Raw LANDFIRE FBFM40 Layer (A) and the final Fuel Model Inputs to FlamMap (B).

5.1.4 REFERENCE WEATHER AND FUEL MOISTURE

Climate and fuel moisture inputs for FlamMap were created by using data collected from a RAWS. The Dry Lake RAWS (050207) was chosen because it best reflected the study area in terms of location, elevation, topographic position and surrounding fuels. Weather observations for a 10-year period (2008-2017) were used. The > 90th percentile, sorted by the Energy Release Component (ERC), was calculated for each variable (1-hour, 10-hour, and 100-hour live herbaceous and live woody fuel moistures and 20-foot wind speed) using Fire Family Plus (Version 4.1) software (Bradshaw and McCormick, 2000). Ninetieth (90th) percentile is used as it represents a very high fire danger condition based on the local weather data and is helpful to show differentiation on the landscape for pre-planning purposes. Twenty (20) feet is the standard height above the vegetation for measuring open wind speed in the US to determine unobstructed wind speed. An annual burn window of June 28 to October 31 was chosen based on the green-up and earliest freeze dates of the RAWS site.

Predominant wind directions and speeds were calculated from the frequency distributions of the RAWS records. For the flame length, rate of spread, crown fire activity, and fireline intensity model runs, an upslope wind direction was used (i.e., the fire was assumed to burn uphill always). This simulated the worst-case scenario (winds aligned with slopes) and is considered to be a better scenario to run for preplanning. Both live and dead fuel moistures for each landscape cell are calculated by the model based on the topography (slope, aspect and elevation) and shading from forest canopy and clouds, as well as the recorded weather (precipitation, high and low temperatures, and high and low relative humidity) for the previous 3 days that lead up to the date chosen to get the best representation of the standard conditions. The dead fuel moistures that have been calculated by the start date and time of the analysis are used to determine the outputs in fire-behavior models. The final weather and fuel moisture inputs to FlamMap are shown in Table 5-3.

Table 5-3. Input Wind and Fuel Moisture Parameters Used for Fire-Behavior Models

90th Percentile Weather Conditions	
Variable	Value
20-foot wind speed upslope	17 mph
Wind direction used	Always Uphill
1-hr fuel moisture	4%
10-hr fuel moisture	4%
100-hr fuel moisture	7%
Herbaceous fuel moisture	30%
Woody fuel moisture	70%

5.1.5 FIRE-BEHAVIOR MODELING RESULTS

Fire-behavior modeling results are shown for the following FlamMap output variables: flame length (Figure 5-2), fireline intensity (Figure 5-3), crown fire activity (Figure 5-4), rate of spread (Figure 5-5), and burn probability (Figure 5-6).

5.1.5.1 FLAME LENGTH

Flame length values generated by the FlamMap model were classified into six categories based on standard ranges: less than 4.0, 4.0–8.0, 8.1–11.0, 11.1–20.0, 20.1–40.0, and greater than 40.0 feet.

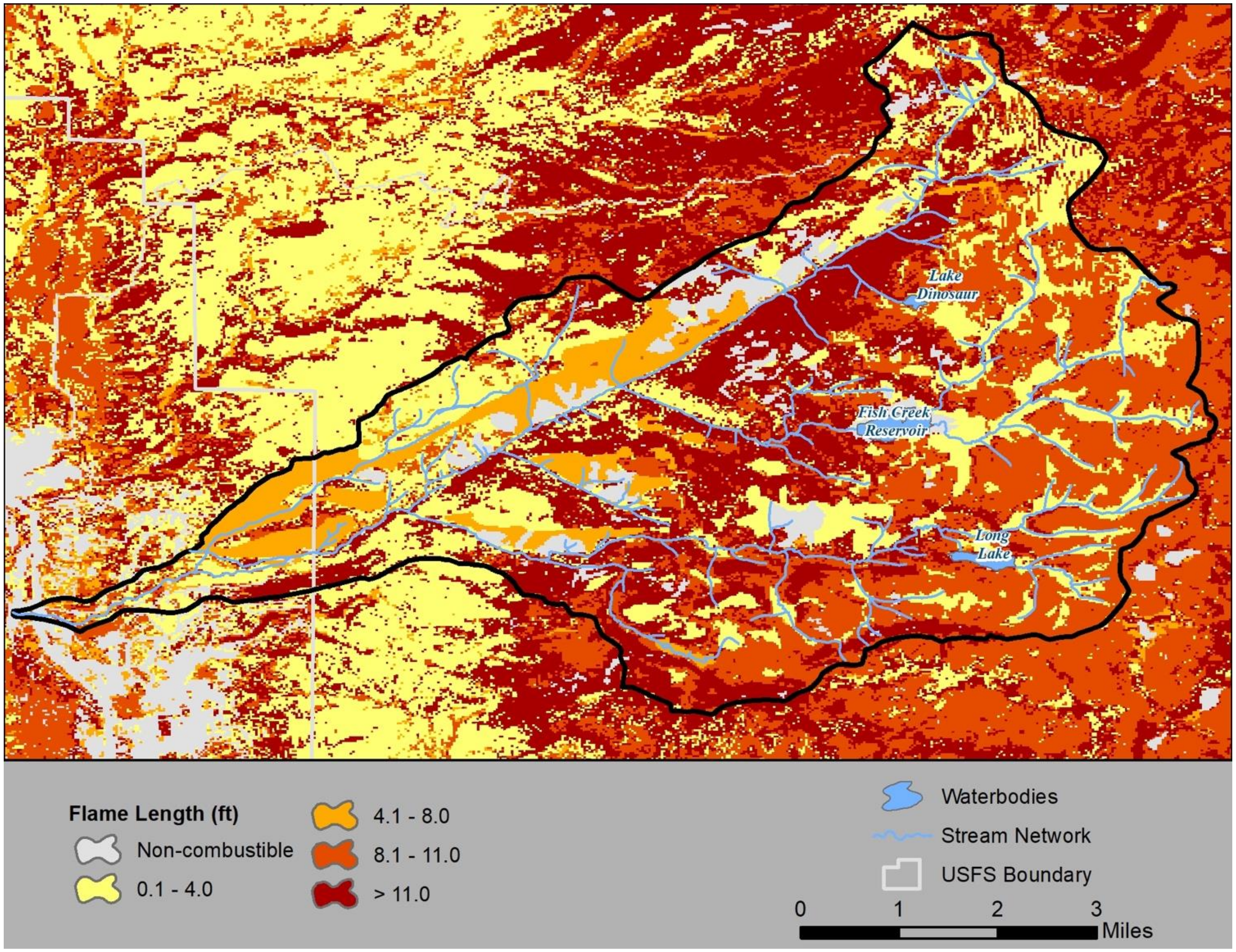

Figure 5-2. Flame Length FlamMap Modeling Results

5.1.5.2 FIRELINE INTENSITY

Fireline intensity is a measure of the power of a fire along the flaming front and is measured in kilowatts per meter (kW/m). It combines heat of combustion and rate of spread information and is used to measure where fire behavior will be most intense on the landscape.

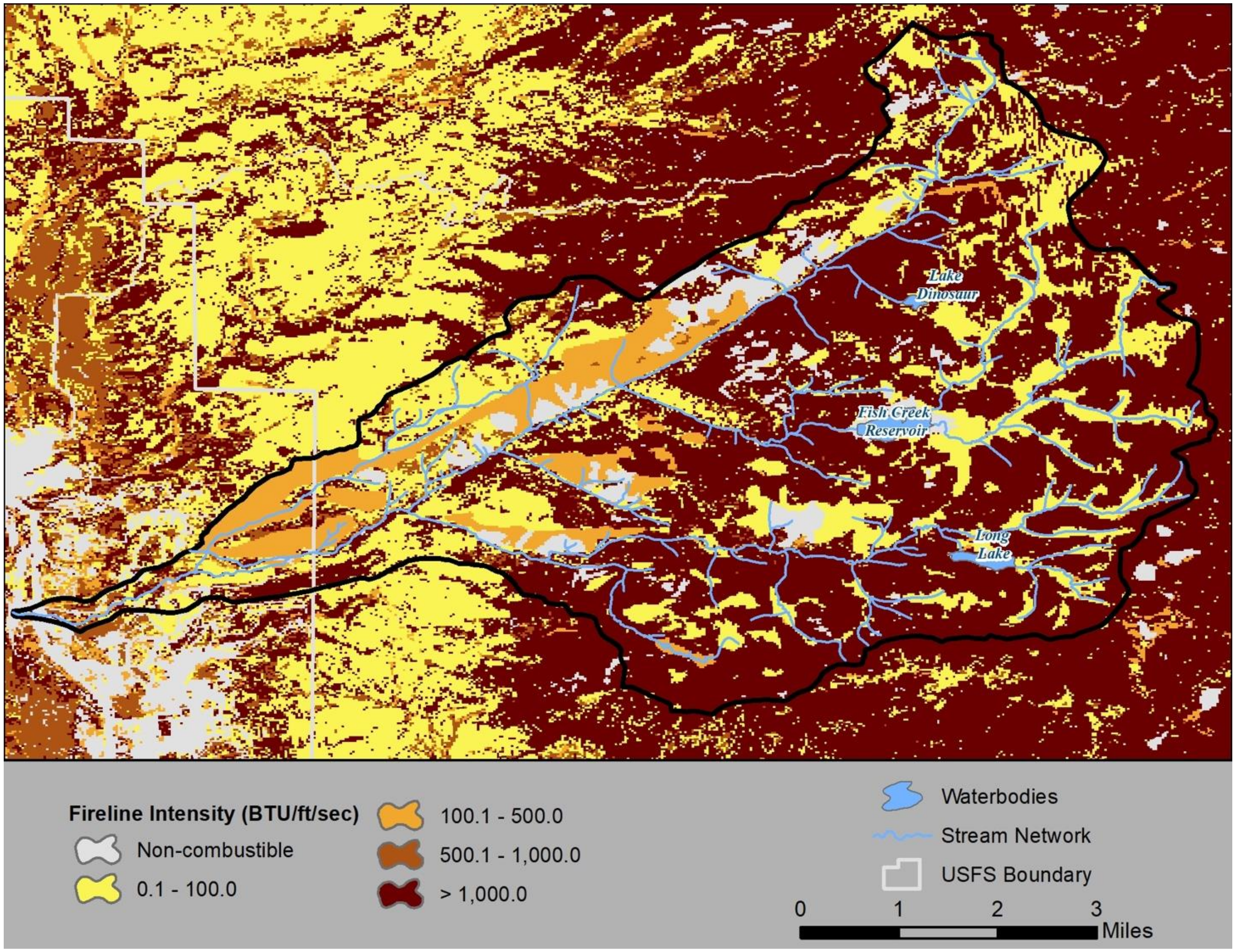

Figure 5-3. Fireline Intensity FlamMap Modeling Results

5.1.5.3 CROWN FIRE ACTIVITY

Crown fire activity values generated by the FlamMap model were classified into four categories based on standard descriptions: active, torching, surface, and noncombustible. In the surface fire category, little or no tree torching will be expected. During passive crown fire activity, isolated torching of trees or groups of trees will be observed, and fire movement through the canopy will be limited to short distances. During active crown fire, sustained fire movement through the canopy is probable.

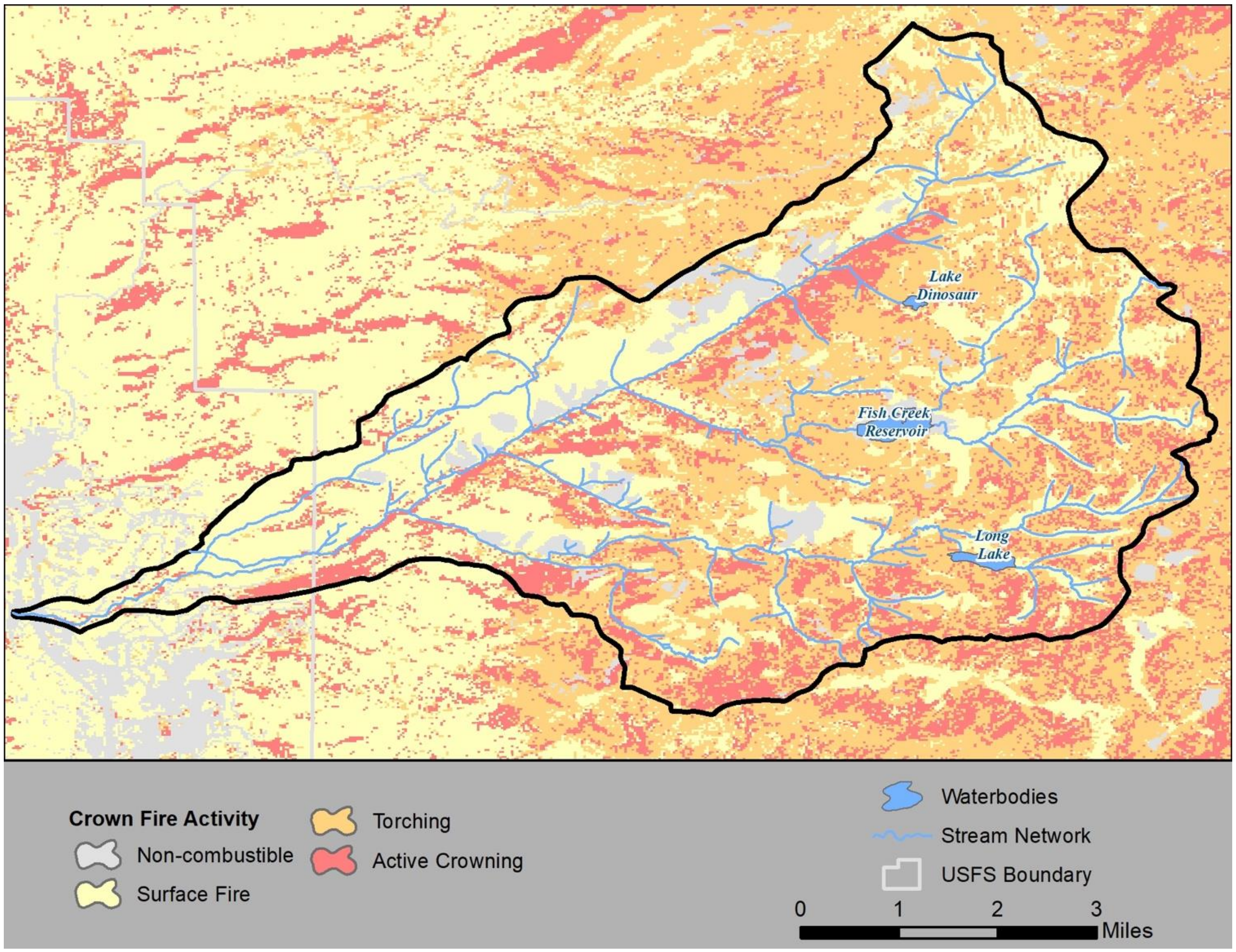

Figure 5-4. Crown Fire Activity FlamMap Modeling Results

5.1.5.4 RATE OF SPREAD

Rate of spread values generated by FlamMap were classified into four categories based on standard ranges: less than 20, 20.0–40.0, 40.1–60.0, and greater than 60 chains per hour (ch/h). A chain is a logging measurement that is equal to 66 feet; 1 mile equals 80 chains, 1 ch/h equals approximately 1 foot per minute, and 80 chains per hour equals 1 mile per hour. Note that a high rate of spread is not necessarily severe in the context of this analysis. Fire will move very quickly across grass fields but will not burn very hot and may not cause any major damage to the soil.

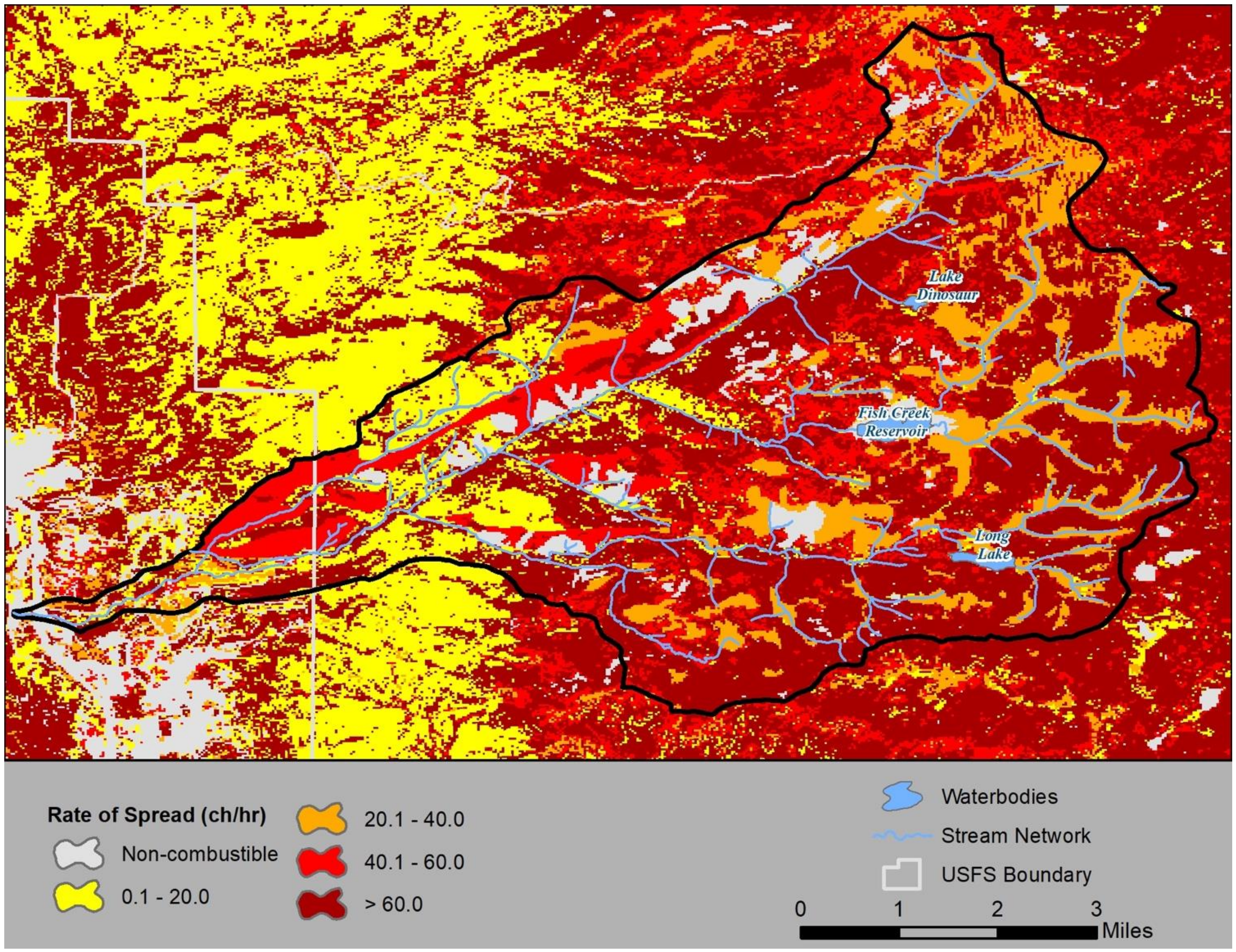

Figure 5-5. Rate of Spread FlamMap Modeling Results

5.1.5.5 BURN PROBABILITY

A burn probability analysis was used to temper the likely fire size and frequency. The Probability of Ignition analysis is used to determine the likelihood that an area will burn, as compared to others, under the same weather conditions. As shown in figure 5-6 and the preceding figures, areas where fire behavior is predicted to be most extreme also have the lowest probability of ignition. This is because fire models calculate the type of fire behavior that would be expected when a fuel model burns, assuming that every pixel will burn. That reflects the *potential* fire behavior. In reality, not all areas will burn at the same time. The results show that high elevation mixed conifer stands have a low probability of burning; but when they do burn, it is very intense.

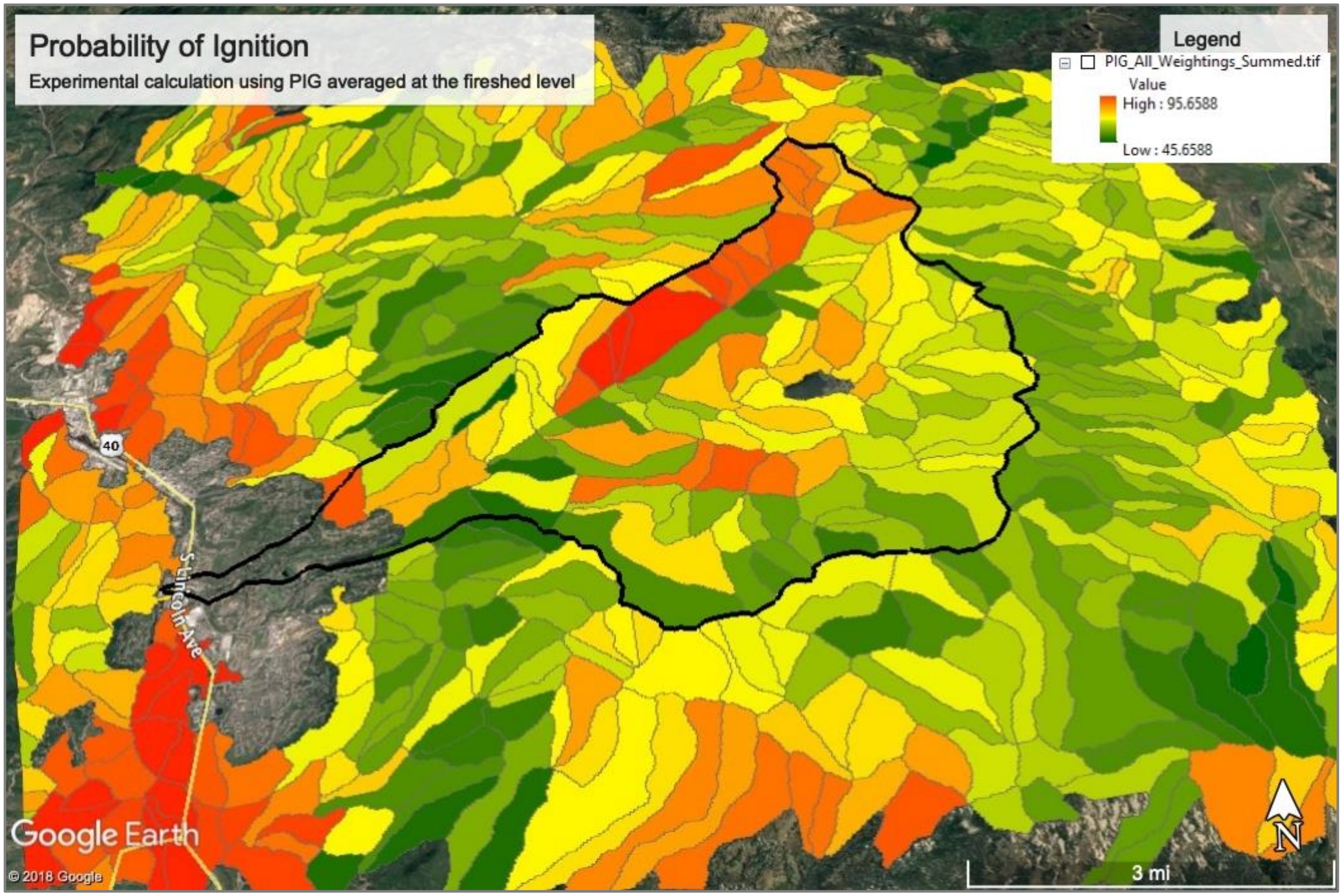

Figure 5-6. Burn Probability FlamMap Modeling Results

5.2 POSTFIRE HYDROLOGIC HAZARD

The postfire hydrologic hazard analysis incorporates results from fire behavior modeling to identify locations within the municipal watershed which are most likely to contribute large sediment loads if the water-supply system if burned, using USGS debris flow prediction models. These models integrate information about fire behavior, terrain, soil erodibility, and local precipitation patterns to estimate the probability of debris-flow occurrence and debris-flow volumes. These models were chosen, because a meaningful postfire hydrologic hazard analysis must consider the interdependence of these variables. For example, a severely burned watershed is much more susceptible to flooding/debris flow hazards than a moderately burned watershed of similar ruggedness with similar soil properties. Further, precipitation is the primary driver of the flooding/debris flow hazard, and the extent to which conditions that make a watershed susceptible (i.e. highly erodible soils, steep slopes, rugged terrain) may be exacerbated by wildfire vary with precipitation volume and intensity.

Three debris flow prediction model sets were used in this analysis to allow for different weighting of the variables, while incorporating the most recent state of the science (Table 5-4). The debris flow prediction models are used by USGS and NOAA to support early warning systems, which provide evacuation warnings, and provide emergency assessments to communities downstream of burned areas. These empirical models were initially developed using data obtained from 53 basins that had been burned by 10 separate wildfires throughout the western US (Model Set 1) and have been continually updated over the past decade (Cannon, 2006 and Gartner et al. 2008). The second model set (Model Set 2) was developed using data from 388 basins impacted by 15 wildfires in the Intermountain West (Cannon et al. 2010). Model Set 3 was developed using data from 1,243 basins burned by 34 fires throughout the western US (Gartner 2014 and Staley et al., 2016).

As shown in Table 5-4, the probability (likelihood) and severity (volume) of debris-flow occurrence is a function of the following variables related to wildfire impacts (soil burn severity, difference normalized burn ratio [dNBR]), topography (ruggedness, slope), soil properties (organic matter, clay, liquid limit, erodibility (K) factor), and precipitation (intensity, volume). The fire behavior modeling results and guidance from the scientific literature provided a means to approximate soil burn severity. Rainfall intensity and volume were obtained from NOAA Atlas 14, Volume 8. Variables that describe the municipal watershed's topography were acquired geospatially through USGS digital elevation models [DEMs]. Soil properties were obtained from the RNF soil survey and were supplemented with National Resource Conservation Service (NRCS) Web Soil Survey and STATSGO datasets.

Because debris flow likelihood and volume are calculated for a specific drainage area, the Fish Creek basin was delineated to provide smaller drainage areas (catchments) appropriate for the model application. Then, a value for each of the above-mentioned variables was spatially calculated for each catchment using ArcGIS tools. The following sections detail methods and data sources used to delineate Steamboat Springs' water supply drainage to the catchment scale and acquire the debris flow model input variables for each catchment

5.2.1 WATER-SUPPLY CATCHMENT DELINEATION

The smallest scale delineation publicly available was from the National Hydrology Dataset (NHD) HUC-12 Subwatersheds. These planning units range from 10,000 to 40,000 acres, while the debris flow models were developed on drainage areas that ranged from approximately 50-2000 acres (with an average size of ~500 acres) [USGS, 2013; USDA NRCS, 2013; and Staley et al., 2016]. Therefore, catchments within the water supply drainage area were delineated in ArcGIS using the ArcHydro Extension to a level that met model requirements.

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Model Set	Likelihood Model $e^x/1+e^x$, where x =	Variables	Volume Model (m^3) Ln (Volume) =	Variables
1 **Cannon 2006 (Likelihood)** **Gartner 2008 (Volume)**	$-7.6 + 0.6 (A_b) - 1.1 (R) + 0.1(C) - 1.4 (O) + 1.1(I)$	Ab: % basin burned at moderate and high severities R: basin ruggedness (relief/area$^{1/2}$) C: % clay in soil O: % organic matter in soil I: average storm rainfall intensity (mm/hr)	$0.59 (Ln(S)) + 0.65(B)^{1/2} + 0.18(R)^{1/2} + 7.12$	S: basin area with slope > 30% (km^2) B: basin burned at moderate and high severities (km^2) R: total storm rainfall (mm)
2 **Cannon 2010 (Likelihood and Volume)**	$-0.7 + 0.03(\%A) - 1.6(R) + 0.06(\%B) + 0.07(I) + 0.2(C) - 0.4(LL)$	%A: % basin area with slope > 30% %B: % basin burned at moderate and high severities C: % clay in soil LL: soil liquid limit	$7.2 + 0.6(\ln A) + 0.7(B)^{1/2} + 0.2(T)^{1/2} + 0.3$	A: basin area with slope > 30% B: basin burned at moderate and high severities (km^2) T: total storm rainfall (mm)
3 **Staley 2016 (Likelihood)** **Gartner 2014 (Volume)**	$-3.63 + (0.41) (PropHM23) (i15) + (0.67) (dNBR/1000) (i15) + (0.7) (KFACT) (i15)$	PropHM23: proportion of basin burned at moderate or severity with slope > 23% dNBR: difference normalized burn ratio i15: peak rainfall intensity over 15 minute period KFACT: soil erodibility index of fine fraction of soils	$4.22 + 0.39(i15)^{1/2} + 0.36(Ln(Bmh) + 0.13(R)^{1/2}$	Bmh: basin burned at moderate and high severities (km^2) i15: peak rainfall intensity over 15 minute period R: total storm rainfall (mm)

Table 5-4. Debris Flow Prediction Models used to Determine Postfire Hydrologic Hazard

When appropriate, the ArcHydro delineation was adjusted manually to maintain relatively consistent catchment sizes and to delineate drainages specific to the water supply infrastructure using High Resolution NHD catchment layer and a 10-meter DEM. The water-supply drainage catchment delineation resulted in 43 catchments that ranged in size from 180 to 630 acres, with an average size of approximately 400 acres. Each catchment was given a unique Water Supply Drainage Identification (WSD ID) number during the delineation process to help with tracking and aid in further processing. The catchment delineation is shown in Figure 5-7.

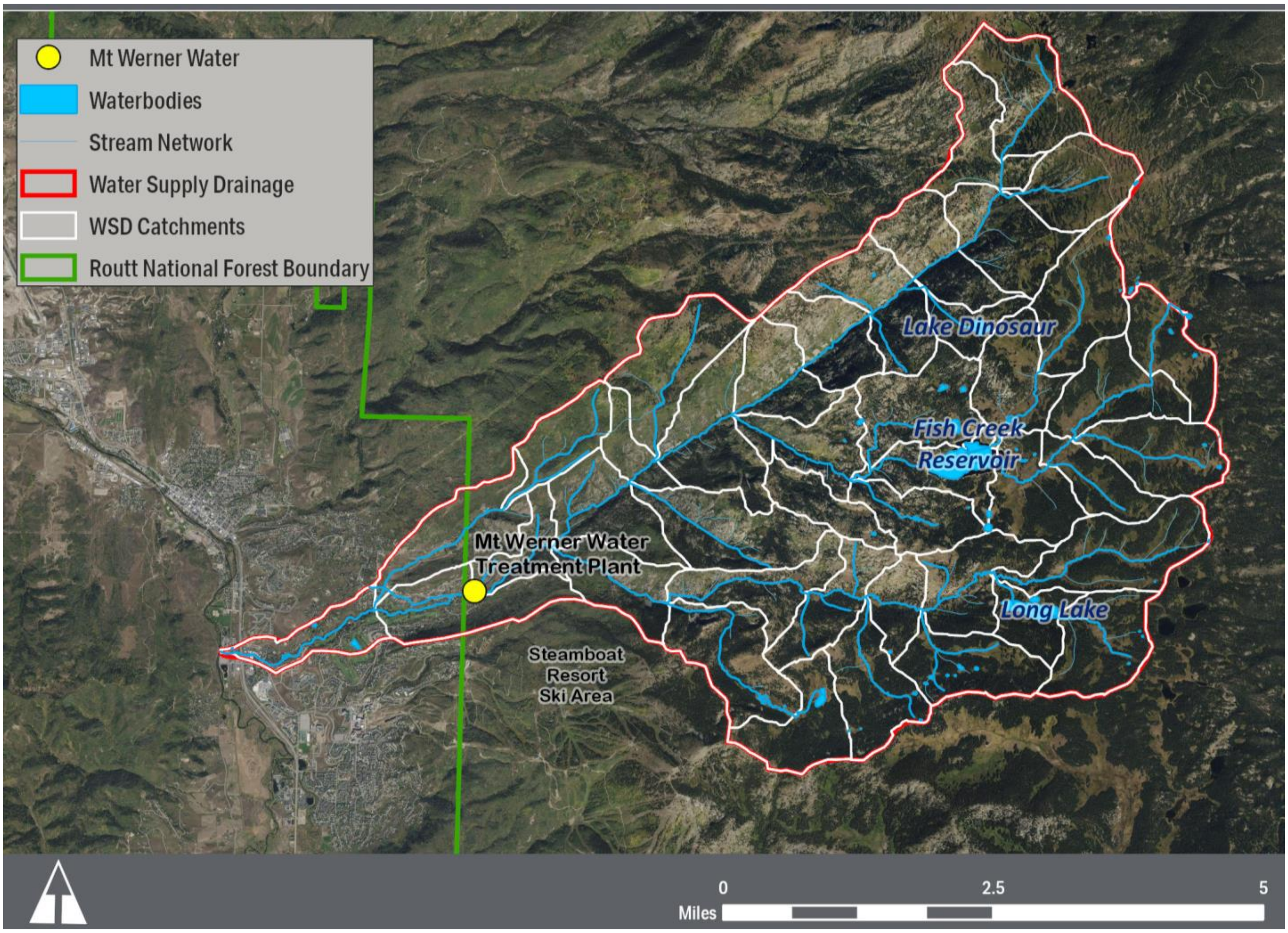

Figure 5-7. Delineation of Catchments within the Water Supply Drainage

5.2.2 SOIL BURN SEVERITY

The debris-flow models require the area and percent of area within the catchment that were subject to a moderate to high-severity burn as well as an estimate for the Differenced Normalized Burn Ratio (dNBR). The fire behavior modeling conducted for the wildfire hazard analysis served as the basis for the soil burn severity estimates, specifically the fireline intensity and crown fire predictions outputs. However, these output datasets do not directly translate to soil burn severity and required interpretation to be used as the required debris flow model inputs. Fireline intensity is a measure of the power of a fire along the flaming front (essentially a measure of energy released at each location) and crown fire activity predicts a fire's movement through the canopy, while soil burn severity is a measure of above- and belowground organic matter consumption from fire [Keeley, 2009].

Because these measurements are not directly translatable, guidance was drawn from previous work conducted by our team in Medicine Bow National Forest, the Cheyenne Municipal Watershed Wildfire Hazard Mitigation Assessment, which had three wildfires occur within the study area over the course of the project (RESPEC and Anchor Point, 2017). Soil burn severity was estimated by spatially correlating BAER soil burn severity maps of past fires within the project area to the fuels model input to FlamMap and the Fireline Intensity fire-behavior modeling outputs to determine critical thresholds on specific vegetation types (i.e., timber) that typically yield the moderate and high burn severity ratings observed on the ground by BAER teams to obtain a predicted soil burn severity estimate. These thresholds were applied to Fireline Intensity dataset developed for Steamboat Springs to predict areas of moderate to high soil burn severity and were used as inputs to Model Set 1 and Model Set 2 (Figure 5-8a).

Guidance was also drawn from a recent USGS, USFS study in Santa Fe National Forest [Tillery and Haas, 2016], which used the areas of passive (torching) and active crown fire from the FlamMap Crown Fire Activity dataset as an approximation for areas burned at moderate to high severity. This method was applied to the Crown Fire Activity dataset developed for the Fish Creek basin to predict areas of moderate to high soil burn severity, as shown in Figure 5-8b. These burn severity estimates were used as inputs to Model Set 1 and Model Set 2.

Finally, the most recent debris flow models (Model Set 3) use dNBR rather than burn severity to characterize wildfire impacts. (dNBR is essentially the difference in “greenness” between a satellite images taken before and after a wildfire occurs. It serves as the basis for the BAER soil burn severity maps, which are created by applying Burned Area Reflectance Classification (BARC) thresholds to, then “ground truthing” the raw dNBR imagery). dNBR estimates for the Steamboat Springs project area were determined following methods developed by Staley et al. [2018], which used the Monitoring Trends in Burn Severity database (3163 burned areas between 2001 and 2014) to define a statistical distribution of dNBR values for each existing vegetation type class in LANDFIRE EVT dataset. As recommended, dNBR values were calculated for 50th, 75th, and 90th percentile probabilities. However, only the 50th percentile distributions were used in the final analysis. The simulated dNBR predictions are shown in Figure 5-8c and were used as an input to Model Set 3.

5.2.3 TOPOGRAPHIC CHARACTERISTICS

The topographic characteristics required for the debris-flow models include Melton’s Ruggedness Number (change in elevation/square root of area), basin area with slopes greater than 30 percent, and the basin area. Slopes in the project area were calculated in ArcGIS using the 10m (DEM) from the National Hydrography Dataset (NHD) Version 2. Melton’s Ruggedness Number was calculated by using the NHD DEM, areas that met the 30 percent slope threshold were extracted, and (for Model Set 3) intersected with the dNBR estimates that met required BARC thresholds within ArcGIS. Elevation and areas with slopes greater than 30 percent are shown in Figure 5-9.

5.2.4 SOIL COMPOSITION

Spatial soils data as well as a tabular soil survey data for the project area within the National Forest were provided by RNF. This data supplemented the NRCS’ Web Soil Survey (WSS) and State Soil Geographic (STATSGO)datasets for Colorado. The soil datasets were merged to create a unified GIS layer for the project area, and the required model input variables were populated in the soil data layer using the soil survey information. The required soil variables are shown in Figure 5-10 and include percent organic material (a), percent clay (b), liquid limit (c), and soil erodibility (K) factor (d)

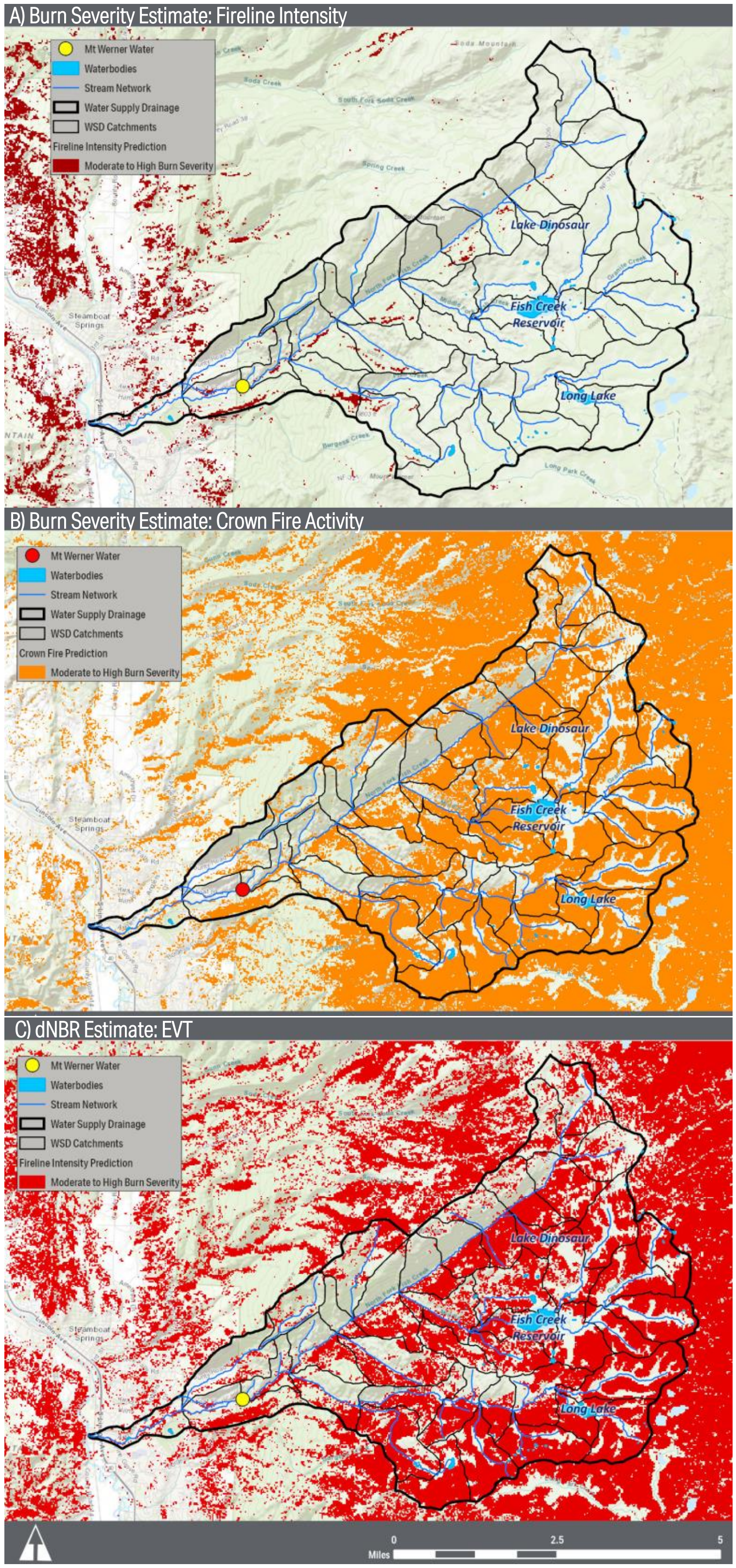

Figure 5-8. Wildfire Impact Predictions (Soil Burn Severity and dNBR) used as Inputs to Debris Flow Models.

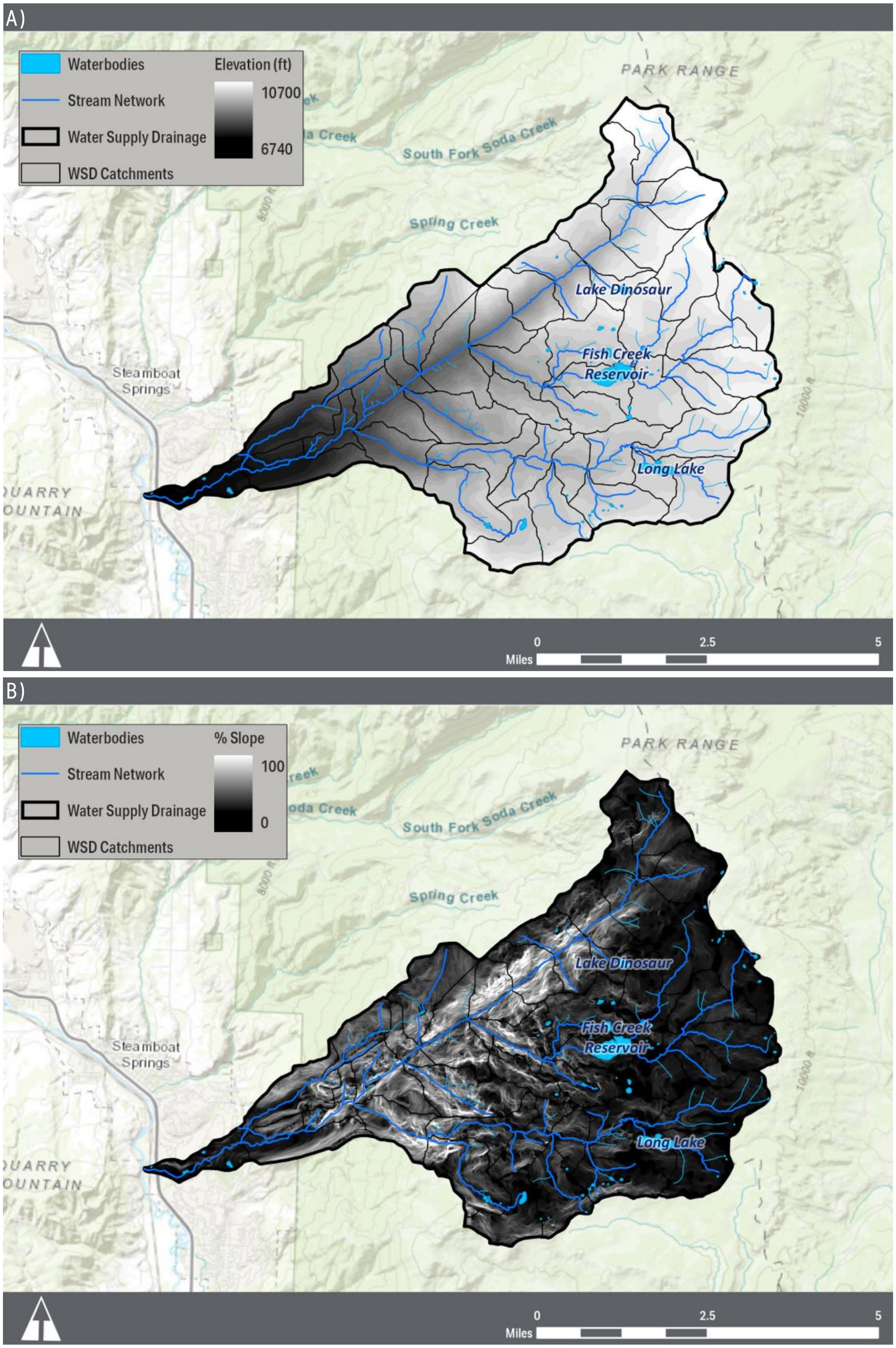

Figure 5-9. Topographic Variable Inputs: A) Elevation (feet) and B) Slopes Greater than 30 Percent.

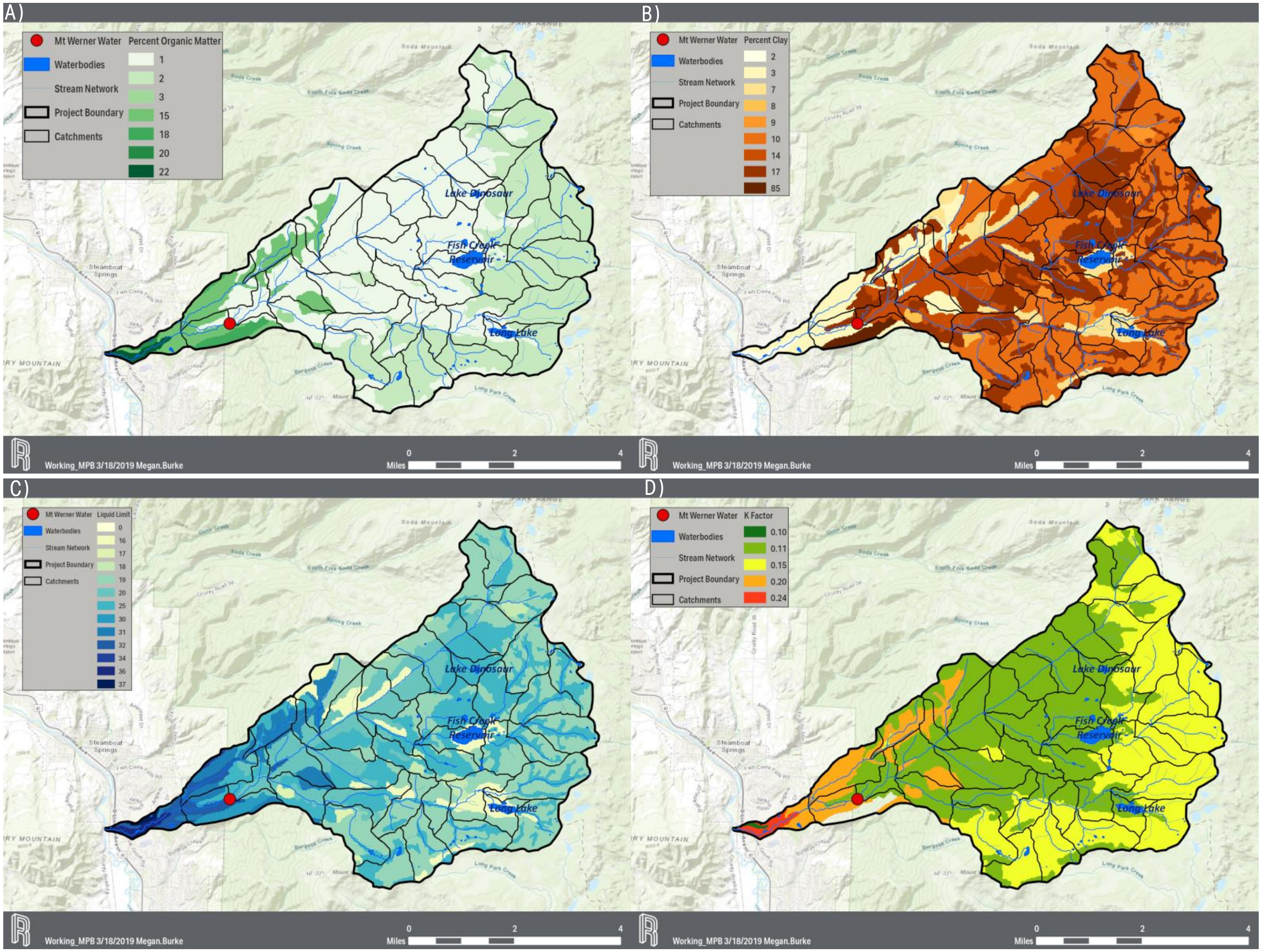

Figure 5-10. Soil Variable Inputs: A) Percent Organic Material, B) Percent Clay, C) Liquid Limit, and D) Soil Erodibility (K) Factor.

5.2.5 PRECIPITATION VOLUME AND INTENSITY

Precipitation volume and intensity were obtained from the NOAA Atlas 14 Volume 1 spatially distributed precipitation-frequency estimates. The NOAA Atlas 14 was recently updated from NOAA Atlas 2; estimates based on data collected through 1966 and published in 1973 were updated to include data collected through 2000. The latest version also enhanced precipitation representation in complex terrain by using a climate-based spatial interpolation. Because this project is focused on quantifying and mitigating hazards to municipal water supply caused by wildfire, the most probable storm event to occur in the first year after a wildfire (the 1-year storm event, 15-minute intensity) is the most relevant to this project. Figure 5-11 provides the spatial distribution of 15-minute intensity of the 1-year storm. While this assessment focuses on the most likely storm, spatial frequency distributions for the 2, 5, and 10-year events are included in the supporting project files, to allow for estimation of impacts of a larger storm event on a fire-impacted watershed through the recovery period. The statewide frequency distribution datasets were obtained as ASCI files from NOAA, and the mean aerial precipitation was calculated for each catchment within ArcGIS to obtain the rainfall intensity and volume for each design storm.

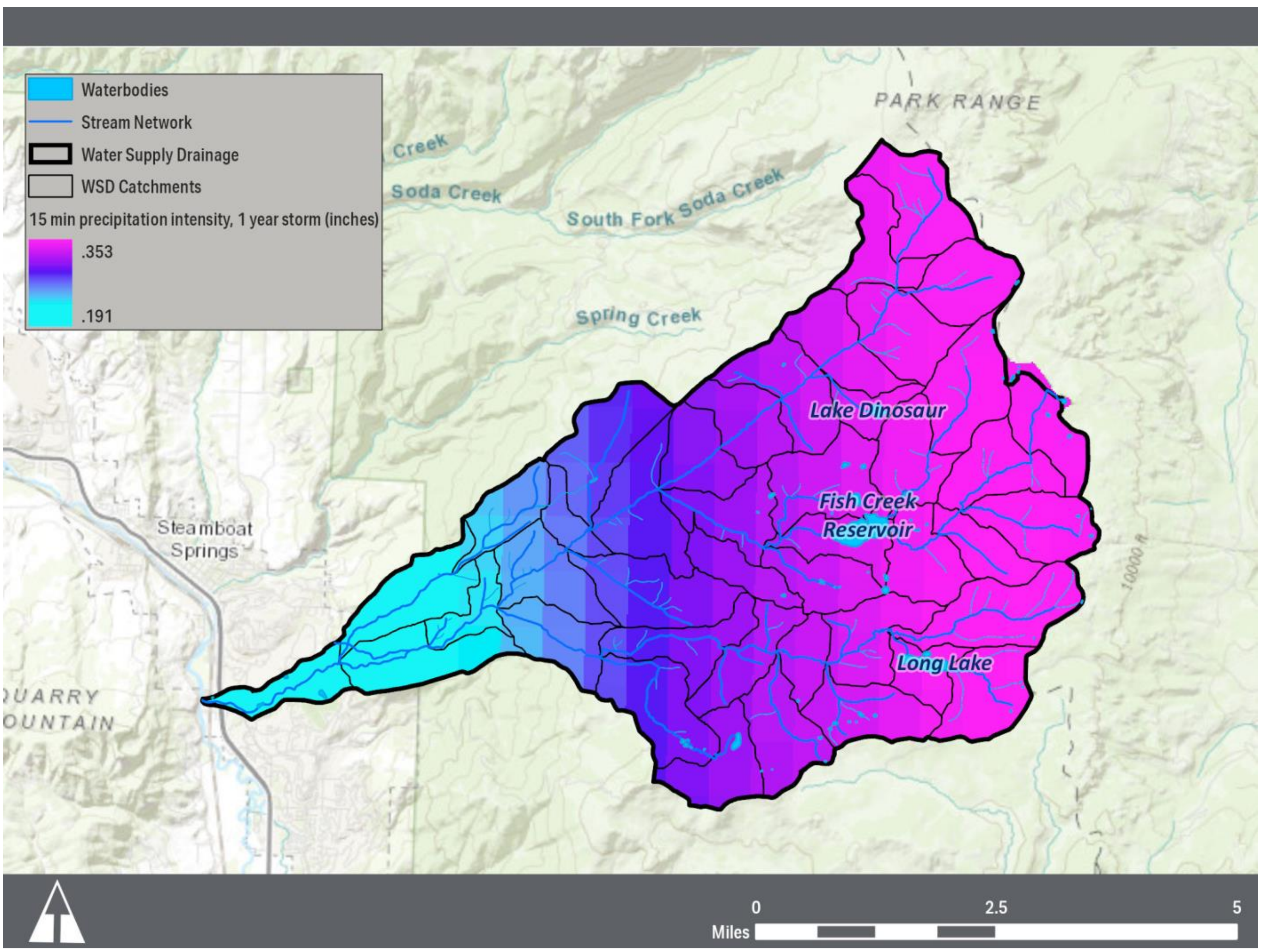

Figure 5-11. Spatial Distribution of 15 minute Precipitation Intensity (1 year Storm).

5.2.6 DEBRIS-FLOW PREDICTION AND RISK MAP

A Model Builder tool was built in ArcGIS to extract the required debris flow model input variables for each catchment, and the debris-flow probability and volume were calculated. Debris-flow probability and volume were computed for each catchment, using each model set. Both the fireline intensity and crown fire activity soil burn severity estimates were used to run Model Set 1 and Model Set 2, while only the EVT dNBR simulation was used to run Model Set 3. This resulted in five separate iterations of the debris flow probability and volume models. Then the expected mass of sediment delivered in a debris flow was estimated using the debris flow volume model results and the assumption of debris-flow composition of 70 percent solid material and 30 percent water (Parrett, 1987; Meyer and Berger, 1992). Results from the debris-flow volume models were multiplied by 0.7 × (0.3 × specific gravity of water + 0.7 × bulk density of soil) × unit conversion factor to obtain an estimate of tons of sediment delivered. The mass estimates were normalized by catchment area to look at the relative contribution of material from each catchment.

Results from the three analyses (probability, volume, relative mass) were binned and integrated to determine a comprehensive output by catchment for each of the five model iterations. This allowed for a comparison of the areas of maximum concern for each model set and burn severity combination. The raw results and comprehensive outputs for each model iteration are not shown here but are included in the supplementary material. The models were in general agreement and results were reviewed with the Core Team. Results of each analysis were averaged over the suite of the model iterations to calculate expected debris flow probability (Figure 5-12a), volume in cubic meters (Figure 5-12b) and relative mass in tons/acre (Figure 5-12c).

A composite hazard index was calculated to determine the primary areas of concern within the water-supply drainage. This was achieved by indexing each of the comprehensive model outputs on a scale of 1-100, summing the indices calculated for each model iteration, then re-indexing to the 1-100 scale (Figure 5-12d). The catchments were then binned and ranked to determine the catchments in 90th percentile, 80-89th percentile, 70-79th percentile, 60-69th percentile 50-59th percentile, of the composite hazard ranking, and these catchments were given a simplified rank of 1-5, respectively. Any catchment that ranked below the 50th percentile was given a simplified rank of 6. The composite hazard index and ranking identified the areas above critical surface water infrastructure with the greatest potential for contributing significant amounts of sediment and debris during postfire storm events to define the Risk Map (Figure 5-12d).

5.2.7 SENSITIVITY ANALYSIS

The Risk Map was overlain with MBRNF datasets including Roadless Areas (Figure 5-13a) and existing roads and trails (Figure 13b) and presented to the Core Team. Based on discussions with the team, it was determined that much of the identified area is in very steep terrain with very limited access. Additionally, much of the area identified in the North Fork Fish Creek drainage is essentially bedrock, which may not be captured in the soil datasets where values are averaged over larger map units. Because the debris models integrate slope, burn severity, soil properties, and precipitation, questions were raised about how much the predictions are driven by wildfire impacts vs. the other variables (slope, soil properties, and precipitation) and how much reducing the potential burn severity would reduce the postfire impacts (i.e. would fuels treatments in these hard to access areas have the desired effect?).

To this end, a sensitivity analysis was conducted to determine the effectiveness of reducing the potential soil burn severity. The soil burn severity and dNBR inputs to the debris flow models (area and percent of each catchment burned at moderate to high severity) were reduced by 25 percent increments and the models were rerun to produce composite hazard index predictions for 0.1, 25, 50, 75, and 100 percent of the predicted burn severity for each catchment. The ratio of the 0.1 to 100 percent composite hazard indices was mapped to show the areas where debris flow risk is more driven by fire impacts than by other variables and where fuels treatments are likely to be most effective in reducing postfire impacts (smallest values indicate the greatest change and values approaching or greater than 1 indicate little to no change). Sensitivity analysis results were overlain with RNF Roadless Areas (Figure 5-14a) and existing roads and trails layers (Figure 5-14b) to assess accessibility and discussed with the Core Team.

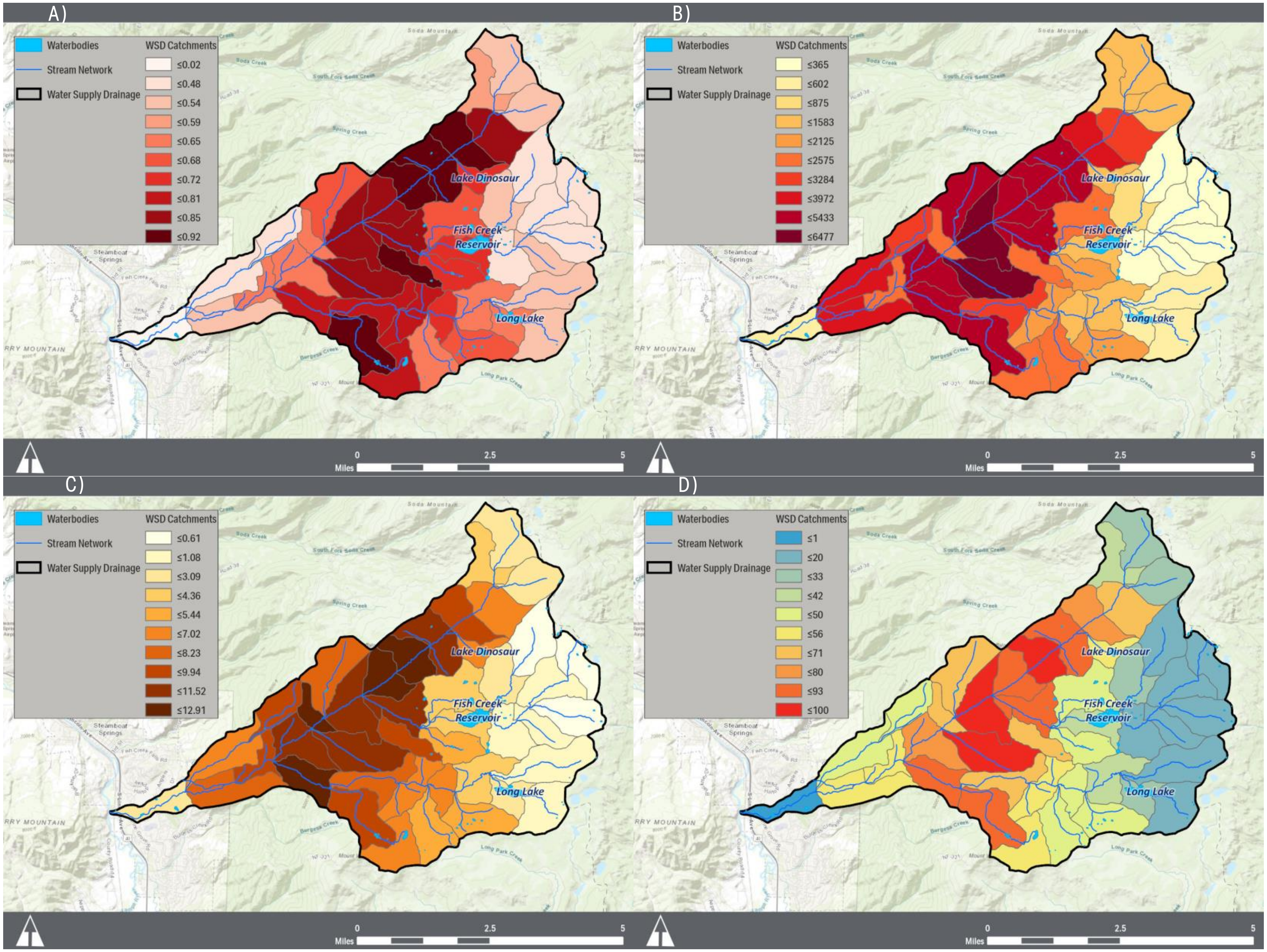

Figure 5-12. Debris Flow A) Probability (percent), B) Volume (m^3), C) Relative Mass (ton/acre), and D) Composite Hazard Index.

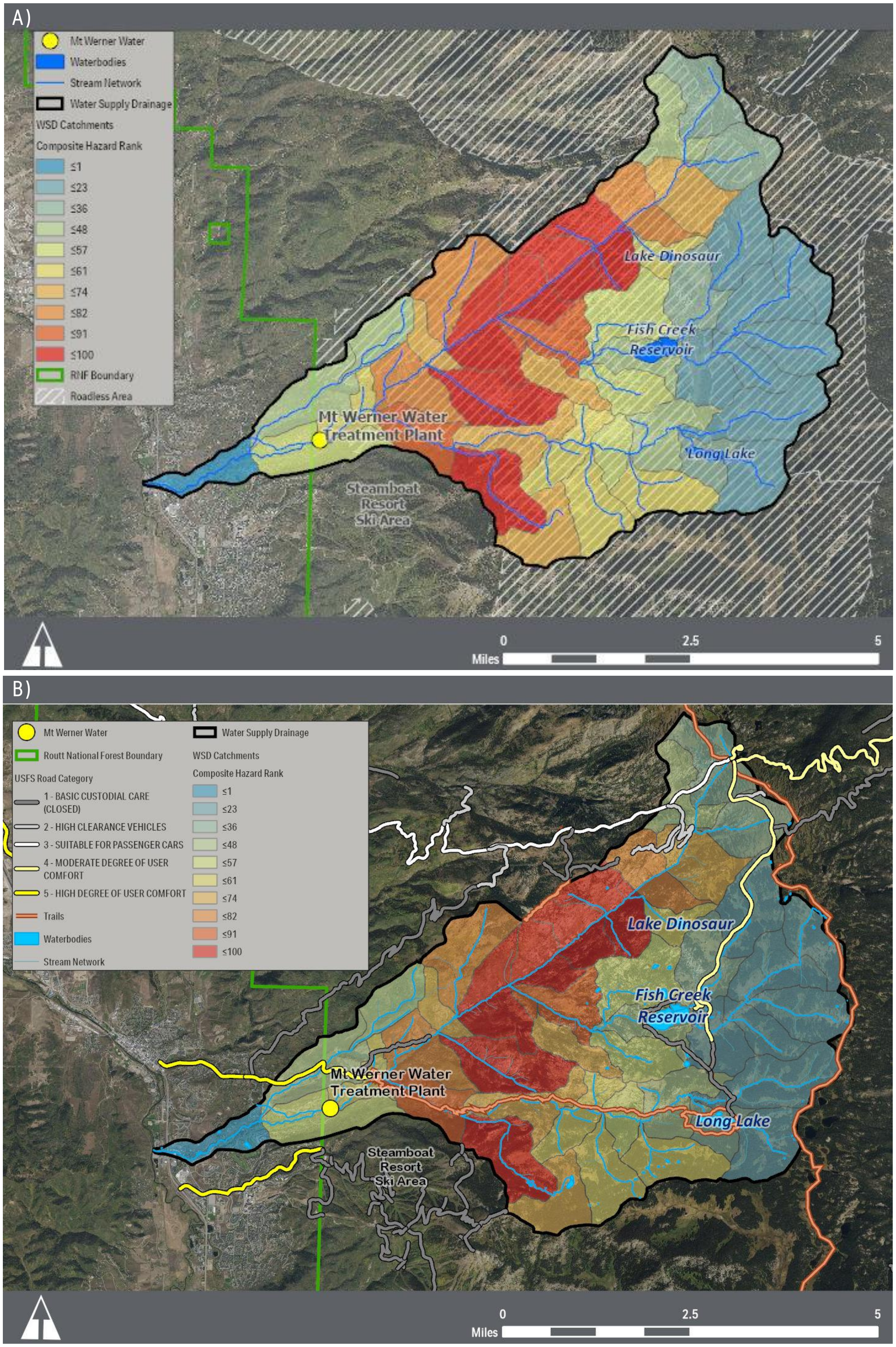

Figure 5-13. Composite Hazard Index Overlain by A) Roadless Areas and B) Roads and Trails.

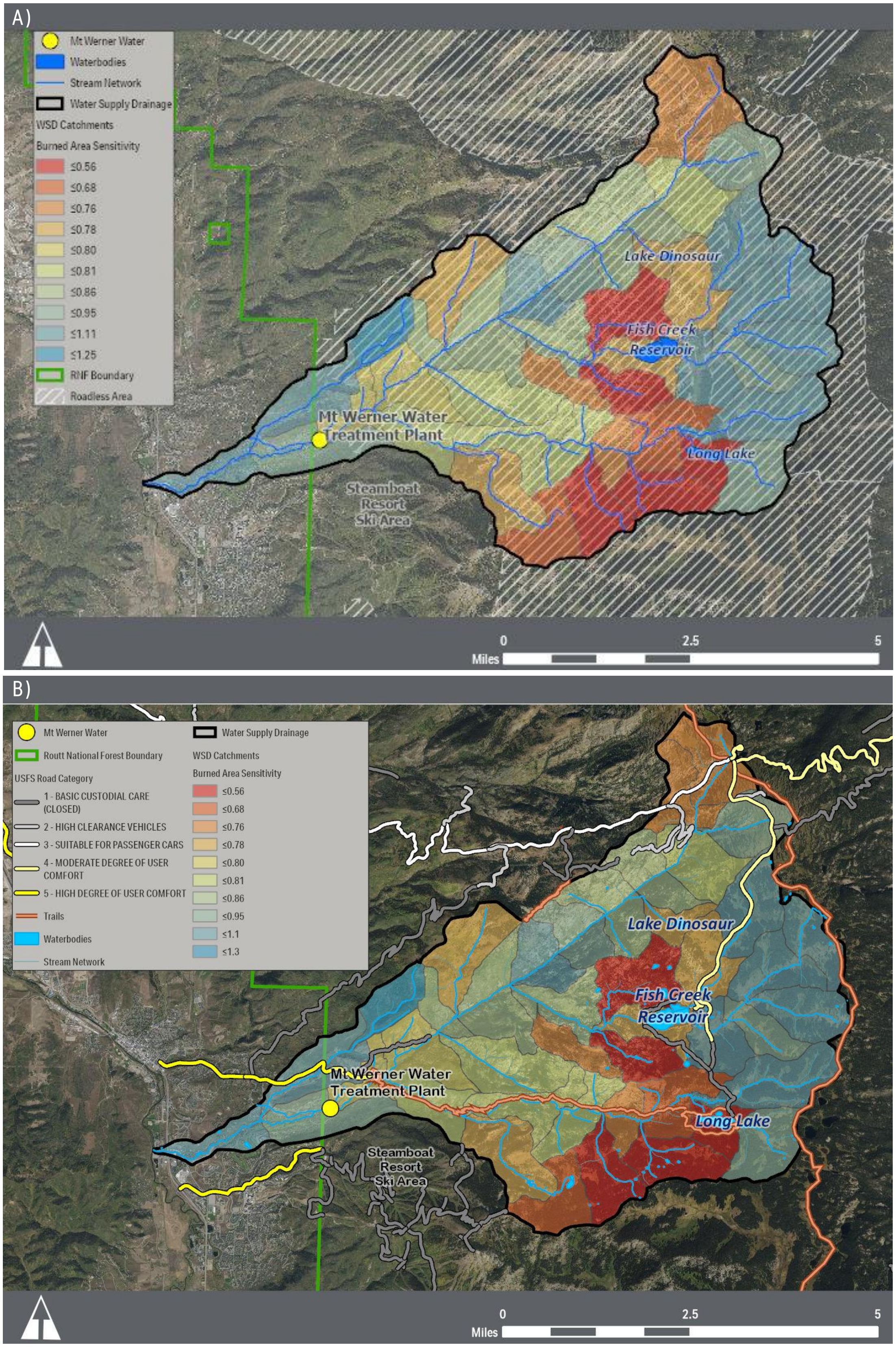

Figure 5-14. Sensitivity Analysis Results Overlain by A) Roadless Areas and B) Roads and Trails.

5.2.8 STREAM NETWORK ASSESSMENT

An assessment of the stream network was conducted to identify areas that may be suitable for in-stream controls to reduce wildfire impacts to water supply. If a wildfire were to occur within the municipal watershed, having locations for potential sediment mitigation projects pre-identified can help facilitate timely implementation. The stream network assessment included a geomorphic indicator analysis to identify stream segments (reaches) that are most likely to supply, transport, or deposit material based on guidance drawn from Rosgen stream-type classifications; a high-level peak flow modeling analysis to estimate the difference in magnitude of pre and post fire peak flow, and a desktop topographic analysis to identify pinch-points and critical infrastructure locations that may be suitable for control structures.

5.2.8.1 GEOMORPHIC INDICATOR ANALYSIS

Geomorphic indicators, such as channel slope and sinuosity, were calculated within ArcGIS to obtain a high-level Rosgen stream-type classification for the reaches within each delineated catchment. Then by using relationships outlined in a Cucharas watershed study and originally developed by Montgomery and Buffington [1993], the reaches were classified as either source, transport, or response reaches as described in Table 5-5.

Table 5-5. Relationship Between Sediment Transport Characteristics and Rosgen Channel Type

Sediment Transport Characteristics	Source	Transport			Response			
Rosgen Channel Type	Aa+	A	B	G	B	G	C	E
Gradient	> 0.10	0.04 to 0.10	0.03 to 0.039	0.03 to 0.039	0.02 to 0.03	0.02 to 0.03	< 0.02	< 0.02

Source reaches are high-gradient headwater streams or small tributaries that tend to be fast-moving, often flow limited, and have more sediment available than can be consistently transported; they tend to move large amounts of sediment intermittently, during peak flow or disturbance events (e.g., postfire storms). Transport reaches have a higher capacity for sediment transport than the amount of material typically supplied by their direct drainage and upstream reaches; thus, readily move sediment downstream. Response reaches are lower gradient and slower moving; often the sediment supply exceeds their ability to carry it downstream. These response reaches are potential locations for sediment control measures. As shown in Figure 5-15, the stream network within Steamboat Spring's municipal water supply drainage consists mainly of source and transport reaches. Only three reaches were classified as response reaches, and they are located just above Fish Creek Reservoir, just below Long Lake, and in the headwaters of Fish Creek's south fork.

5.2.8.2 HIGH LEVEL HEC-HMS ANALYSIS

A hydrologic model was set up using the Army Corp of Engineers Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) to determine the expected change in streamflow magnitude if a wildfire were to occur in Fish Creek Basin. The catchment delineation, soil burn severity estimates, and soil datasets developed for the postfire hydrologic assessment were used to build the model and curve number guidance was drawn from our team's previous postfire runoff hydrologic modeling of peak flows for the Waldo Canyon Fire. The pre and post fire HEC-HMS models were run for both the 2 and 100 year storm events; change factors for expected flow increase are shown in Figure 5-16. In the scenario modeled, the postfire 2 year peak flows predictions exceeded the pre-fire 100 year peak flows predictions. While this large difference in peak flows is based on fire behavior modeling predictions at 90th percentile conditions, the takeaway is that storms that currently produce little runoff can behave much differently postfire. It is also important to note that model parameters were not calibrated to observed streamflow, and results should only be used to understand relative changes in magnitude. The intention of this modeling effort was to determine relative pre/postfire streamflow within the watershed and provide a framework for future efforts. A USGS streamgage is located on Fish Creek just below the FCFP, and the model should be calibrated prior being used to for design purposes.

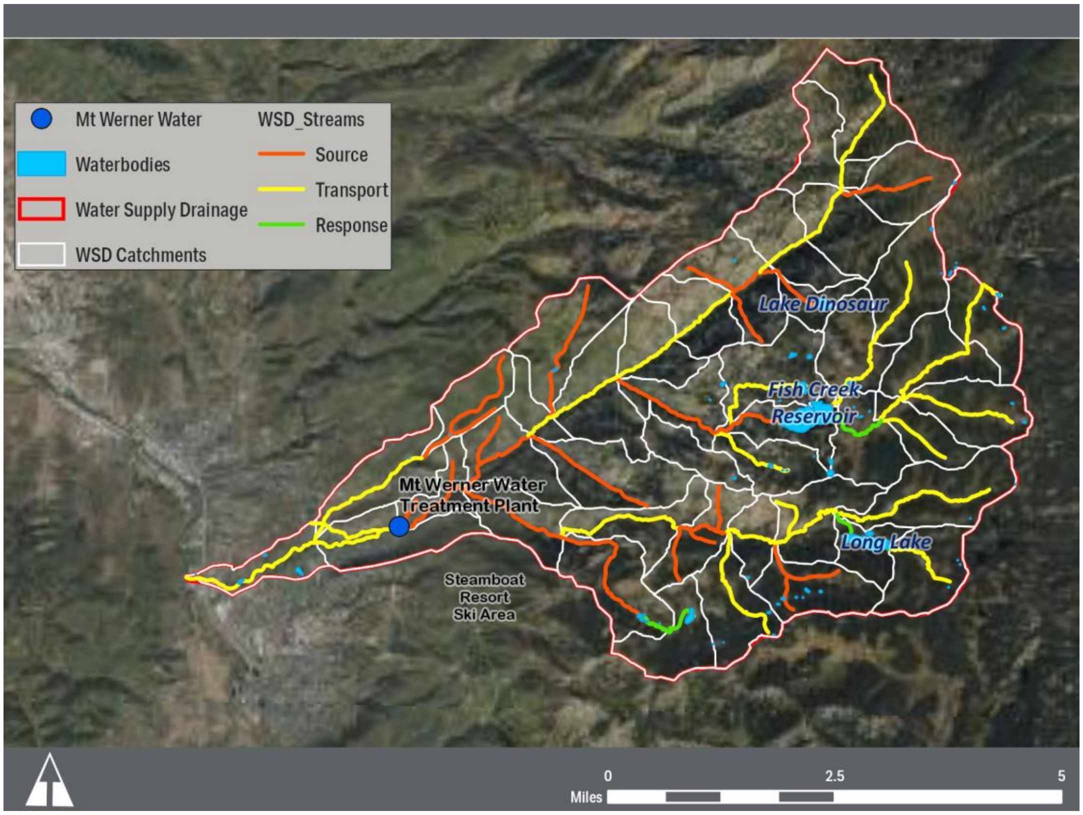

Figure 5-15. Source, Transport, and Depositional Reaches Identified by Geomorphic Indicator Analysis.

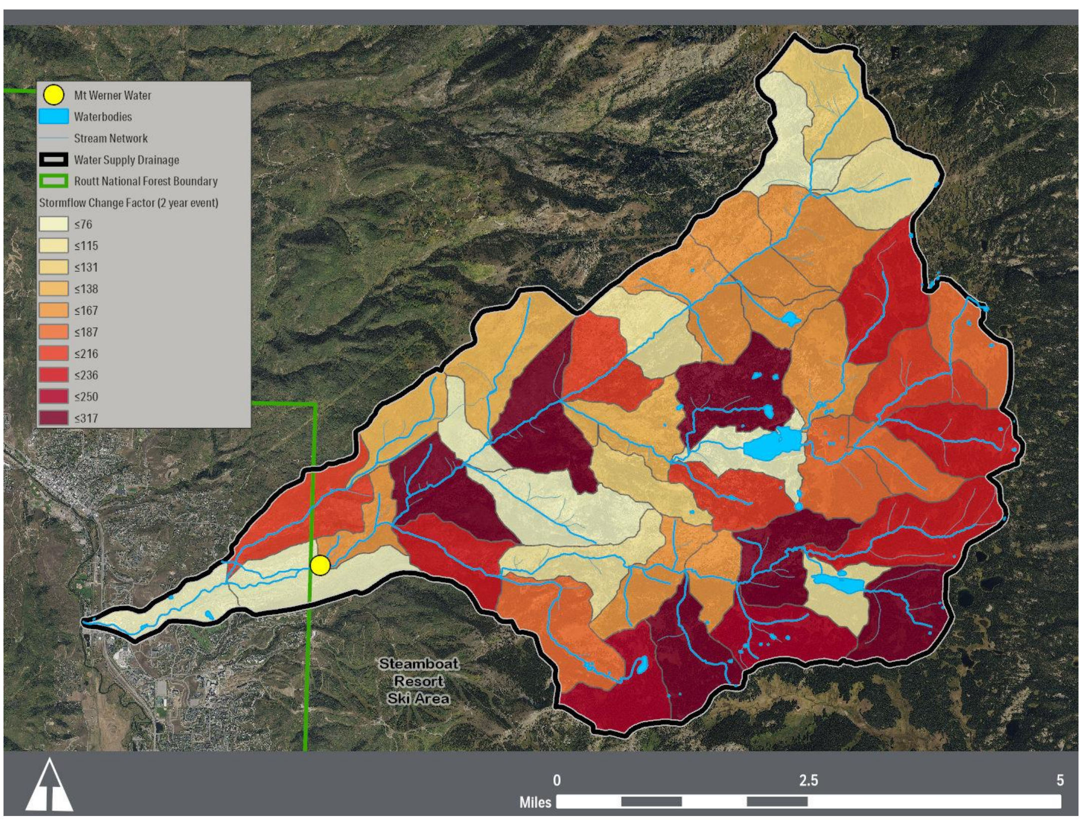

Figure 5-16. Source, Transport, and Depositional Reaches Identified by Geomorphic Indicator Analysis.

5.2.8.3 DESKTOP TOPOGRAPHIC ANALYSIS

Finally, a desktop topographic analysis was conducted to identify locations above critical infrastructure that may be suitable for hydrologic and/or sediment control structures. A 10-foot contour interval layer was created using the DEMs obtained for the postfire hydrologic assessment and imported into Google Earth. The contour map helped to identify pinch points that could potentially accommodate sediment basins, and the RNF roads layer was used to identify locations where postfire flooding could potentially cut off access to water supply infrastructure; these datasets were also supplemented with information from the previous stream network analyses. Additionally, the area surrounding the FCFP was investigated to determine what measures could be taken to protect the intake and the plant itself. Potential hydrologic and sediment control locations were mapped and presented to the Core Team for further discussion (Figure 5-17).

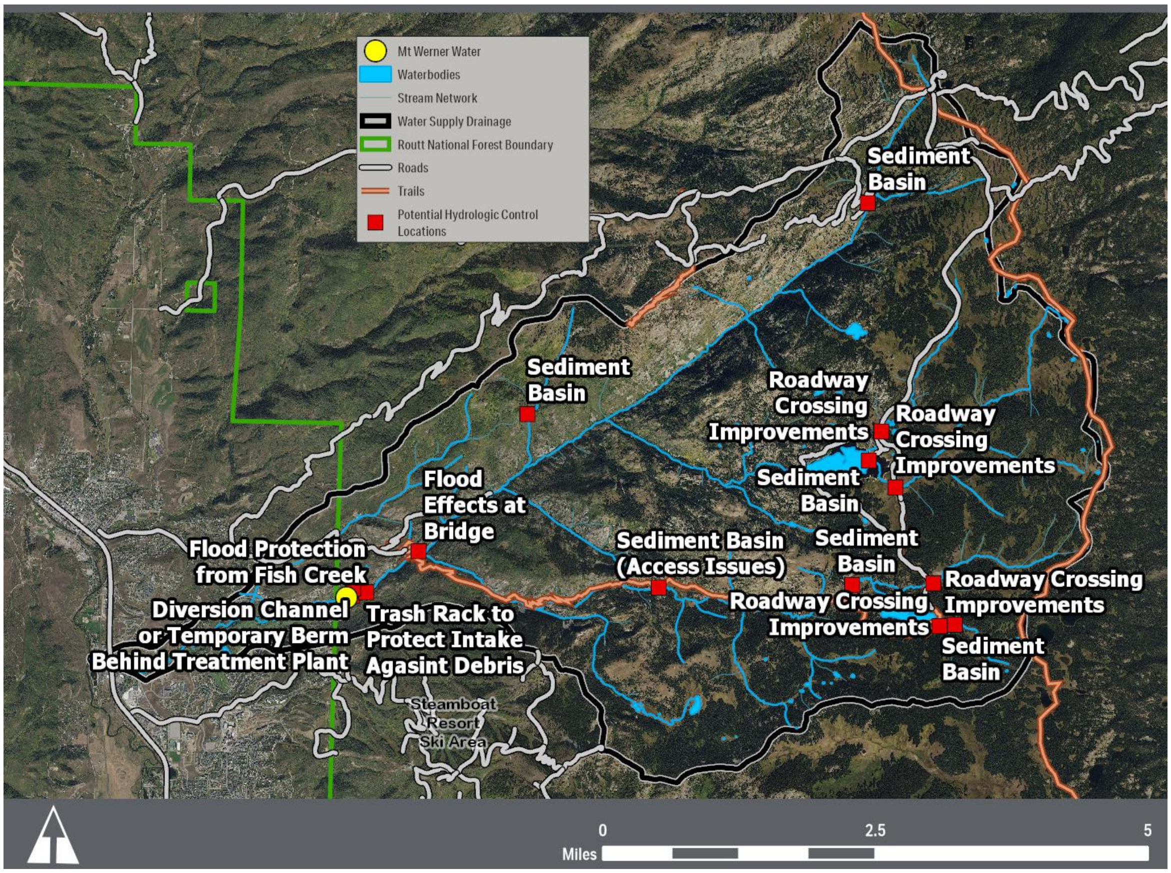

Figure 5-17. Potential Sediment and/or Hydrologic Control Locations Identified through the Stream Network Assessment.

5.3 FINAL PRIORITIZED WATERSHED MAP

A Core Team meeting was held on June 13, 2019 to review the results of the watershed risk assessment. Based on accessibility and fuels treatment appropriateness in different forest types, areas were identified for continuation in the prioritization process for treatments on the landscape. Hydrologic and sediment control options were discussed in the context of tradeoffs between preemptive mitigation and the impacts of disturbing healthy riparian areas, as well as permitting requirements under normal and emergency response conditions. Discussions also included the importance of engaging and educating residents and recreational users in the watershed. Areas on the landscape identified to investigate for fuels treatment opportunities and potential hydrologic/ sediment control locations are shown overlain with RNF road and trails layers in the Final Watershed Prioritized Map (Figure 5-18). These were discussed, along with previous and planned fuels management projects compiled for the Routt County Wildfire Mitigation Conference (Figure 5-19) to identify opportunities to build upon previous and ongoing efforts in the basin.

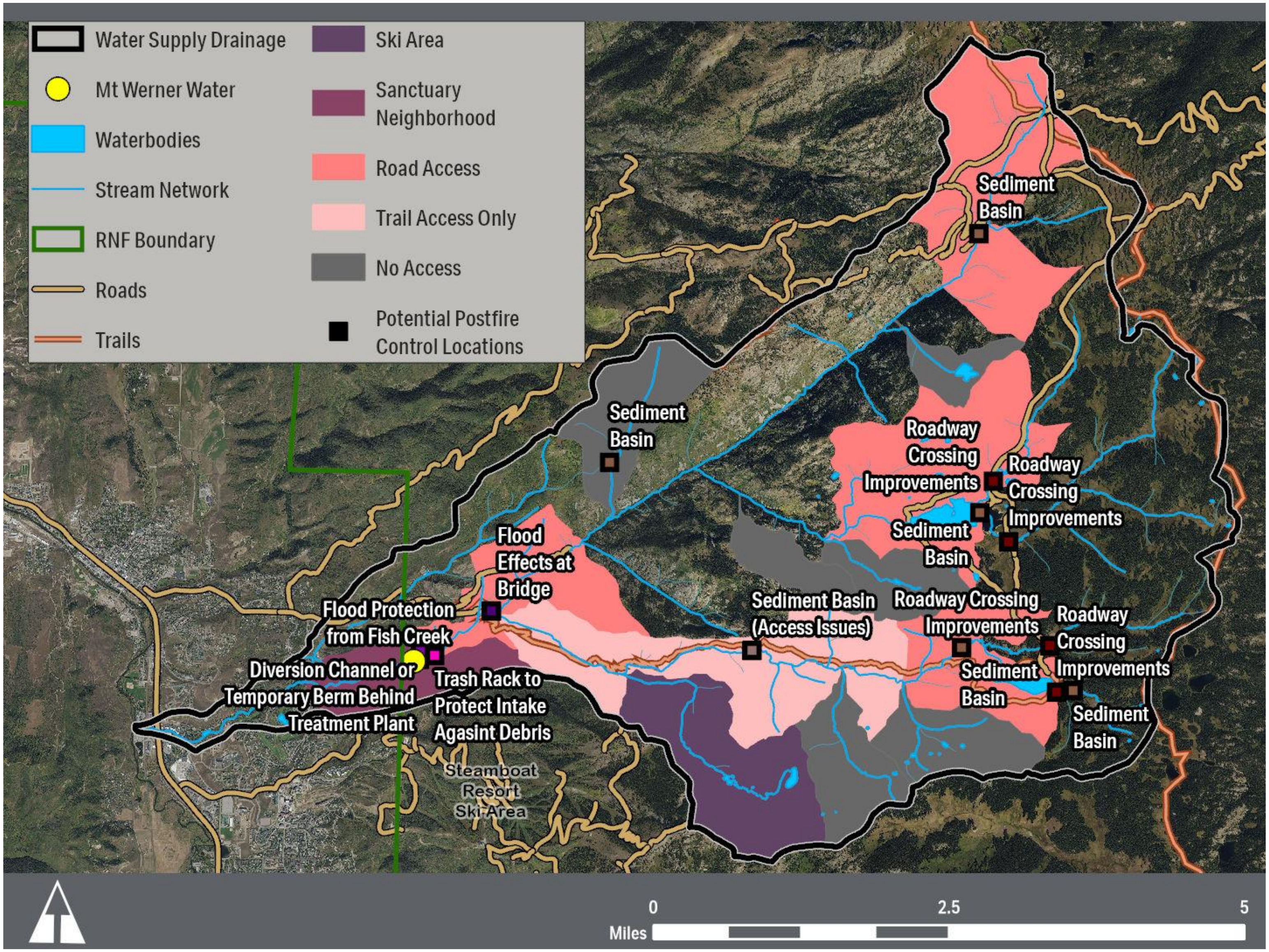

Figure 5-18. Final Watershed Prioritized Map , Overlain with Road and Trail Access.

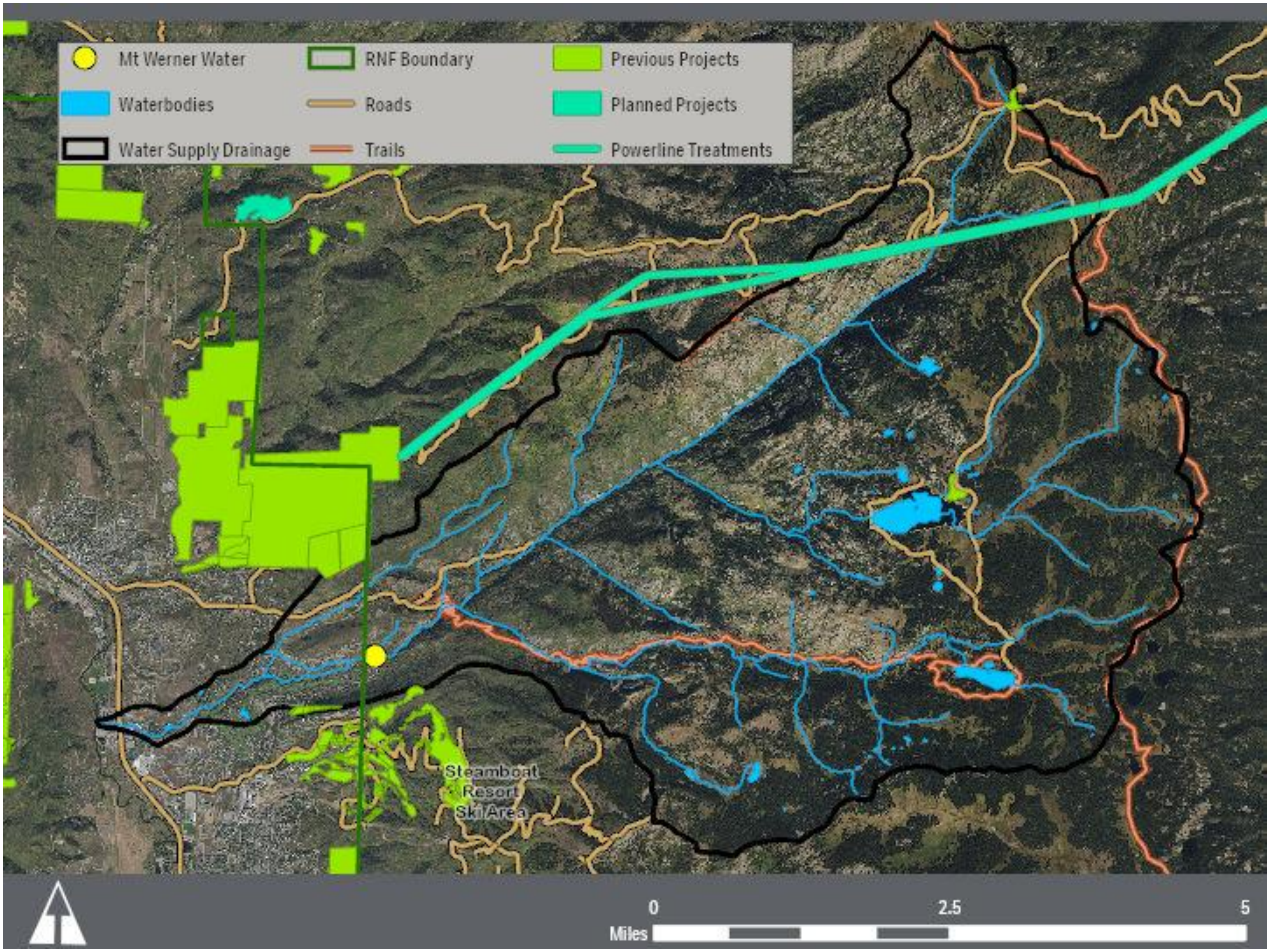

Figure 5-19. Previous and Planned Routt County Forest Management Projects, Overlain with Road and Trail Access.

6 SUMMARY OF FINDINGS

The risk assessment identified areas on the landscape with the highest potential for high-intensity wildfire and sediment delivery to Steamboat's water supply infrastructure. The highest risk areas for postfire erosion were identified in the North Fork Fish Creek drainage, steeper tributary drainages lower in the watershed at their confluence with the mainstem, and the headwaters of the southern-most tributary to Fish Creek's south fork (bordering the Steamboat Ski Resort). Much of this area, and the North Fork Fish Creek drainage in particular, is characterized by steep slopes and rugged terrain, as well as Precambrian igneous and metamorphic rocks resistant to weathering and erosion.

A sensitivity analysis was conducted to help determine how much the risk is driven by factors that we can't do anything about (e.g. soil, topographic, and precipitation characteristics) vs. wildfire impacts (e.g. soil burn severity) which may be able to be addressed through fuels management. The sensitivity analysis revealed that reducing burn severity in many of the highest risk areas (i.e. North Fork fault canyon) did not substantially reduce the overall risk; fuels treatments in these areas would not only be very hard to accomplish given the steep, rugged terrain, they would ultimately be unlikely to have the desired effect. The inaccessible areas in the North Fork Fish Creek drainage were not further considered for treatments; instead emphasis should be placed on preventing opportunities for wildfire to enter the canyon from below.

The moderate risk areas (the 50^{th} to 80^{th} percentiles in the composite hazard index), however, showed a considerable reduction in risk when the burn severity input was reduced. These areas are primarily located in the Middle Fork Fish Creek and Fish Creek tributaries below reservoirs and above the confluence with the mainstem, in the southern portion of the basin as it transitions from flatter upland areas in the headwaters to steeper canyons lower in the watershed; as well as in the North Fork Fish Creek headwaters at the top of the watershed. These areas were selected for continuation in the treatment identification process and are symbolized in the Final Watershed Prioritized Map based on access considerations and/or partnership opportunities

The headwaters above both Fish Creek and Long Lake Reservoirs ranked the lowest in both the risk assessment and sensitivity analyses. While these areas exhibited extreme fire behavior when modeled at the 90^{th} percentile condition class, this is to be expected for high elevation mixed conifer forests. Forests of this type are classified in the Fire Regime Type IV, which means that they have a greater than 200 year return interval and generally burn at stand replacement severity (Wildland Fire Leadership Council, 2016). The headwater areas above the reservoirs are characterized by high elevation spruce and mixed conifer, interspersed with montane meadows and fen wetlands (groundwater supplied) in the riparian corridors. The low relief, groundwater influence, and wetland buffering capacity all serve to reduce the potential for erosion and transport of sediment. Benefits of placing fuels treatments in these areas would likely not outweigh the damage caused by disturbing a healthy system. However, a severe beetle infestation or long-term drought could change this balance. Emphasis should be on protection and monitoring of pests and climate threats.

The stream network assessment highlighted that the Fish Creek stream network is a high energy system without many opportunities for sediment deposition between the water supply intake and the high risk areas in the North Fork Fish Creek drainage and moderate risk areas below the reservoirs. Above the reservoirs, the riparian and wetland areas currently serve to buffer sediment contributions from upland areas. While preemptive installation of sediment control structures is not recommended , a wildfire above the reservoirs and the associated postfire impacts could overwhelm the ability of these natural features to buffer sediment delivery to the reservoirs. Potential sediment control locations were identified at the reservoir inlets, and the HEC-HMS model application can be calibrated to inform initial design. If a fire were to occur in the watershed, it will be also critical to maintain access to the reservoirs and water supply infrastructure; roadway crossings improvements and hydrologic controls in the vicinity of the plant can help ensure operations can continue.

7 PLANS & PROJECTS

The following section describes the types of projects and processes that can be employed to mitigate wildfire impacts to water supply before, during, and after a fire occurs, organized around the following topics: fuels management, sediment/ hydrologic controls, education/ outreach, and continued coordination. The plans and projects discussion is supplemented with insight gained from the Core Team, which has been invaluable in helping to identify project opportunities that would be both actionable and effective. Specific recommendations are listed for each topic, generally ordered by priority based on their perceived effectiveness and ease of implementation, along with an opinion of probable costs. Water supply system infrastructure/ operational improvements involved a separate analysis of FCFP, discussed in Section 8.

7.1 FUELS MANAGEMENT

Fuels-management activities are designed to change the structure of wildland vegetation for the purpose of altering and diminishing potential fire behavior and are accomplished through mechanical treatments, prescribed fire, or a combination of the two. Specific mitigation activities for fuel management depend on the vegetation characteristics and calculated values within the wildfire behavior modeling component. For example, in forest ecosystems with low- and mixed-severity fire regimes, prescriptions can be designed to improve watershed sustainability by increasing the survivability of trees after wildfires and improving the success of fire-suppression efforts. For high-severity fire regimes, fuels-management objectives can change fire behavior by slowing overall fire growth and improving fire suppression. Mechanical treatment reduces the amount of vegetation which has built up to dangerous levels or changes the arrangement of these fuels in the environment (e.g. thinning of dense stands of trees, or other fuel treatments that make an area better able to withstand fire). Such treatments might include piling brush, pruning lower branches of trees, or creating fuel breaks, so that when a fire does burn through a treated area, it is less destructive, less costly, and easier to control. Tools used to carry out the mechanical treatment of hazardous fuels range from hand tools such as chainsaws, to large machinery like skidders and woodchippers. Often, mechanical fuels treatments are followed by prescribed fire to create effective hazard reduction. Prescribed fires and even some wildfires can be managed to benefit natural resources and reduce the risk of high-intensity wildfires in the future. Specialists write burn plans for prescribed fires that identify – or prescribe – the best conditions under which trees and other plants will burn to get the best results safely. Burn plans consider temperature, humidity, wind, moisture of the vegetation, and conditions for the dispersal of smoke. Prescribed fire specialists compare conditions on the ground to those outlined in burn plans before deciding whether to burn on a given day.

Both the forest type and access considerations in the Fish Creek basin identified in Core Team meetings helped to guide the fuels management recommendations. Because fires in mixed conifer forests are prone to ember generation that will travel ahead of the main fire, the amount of risk that can be mitigated through landscape scale fuels treatments is limited. Core Team members reported that 2018's Silver Creek and Ryan Fires (located just to the north and south of Fish Creek basin, respectively) spotted over six bulldozer lines, and that typical fuel breaks would not have slowed those fires. With the Roadless Area designation, getting equipment in to accomplish a landscape scale treatment would be administratively and physically difficult and prescribed fire is a risky tool with this type of forest. Conversely, the type of vegetation breaks (i.e. the transition from mixed conifer to aspen and meadows) found particularly in the upper portion of the basin, effectively function as fuel breaks (as was observed in the Sliver Creek and Ryan Fires). Maintaining healthy forests and riparian corridors is, and should remain, a priority with the added value of fire protection.

Wetlands and riparian corridors in Fish Creek basin's headwaters above the reservoirs are critical areas that can help to minimize the spread of wildfire and to mitigate post-fire erosion and runoff impacts to water quality in Fish Creek Watershed. The USFS has several tools/procedures in place to assess the existing condition in wetland and riparian corridors; this has not been done in Fish Creek's headwater areas above the reservoirs (as assessments are typically done in conjunction with project planning and there has not been any planned projects these areas). An initial high-level assessment is recommended to determine baseline conditions and identify potential concerns. Findings of the initial assessment will determine next steps (i.e. additional assessment needs, if conditions exist that should be addressed, how often to revisit, etc.). The idea is to monitor and maintain the health of these areas over the long term, as continued monitoring and assessment can alert resource managers to impacts from climate change and/or pest infestations. Further, the UYRW Plan identifies "riparian health assessments" and "critical wetlands identification & mapping" as priority objectives, and monitoring conditions in the Fish Creek basin can add to the understanding of wetland and riparian health in the UYRW as a whole.

The upland mixed conifer forest above the reservoirs has been anecdotally described by the Core Team as being a healthy system. However, one does not have to look too far in any direction to see once healthy forests that now have elevated risk for severe wildfires due to climate change impacts and pest infestations. It will be important to understand and monitor the stand conditions in, as well as future management options for, these upland forests. Based on Core Team discussions, it would be beneficial to reconstruct the fire history in the basin to help determine recurrence intervals and inform stand condition assessments. Additionally, CSFS is currently working with the Adaptive Silviculture for Climate Change ASCC project to investigate different types of landscape scale treatments to inform forest management decisions in the face of climate change in the long-term (50 years down the road). A collaborative project is currently being set up in a high-elevation, spruce-fir forest (similar to Fish Creek basin) in Jackson County to develop and monitor forest management prescriptions that would respond to an array of climate adaptation options (resistance, resilience, and transition). Solutions identified in this project could inform future management decisions in the long-term (e.g., 50 years), if continued monitoring of the headwater areas reveals detrimental impacts.

Emphasis should also be placed on protecting the watershed from human ignition sources. As shown in Figure 5-19, several projects have been completed along Fish Creek basin's western boundary that can serve to buffer the watershed from fires ignited within the community. RNF has also completed hazard tree removal along roads and trails within the watershed, including along Buffalo Pass Rd and the Fish Creek Falls Trail, and fuels treatments were implemented around Summit Lake and Granite campgrounds in 2006. With the high recreation use in the watershed, opportunities for targeted treatments around high use areas such as campgrounds and trailheads should be continually investigated; and these previous treatments should be inspected and if needed, revisited. For example, improvements are slated for Buffalo Pass Road (Forest Road 60) and the road to Fish Creek Reservoir (FDR 310), which could provide opportunities for fuels management projects (e.g. vegetation breaks, canopy opening, hazard tree removal). Trails could provide access for cleaning up dead/downed timber along high-use corridors, and wildfire protection in the watershed should be included in considerations in any current or future trail project planning processes.

Additionally, the Fish Creek Sanctuary CWPP identified several projects in the wildland urban interface (WUI), intended to protect the community from forest fires. The Fish Creek $(CWP)^2$ seeks to protect the watershed from fires originating from the community, and the identified projects would serve a dual purpose. It is understood from Core Team discussions and stakeholder input from the public meeting that some of the Sanctuary CWPP projects were achieved but that efforts were stalled based on community objections.

Efforts should be made to communicate the importance of fuels management for water supply protection in the neighborhood and these remaining projects should be revisited.

The Steamboat Ski Resort has also accomplished several fuels treatment projects in the course of facilities development that can serve as a buffer at the watershed's southern boundary, as shown in Figure 5-19. Opportunities may exist to partner with the Ski Resort on planned projects that can also benefit the basin. The Pony Express/ Pioneer Ridge project described in the Ski Resort's 2011 Master Development Plan Amendment and the1996 Final Environmental Impact Statement (FEIS), Steamboat Ski Area Expansion includes hazard tree removal in the new Pioneer Ridge area which could also serve as fuels treatments to buffer the high risk areas at Fish Creek basin's southern boundary. This project supports Burgess Creek CWPP recommendations and has already been approved through the National Environmental Policy Act (NEPA) process but has not yet been implemented.

With the limited road access in the Fish Creek Basin, maintaining the existing road access and protecting critical infrastructure will be crucial to both wildfire incident and postfire emergency response. RNF's 2015 Hahns Peak/ Bears Ears Travel Analysis report listed all of the existing roads in the watershed as "likely important for future use" and noted "insufficient resources for maintenance of the existing system of roads and trails" and access needs, including emergency access, as key issues. Improving level one (closed to the public) roads for emergency access should be investigated and balanced with the potential that improved access may also result in additional unsanctioned use and potential ignitions. Level one road assessments should also consider the fire response plan for the watershed (e.g. if it will be fought primarily using aircraft, does it make sense to improve these roads?). It should also be noted that the City and District recently entered into an agreement with USFS to allow aircraft to use Fish Creek Reservoir and Long Lake Reservoir as water sources; providing access to resources needed to fight fires in the basin and surrounding areas.

Further, power lines and power line access roads exist in the basin's northeast corner, which are maintained and operated by the Yampa Valley Electric Association (YVEA) and Western Area Power Authority). The recent California wildfires demonstrate the devastating impacts that can result from an arcing power line, and Steamboat Springs should work with the power companies to ensure that they have adequate procedures in place to protect from ignitions, particularly during red flag conditions. (WAPA is currently working with RNF on plans for hazard mitigation work around their power lines). Finally, actions should be taken to protect the FCFP itself; sanitation cuts around the plant can help to ensure that the plant can still be accessed and operated if fire occurs in the basin.

7.1.1 SPECIFIC RECOMMENDATIONS & OPINION OF PROBABLE COSTS

Specific fuels-treatment prescriptions are included for the FCFP, Sanctuary Neighborhood, and Ski Resort; more general treatment descriptions are included for the identified areas within RNF (Table 7-1). Fuels-treatment prescriptions within RNF must also meet the Forest's management objectives and permitting requirements; final design criteria will need to account for desired end goals beyond reducing fire severity and postfire impacts. For instance, designing a treatment for maximizing elk habitat is different than designing for management of dispersed campers, even though both designs will meet the fire needs as required to protect the downstream water supply system. For this reason, final design is not appropriate until a project is ready to move into design/build mode and final permitting requirements are identified. However, project descriptions provide insight into what is required for implementation. It should also be expected that support to accomplish NEPA compliance be a component of new fuels management projects within RNF.

Table 7-1. Fuels Management Project Recommendations

Opportunity	Recommendation	Project Lead	Project Partners	Estimated Cost
Treatment Plant	Protect critical infrastructure from approaching fire by creating defensible space using Zone concept.	City/ District	CSFS, Routt County OEM, NRCS	Variable depending on type and amount of vegetation to be cleared; $1,500-2,000/ acre.
Sanctuary Neighborhood	Evaluate and complete recommendations from Fish Creek Sanctuary CWPP to reduce risk of fires in and originating from the community. Achieve FireWise certification for the neighborhood.	Sanctuary HOA	City/ District, CSFS, Routt County OEM, NRCS	Variable depending on type and amount of vegetation to be cleared; $3,000-4,000/ acre
Steamboat Ski Resort	Work with Ski Resort to complete hazard tree removal components of the Pioneer Ridge and Pony Express projects and evaluate/ complete Burgess Creek CWPP project recommendations within the Ski Area to reduce risk in critical areas at the basin's southern border.	Ski Resort	City/ District, USFS, CSFS, Routt County OEM	Variable depending on type and amount of vegetation to be cleared; $4,000-5,000/ acre based on previous Ski Resort fuels treatments.
Road Treatments	Evaluate and maintain existing fuels treatments along roads within the basin to minimize potential for ignitions to spread along road corridors. If needed, treat vegetation 100ft on each side of roads within the basin; clear or chip dead and down fuels; thin trees to increase crown spacing; prune remaining trees; and, mow herbaceous plants.	USFS	City/ District, CSFS, Rocky Mountain Youth Core	$3,000-4,000/ acre, based on Routt Co 2010 Hazard Mitigation Plan.
Campgrounds/ Trailheads	Evaluate and maintain fuels reduction projects at campgrounds and trailheads. If needed, conduct pruning/ hazard tree removal to minimize the potential for ignitions to spread in areas of high recreational use.	USFS	City/ District, CSFS, Rocky Mountain Youth Core	$3,000-4,000/ acre, based on Routt Co 2010 Hazard Mitigation Plan.
Trail Treatments	Evaluate and maintain existing treatments along trails. Where needed, prune trees on either side of trail (width determined by trail type); cut and move dead and down trees away from trail. Some trails can be used as fire breaks against an oncoming fire; preemptive maintenance on the front-end results in less work to improve and strengthen fireline when needed.	USFS	City/ District, CSFS, Rocky Mountain Youth Core	Variable. Hand work and small equipment will be labor intensive. Could be done as volunteer project (estimate 40 hours/ project to coordinate volunteers), or contract with Rocky Mountain Youth Corps ($6,000/ week).
Wetland/ Riparian Corridor Assessment	Assess, monitor, and maintain wetlands and riparian corridors in the upper watershed. Complete riparian health assessments and critical wetland inventory identified in UYRW Plan to understand baseline conditions and be alerted to detrimental impacts that could reduce the effectiveness of wetland and riparian areas to serve to buffer wildfire and postfire impacts in a timely manner.	USFS	City/ District, CSFS, Routt County Conservation District, YVSC	Work with USFS to establish monitoring plan and determine cost. Plan for 1-day initial assessment and follow up based on assessment.
Upland Forest Condition	Assess and monitor upland forest condition. Reconstruct fire history in the basin to better inform potential fire intervals; Monitor ASCC network/ CSFS long-term project aimed at developing and monitoring management prescriptions for high elevation spruce-fir forests that would respond to an array of climate adaptation options to inform long-term (50 year) decisions.	CSFS	City/ District, USFS, Routt County Conservation District, YVSC	Work with CSFS to determine scope and costs of study to reconstruct fire history in basin and disseminate findings from ASCC study findings.

7.2 SEDIMENT/ HYDROLOGIC CONTROLS

Postfire sediment and/or hydrologic control treatments can be applied to the land surface to reduce erosion at the source, as well as in-channel to reduce stream velocities, provide opportunities for sediment loads to be deposited before reaching critical infrastructure, and reduce the occurrence of in-channel scour. Land surface treatments stabilize burned areas by providing soil cover and reducing erosion, trapping sediment and reducing sedimentation, and/or reducing water repellency and improving infiltration; they also maintain ecosystem integrity by preventing expansion of unwanted species. Land surface treatments include practices such as mulching, reseeding, slash spreading, and erosion barriers. In-channel treatments are used to reduce or mitigate effects to water quality, loss of water control, slow water velocity, trap sediment, and maintain channel characteristics. Channel treatments can include grade stabilizers, check dams, debris/sediment basins, and stream channel armoring (Napper, 2006).

Potential sediment and hydrologic control locations were identified through the desktop topographic analysis, along with actions that can be taken in the vicinity of FCFP to protect the plant itself from damaging postfire floods and debris. Most of the potential sediment basin locations are found either above the reservoirs in areas that already benefit from wetland and riparian buffers, or in relatively inaccessible areas and/or headwater tributaries where installation would be difficult and impacts, relatively small. Based on discussions with the Core Team, preemptive installation of in-channel sediment controls in the Fish Creek Basin would cause great disturbance in healthy, functioning riparian areas, which may be all for naught, if the fire does not hit that particular drainage. Instead, a preparedness approach is suggested.

Immediately following a wildfire on National Forest System lands, a Burned Area Emergency Response (BAER) team is deployed to assess and address postfire conditions. BAER is an emergency program for postfire stabilization work that involves time-critical activities to be completed before the first damaging storm event. Teams are staffed by specially trained professionals: hydrologists, soil scientists, engineers, biologists, vegetation specialists, archeologists, and others who rapidly evaluate the burned area and prescribe emergency stabilization treatments to protect the land quickly and effectively. A BAER assessment usually begins before the wildfire has been fully contained and initial requests for funding of proposed BAER treatments are supposed to be submitted by the Forest Supervisor to the Regional Office within 7 days of total containment of the fire. Timing is critical and treatments must be installed as soon as possible, before the first postfire storm. Normal permitting constraints (i.e. NEPA) are lifted for postfire emergency response, and implementation funding is typically available three days after recommendations are submitted. An overview of BAER is included to provide more clarity on the process:

- A BAER assessment team conducts field surveys and uses science-based models to rapidly evaluate and assess the burned area and prescribe emergency stabilization measures. The team generates a soil burn severity map by using satellite imagery which is then validated and adjusted by BAER team field surveys to assess watershed conditions and model potential watershed response from the wildfire. Areas of potential flooding or excessive sedimentation are identified, and treatment options evaluated.
- The BAER team presents these findings in an assessment report that identifies immediate and emergency actions needed to address post-fire risks to human life and safety, property, cultural and critical natural resources. The BAER report describes watershed pre- and post-fire watershed response information, areas of concern for life and property, and recommended short-term emergency stabilization measures.

- Treatments are typically recommended for severely burned areas, steep slopes, and places where water run-off will be excessive and may impact important resources; and, as depicted in Figure 7-1, there are a variety of emergency stabilization actions that the BAER team can recommend, such as:
  - mulching with agricultural straw or chipped wood, digging of below-grade pits to store sediment, and other treatments to keep roads and bridges from washing-out during floods;
  - placing contour logs, straw wattles, and other cover material, and/or reseeding on burned slopes to slow runoff and trap sediment;
  - armoring stream banks/beds using large rocks and logs to protect against erosion;
  - modifying drainage structures, including installing debris racks and additional drainage features to allow drainage to flow if culverts become plugged, upsizing culverts to handle increased post-fire run-off, installing rolling dips, and constructing emergency spillways.

Figure 7-1. Examples of Emergency Stabilization Actions that BAER may Recommend.

- Special Emergency Wildfire Suppression funds are authorized for BAER activities and funding for emergency stabilization projects is usually approved within 3 days. (For larger, more complex fires, where funding requests exceed $500,000 approval must come from the Washington Office and may take up to 7 days.) Once approved, funds can be accessed immediately.

- BAER projects are funded for no more than one year following containment of the wildfire, with the exception that emergency stabilization funding can be used for up to an additional two years for treatment effectiveness monitoring and to repair/ replace emergency stabilization structures or treatments where failure to do so would imperil watershed functionality or result in serious loss of downstream values. (i.e. Treatments can be maintained w/in 3yrs of the fire using BAER funding).
- While BAER funding cannot be used for long-term recovery and restoration, USFS recognizes the need to support efforts to improve fire-damaged lands that are unlikely to recover naturally. These non-emergency actions may include restoring burned habitat, reforestation, other planting or seeding, monitoring fire effects, replacing burned fences, interpreting cultural sites, treating noxious weed infestations, and installing interpretive signs. The USFS has started a demo-program to help fund long term recovery and restoration efforts; an early example includes the Coalition for the Upper South Platte and grant funding for projects in watersheds impacted in the Hayman and Waldo Canyon fires. And, the USFS' Emergency Forest Restoration Program (EFRP) is a potential resource for to fund restoration in non-industrial private forests.
- Finally, interagency coordination is an important part of the process. BAER team leaders make sure that the modeling and assessment conducted for the BAER report considers downstream entities and provides the information needed to develop a response plan for non- National Forest lands. The BAER team and NRCS Resource Conservation Districts (RCDs), work together and coordinate with other federal and local agencies, and counties that assist private landowners in preparing for increased run-off and potential flooding. Federal assistance to private landowners regarding post-fire impacts is led by the NRCS through the Emergency Watershed Protection (EWP) program.

The information gathered for and generated from the risk assessment can help inform and expedite a BAER assessment and response. Values-at-risk, including the Fish Creek Reservoir, Long Lake Reservoir, the FCFP intake, the water supply conveyance stream network, and access to roads to all facilities, have been identified and mapped; these can be provided immediately to a BAER team. The debris flow and peak flow modeling developed using the modeled fire behavior conditions can inform the identification of areas with high potential for postfire runoff and erosion; and datasets compiled for these efforts will be available to the BAER team to help streamline initial data gathering. Steamboat can support BAER efforts by working with RNF engineers to understand existing culvert capacities on access roads; the current work on Buffalo Pass road may provide opportunities to partner with the RNF to improve existing road crossings to better accommodate postfire conditions. Additionally, having local suppliers of erosion control materials (i.e. wood straw, wood shred) and a memorandum of understanding in place to help with spreading of materials can help expedite the response. Finally, it has been noted in Core Team meetings that real-time precipitation data and additional stream gauging in the watershed would be very beneficial to support BAER assessment as well as early warning systems for postfire flooding and FCFP operations.

7.2.1 SPECIFIC RECOMMENDATIONS & OPINION OF PROBABLE COSTS

As with the fuels management recommendations, final design for any sediment/ hydrologic control project within the RNF must be determined through the Forest Service planning/ permitting process. It was determined through Core Team discussions that cost and disturbance impacts of/from installing sediment/ hydrologic control structures before a fire occurs would outweigh the benefits. Therefore, recommendations focused on preparing Steamboat Springs to respond to postfire conditions in a timely, effective manner. In the event of a wildfire in the watershed, a BAER team will assess the burned area and prescribe emergency stabilization treatments (funded through the program and exempt from NEPA permitting). The BAER process, along with actions Steamboat Springs can take to support BAER and facilitate implementation of projects to protect the water supply system/ ensure FCFP can be accessed/ operated are shown in Table 7-2.

Table 7-2. Sediment/Hydrologic Controls Management Project Recommendations*

Opportunity	Recommendation	Project Lead	Project Partners	Estimated Cost
BAER Support	If a wildfire occurs in Fish Creek basin, a BAER team will be on the ground immediately (sometimes before the fire is 100% contained) to rapidly evaluate the burned area and prescribe emergency stabilization treatments, including: mulching, reseeding, slash spreading, erosion barriers, grade stabilizers, check dams, debris/sediment basins, culvert upsizing, channel armoring, etc. City/ District can support BAER by having local suppliers of erosion control materials (i.e. wood straw, wood shred) and a memorandum of understanding in place to help with spreading of materials, and/or organizing volunteers. Data generated from this report and the recommendations below can be used to help expedite the response. BAER teams coordinate with NRCS Resource Conservation Districts (RCDs) other agencies, and counties that assist private landowners in preparing for postfire impacts to ensure assessments address downstream users. Federal assistance available through the NRCS' Emergency Watershed Protection (EWP) program and FEMA's Fire Management Assistance Grant (FMAG) program.	USFS	City/District, Routt County RCD, NRCS	BAER funding is available for emergency stabilization projects immediately after assessments are complete. (Up to $500,000 approved within 3 days, and larger amounts, within 7 days.) NRCS EWP and FEMA FMAG funding requires 10-25% match. Note: FEMA has also priced postfire landscape treatments at $5,250/ acre for soil stabilization, flood diversion, and reforestation.
Treatment Plant Protection	Construct diversion channel or temporary berm for the northeast drainage on the backside of the building to protect FCFP buildings and ponds from flooding and debris.		NA	$20,000 (diversion/ temporary berm)
Fish Creek Reservoir	Sediment Basins at the inflow to Fish Creek Reservoir. Capture sediment and debris upstream of the reservoir.	City/ District	USFS	Variable, dependent on material and capacity; range from $45,000 (silt curtains) to $210,000 (sediment basins).
Long Lake Reservoir	Sediment Basins at the inflows to Long Lake Reservoir. Capture sediment and debris upstream of the reservoir.	City/ District	USFS	Variable, dependent on material and capacity; range from $25,000 (silt curtain) to $85,000 (sediment basin).
Roadway Crossing Improvements	Evaluate roadway crossings along 310 at the 2 tributaries to Long Lake Reservoir and 2 tributaries to Fish Creek Reservoir. If needed, improve/upsize culverts.	USFS	City/ District	$9,000-30,000 per crossing depending on improvement needs.
Sediment basins at locations with good geometries	Locations with good geometries for sediment basins installation were identified: on Fish Creek, downstream of Long Lake; North Fork Fish Creek, and Unnamed Tributary to North Fish Creek. Depending on actual location of a fire within the watershed, installing control structures in these locations could capture some sediment/ debris before it reaches the FCFP intake.	USFS	City/ District	Variable depending on postfire conditions, which will determine location, size, and access issues; $150,000 (sediment basin)
Rain Gauge Installation	Partner with NWS to install a rain gauge in the upper watershed. Having high resolution precipitation data in the basin will help to characterize watershed response to precipitation events pre-fire; this will help refine post-fire modelling efforts.	NWS	City/ District, USFS	Rain gauge $400 (conforms to NWS recommendation; snow is additional $700) Enclosure $350 Power (solar and battery) $400 Datalogger with cellular plan 1 year $1200; each additional year $150 Software $700

* Note: With the exception of rain gauge installation, projects recommended within this table are suggested for implementation after a fire occurs and should be selected and further refined based off the properties of the actual fire.

7.3 EDUCATION/ OUTREACH

With its designations as Ski-Town USA, Bike Town USA, and miles of world class trails surrounding the community, Steamboat Springs is a mecca for outdoor enthusiasts. While the outdoor recreation community advocates responsible use (i.e. "leave no trace" and "tread lightly"), it just takes one careless act to spark a fire. Increasing public awareness about where Steamboat Springs' water comes from and the importance of protecting the water source is perhaps one of the most effective things that the City and District can do to protect the watershed from wildfire.

The Fish Creek basin contains two campgrounds and several highly used hiking and mountain biking trails. (There is also unsanctioned use of trails and roads in the watershed, which RNF has been attempting to rectify with projects such as the Buffalo Pass Road improvements and trails projects.) The Fish Creek Trail has been deemed a National Recreation Trail and sees thousands of visitors each year. The trail follows Fish Creek upstream from its confluence with the North Fork Fish Creek in the lower part of the watershed for five miles along its southernmost fork to Long Lake Reservoir. Then it continues another 2.4 miles to the watershed boundary at the top of the divide (where it joins the continental divide trail). The lower and most heavily used portion of the trail traverses some of the highest risk areas identified in the hazard analysis. The high recreational use increases the chances for ignition in these areas; and, the importance of educating the community and its visitors about the dangers of wildfire in the water-supply drainage area cannot be overstated.

Many members of the Core Team have experienced that some of the traditional means of conducting public outreach (i.e. public meetings) are not always very effective in reaching today's audience. In order to engage the people that live, work, and play in the watershed, it is important to meet them there. We suggest informational signs at trailheads and campground to make the public aware that they are in the municipal watershed, wildfire impacts to watersheds, and to take extra care while recreating in Fish Creek basin. This can and should be done through partnerships with key stakeholders; the UYRW Plan identifies Outreach & Education as one of its top priority objectives and the Fish Creek Sanctuary CWPP identified several locations in the neighborhood for fire danger signage. Moreover, it has been noted in Core Team meetings that people often gloss over standard or "boring" signage. A creative approach to designing informational signage could be taken that would amplify the message, such a contest for students or community artists.

Volunteer days and/ or events at trailheads could be employed to reach recreational user groups; engaging these groups in the protection and care of the watershed can bring a sense of ownership and encourage a culture of stewardship across their membership. The YVSC, and other community organizations, often hold creative outreach events and are valuable partners in conducting this type of outreach. For example, Yampatika holds Fish Creek Watershed walks throughout the summer and often staffs an informational table at the trailhead during busy weekends; these efforts could be built upon to incorporate a discussion of wildfire and drinking water impacts. YVSC has compiled a comprehensive list of watershed stakeholders and outreach partners (included in the supplementary files), which can serve as a resource for future outreach.

Additionally, the City, community, RNF, CFSF, and several outdoor recreation organizations have webpages and WMIs that link to trail descriptions and maps. The City's trail Web Map Interface (WMI) features a pop-up window that warns users of the damage that can be done by biking on wet and/or muddy trails; a similar feature could be added to other websites frequented by recreation users to encourage fire safety on trails in Fish Creek basin.

Figure 7-2. Fish Creek Trail (above) and Yampatika Naturalist Walk (below).

Opportunities to build on other successful community outreach campaigns/ events should be sought out. For example, visitors to Steamboat Springs can also be reached in their hotel rooms and ski condos; some of the area resort vendors place “drink the tap water” signs over the sink to help meet their companies’ sustainability goals. The City and District could work with the Chamber of Commerce to encourage fire safe behavior from visitors to Fish Creek basin. Finally, the City, County, CFSF, and RNF should all conduct education and outreach on fire safety, and these can be used to amplify the message of watershed wildfire protection; some recent examples include the Routt County Wildfire Hazard Mitigation Conference and “Meet the Chief at the Farmers Market.” The newly established Routt County Wildfire Council (discussed further in Section 7.4) could serve as an integration point for coordinated outreach between partners.

7.3.1 SPECIFIC RECOMMENDATIONS & OPINION OF PROBABLE COSTS

All of the recommendations for education and outreach projects shown in Table 7-3 should be considered a collaborative effort between key stakeholders. Many of these can be achieved with little initial costs and/or with the help of volunteers; however, that does not by any means imply that these recommendations would be less effective in protecting Steamboat’s water supply than more costly land and water management alternatives. In fact, an engaged, educated public can establish a strong foundation for success which can be built upon to accomplish the other project recommendations.

Table 7-3. Education/ Outreach Project Recommendations

Opportunity	Recommendation	Project Lead	Project Partners	Estimated Cost
Informational Campaign to Increase Public Awareness of Risks Wildfire Poses to Water Supply and Encourage Responsible Behavior in the Watershed	Signage - place interpretive signs at trails and campgrounds; Evaluate Fish Creek Sanctuary CWWP signage recommendations, and, if needed, place fire awareness signs in the neighborhood.	City/ District	USFS, Yampatika, YVSC	Informational campaign would require design of materials and time commitment to organize with key stakeholders. Some of this work could potentially be done in house with the City's talented Communications Manager and designers (estimate 20-40-hour commitment to each action item). Alternatively, this could be contracted as a public relations project (estimated cost of $50,000)
	Watershed Walks - work with Yampatika to incorporate discussion of wildfire and drinking water impacts in their watershed walks.	City/ District	USFS, Yampatika, YVSC	
	Trail Web Map Interface (WMI) - work with partners to get information about responsible recreation use in the watershed on WMIs and trail information webpages to reach recreational users where they normally go for information about trails and conditions.	City Parks & Recreation and Communication Departments	Routt County Riders, USFS, YVSC, Yampatika	
	Hotel & Resort Partnership - work with area vendors to place informational material in hotel rooms and rental units.	City/ District	Chamber of Commerce	
Volunteer Days	Work with key stakeholders to organize volunteer days in the watershed (could be used to facilitate treatments along trails).	YVSC	City/ District, USFS, Rocky Mountain Youth Corps	Time commitment to organize volunteers (estimate 40 hours per volunteer activity. Rocky Mountain Youth Core can be contracted at $6,000/ week for applicable projects.
Integrated Outreach	Collaborate with key stakeholders on mutually beneficial outreach events/ efforts. This is already occurring with events like the Routt County Wildfire Hazard Mitigation Conference and the establishment of the Routt County Wildfire Council. Work with the Council to continue to explore and support opportunities for mutually beneficial outreach.	City/ District	CSFS, YVSC, Routt County Extension, USFS, etc.	No additional cost but requires Routt County Wildfire Council and partners to continue to support mutually beneficial outreach.

7.4 CONTINUED COORDINATION

Coordination will be integral, not only for education and outreach, but also for implementing the recommended preemptive mitigation measures, ensuring that a wildfire response is informed by this planning effort, and facilitating watershed emergency response, restoration, and recovery projects. One of the outcomes of the 2019 Routt County Wildfire Hazard Mitigation Planning Roundtable and Conference was to establish a Routt County Wildfire Council. The Council includes the City's Water Resource Manager, the District's General Manager, and the agencies and organizations represented by the Core Team. This is major accomplishment in terms of putting a mechanism in place that can facilitate not only integrated wildfire mitigation planning efforts, but also moving the recommendations from the Fish Creek $(CWP)^2$ forward.

Coordination and collaboration between local, state, and federal agencies will be critical for navigating the permitting requirements for any new projects within the National Forest. For example, compliance with NEPA typically applies whenever a planned project is located on federal lands, needs passage across federal lands, is funded entirely or partially by federal agencies or programs, or needs to secure a federal permit. For proposed projects within the RNF, USFS would be considered the "lead or action agency" in the NEPA process. Some procedural requirements within NEPA are expedited through the Healthy Forest Restoration Act (HFRA) process, which facilitates state and local partnerships and created categorical exclusions for certain hazardous-fuel-reduction actions that meet certain requirements (i.e. wildland-urban interface [WUI] designation). Steamboat Springs' municipal watershed and reservoirs are listed as critical values in the Routt County CWPP. Given the flexibility of HFRA language and previous application, this should satisfy requirements, but, a WUI designation for the basin is still preferable. Routt County is planning to update its CWPP next year, with assistance from the newly established Routt County Wildfire Council and WUI designation for Fish Creek Basin is anticipated in this upcoming CWPP update.

There are several resources available for collaborative projects aimed at restoring landscapes, reducing wildfire threats to communities and landowners, and/ or protecting water quality and enhancing wildlife habitat once they have satisfied permitting requirements. For example, a previous watershed wildfire hazard mitigation assessment conducted by our team for a watershed in the Bighorn National Forest (BNF) expedited permitting project recommendations through the HRFA process and is currently funding implementation through an USFS and NRC's Joint Chiefs' Landscape Restoration Partnership grant program (RESPEC and Anchor Point, 2017). BNF partners noted that the collaboration of local, state, and federal partners was one of the primary reasons the project was awarded Joint Chiefs' funding. Further, the direct linkage between forest management, watershed management, and water quality protection can serve to align diverse interest groups and secure funding through sources that may not otherwise be available for a typical forestry project. Examples of potential funding sources that should be further investigated include:

- The USFS works with the NRCS through the Joint Chiefs' Landscape Restoration Partnership, to improve the health and resiliency of forest ecosystems where public and private lands meet. The desired outcome of this effort is to restore landscapes, reduce wildfire threats to communities and landowners, protect water quality, and enhance wildlife habitat. The partnership began in 2014, and each year the agency selects new projects which run for a 3-year period. Projects are focused within a shared landscape in areas where public forests and grasslands intersect with privately owned lands to provide private landowners with conservation resources to complete restoration efforts on their land for healthier and more resilient forest ecosystems.

- The USFS's Collaborative Forest Restoration Program (CFLRP) addresses landscape level project funding using multiple partners and stakeholders. The funding for this program can vary from year to year depending on prior projects funded, but it could be a viable funding opportunity for a project to address wildfire hazard mitigation within a municipal watershed. This program was reauthorized in the 2018 Farm Bill through fiscal year 2023.
- The National Forest Foundation is the nonprofit partner of the USFS and is most direct conduit to applying nonfederal funds to on- the-ground work efforts on the forest. The NFF maintains a robust relationship with dozens of corporate entities across the entire spectrum of business including; Miller Coors, Walt Disney, REI, Polaris and many others. The role of the NFF could be to leverage local funding with corporate sponsorship.
- CSFS' Forest Restoration and Wildfire Risk Mitigation (FRWRM) program was established through Senate Bill 17-050 to provide state support in the form of competitive grant funds that encourage community-level actions across the state to reduce the risk of wildfire to people, property and infrastructure in the WUI; promote forest health and forest restoration projects; and, encourage utilization of woody material for traditional forest products and biomass energy. The grant program funds fuels and forest health projects, and/or capacity building projects on non-federal lands in Colorado. Eligible applicants include local community groups, local government entities, public and private utilities, state agencies, and non-profit groups.
- The Nature Conservancy (TNC) is the largest environmental nonprofit by assets and by revenue in the Americas. TNC pursues nonconfrontational, pragmatic solutions to conservation challenges working with partners including indigenous communities, businesses, governments, multilateral institutions, and other nonprofits.
- The Rocky Mountain Elk Foundation (RMEF) is a nonprofit organization dedicated to protecting and enhancing elk habitat, restoring elk to native ranges, and educating others about wildlife and habitat conservation. The RMEF helps fund and conduct a variety of projects to improve essential forage, water, cover, and space components of wildlife habitat and supports research and management efforts to help maintain productive elk herds and habitat.
- Trout Unlimited (TU) provides funding and volunteer labor for a variety of stream and watershed projects such as erosion control and fish habitat structures, willow and other riparian plantings, and stream protection fencing. Healthy trout fisheries indicate well-functioning, sound ecosystems; work aimed at restoring trout habitat will ultimately benefit the overall environment. Partnerships are encouraged and can include local conservation districts and state and federal agencies.
- Blue Forest Conservation is fighting fire with finance through an innovative public-private partnership to restore forests and protect communities. The Forest Resilience Bond (FRB) program is an environmental impact bond that deploys private capital to make our national forests more resilient to a changing climate. By investing in restoration projects that protect forest health, the FRB program mitigates the risk of catastrophic wildfire while also protecting water resources, avoiding carbon emissions, and creating rural jobs. The FRB program contracts with the beneficiaries to share in the costs of forest restoration while providing modest returns to investors.

Once a wildfire is contained enough to begin the response and recovery process, coordination will be vital to securing funding and ensuring timely, effective implementation of water supply protection projects. Colorado recently held the nation's first conference focused on addressing postfire impacts "After the Flames." One of the key takeaways from communities in Colorado and other western states that have experienced wildfire and postfire flooding was that communities with strong coalitions in place before emergencies occurred were much better equipped to respond to emergency conditions. While BAER teams and funding are available to support the emergency response and stabilize the watershed immediately postfire, longer term rehabilitation and recovery are beyond the scope of this program. Assistance is available through other federal programs that require coordination between local, state, and federal partners. Routt County OEM and other key partners will be critical in accessing the resources needed to support recovery efforts, and the City and District should work with these partners to understand and navigate the available programs and ensure that eligibility requirements are met before the need arises.

- In particular the NRCS EWP Program could be used to aid private landowners downstream of RNF. This program is focused on helping private landowners recover from natural disasters. This could be applicable if a natural disaster created hazard conditions that could lead to intense wildfires, such as storm events that leads to deadfalls of trees. This program also funds postfire recovery efforts on private lands which could benefit protecting the water supply system.
- The FEMA Fire Management Assistance Grant (FMAG) Program is also available to states, local and tribal governments for the mitigation, .management, and control of fires, if the potential exists for destruction that would be considered a major disaster. The FMAG process is initiated when a State submits a request for assistance, at a time when threat of major disaster exists and provides 75 percent cost share. Additionally, FEMA's Pre-Disaster Mitigation (PDM) grant program awards planning and project grants and provides opportunities for raising public awareness about reducing future losses before disaster strike with a goal to reduce overall risk to population and structures from future hazard events, while also reducing reliance on Federal funding in future disasters.
- The USFS has recognized the need to support postfire recovery and restoration and has started a demo-program to help fund long-term recovery efforts; continued communication/ coordination with USFS partners will ensure that Steamboat Springs is aware and can take advantage of these funding opportunities as they develop should the need ever arise. Additionally, the USFS' EFRP funds restoration projects in non-industrial private forests
- RenewWest is veteran-founded company dedicated to reforesting areas through the sale of high-quality carbon offsets that helps fund recovery/ restoration projects in burned forests.
- New (and new opportunities with existing) private companies and nonprofit organizations to fund watershed recovery/ restoration will continue to surface as this issue gains national attention. For example, Coalitions and Collaboratives (COCO) is a nonprofit organization that grew out of the Coalition for the Upper South Platte, which was formed in response to 1996 Buffalo Creek Fire and subsequent postfire flooding. With 20 years of experience in helping watersheds recover from wildfire impacts, COCO has become an integration point for information on postfire recovery practices and processes (including funding opportunities); a COCO affiliation is recommended to ensure that Steamboat Springs becomes aware of new and future opportunities as they arise.

Finally, if fire were to threaten Fish Creek basin, the response should consider the Fish Creek $(CWP)^2$ and particularly, the risk assessment findings; this requires that findings from the $(CWP)^2$ be conveyed to the Incident Command (IC) so that they can be used to inform the fire response. The importance of protecting the water supply is already included in the RNF Fire-Management Strategy; and, the risk assessment results (which are provided as GIS layers and in Google Earth format) can guide suppression efforts to keep fire out of the areas that pose the highest risk to water supply. Since Steamboat Springs Fire Rescue would either be IC (for fires within the fire protection district) or the point of contact for IC (first on scene, initial IC, then transfer command to partners for fires on public lands), Steamboat Springs Fire Rescue would be the most appropriate entity to serve as the liaison for the Fish Creek $(CWP)^2$ and has agreed to serve in this capacity.

7.4.1 SPECIFIC RECOMMENDATIONS & OPINION OF PROBABLE COSTS

If there is anything that Steamboat Springs can take from Colorado's wildfire impacted communities, it's to have the mechanisms in place to respond to wildfire before it occurs. Benjamin Franklin's adage, "an ounce of prevention is worth a pound of cure," is very apropos. The development of this $(CWP)^2$ has been called for in just about every City, County, and community planning document reviewed for this effort, and water supply protection from wildfire has become a priority for both the Colorado State and US Forest Service. Now that the Fish Creek $(CWP)^2$ has been developed, its success is dependent upon the continued collaboration and coordination of these key stakeholders to see it through. Recommendations shown in Table 7-4 should be considered high priority.

Table 7-4. Continued Coordination Project Recommendations

Opportunity	Recommendation	Project Lead	Project Partners	Estimated Cost
Fish Creek Basin WUI Designation	Secure WUI designation for Fish Creek basin in upcoming CWP update.	Routt County OEM	City/ District, CSFS, Routt County Wildfire Council	Plans to update the CWPP next year, led by Routt County OEM with guidance from Wildfire Council; update will achieve WUI designation. (CWPP updates contract out at $50,000-100,000 depending on complexity).
Permitting Collaboration	Identify permitting requirements and HRFA opportunities for recommended projects in RNF. Landscape treatment projects have been selected to complement Planning will identify scope and costs for projects in RNF and accomplishing permitting will make projects eligible for grant funding	USFS	City/ District, CSFS	NEPA Permitting can be costly, upwards of $100,000. But these costs can be balanced by funding programs to accomplish projects once the permitting requirements are met.
Funding Program Investigation	Investigate key funding programs for preemptive watershed wildfire protection and watershed restoration and connect with program liaisons to identify requirements, deadlines, etc. Work with partners to ensure eligibility requirements for grant programs are met before they are needed to facilitate a timely, planned response. Plan for emergency funding to run out and the need to secure rehabilitation & restoration funding.	City/District	Routt Co EM, CSFS, USFS, NRCS, FEMA	Anticipate time commitment of 20-60 hours to investigate requirements and connect with liaisons for identified key funding programs. The summary report currently being generated from the inaugural 2018 "After the Flames" will be a good resource to identify novel/ future funding opportunities.
Establish/ Support Routt County Wildfire Council	Continue to collaborate with key stakeholders to support integrated wildfire preparedness planning; the Routt County Wildfire Council can serve as the integration point to carry $(CWP)^2$ recommendations forward, with the City's Water Resource Mgr. and District's GM representing the watershed/ supply.	CSFS	YVSC, Routt County Ext., City/ District, USFS, etc.	Anticipated time commitment of 40 hours/ year for council members, 80 hours/ year for lead organization. This is already occurring. Little to no additional cost but requires continued support of participating entities.
Fish Creek Bridge	Work with Routt County OEM to monitor flood and scour effects at bridge for pedestrian safety issues and large debris that can cause problems downstream.	City Public Works/ District	Routt County OEM, City Fire Rescue	Little to no additional cost.
Incident Command Liaison	The Incident Command (IC) liaison will convey information from the risk assessment to IC if a fire does occur in the watershed. This will help ensure that the identified areas of concern will be included at "values at risk." Since Steamboat Springs Fire Rescue (SSFR) would either be IC (for fires within the fire protection district) or the point of contact for IC (first on scene and initial IC, then transfer command to partners for fires on public lands), SSFR is the most appropriate entity to serve as the liaison for the $(CWP)^2$.	City Fire Rescue	MWW General manager, City of Steamboat Water Resource Manager, Routt County OEM	No additional cost. Commitment from liaison.

8 INFRASTRUCTURE/ OPERATIONAL IMPROVEMENTS

The Fish Creek Filtration Plant (FCFP) is a 7.5 million-gallon per day (MGD) conventional filtration facility which is jointly owned by the City and District. The FCFP follows a treatment train of pre-sedimentation, influent flow control and metering, coagulation, flocculation, sedimentation, filtration, and free chlorine disinfection. Under the partnership structure, both entities own a portion of the treatment infrastructure, and the District is responsible for the operation, maintenance, and management of the facility.

The FCFP is the primary source of potable water for both the City and the District. The Yampa River Well Filtration Plant (YRWFP) serves as a secondary potable water source to this system. Water quality changes resulting from watershed fires could potentially impact the facility's ability to reliably meet City and District demands. The purpose of this section is threefold: 1) to evaluate the current limitations of the FCFP to handle source water quality changes associated with watershed fires; 2) to present several potential facility improvements which would enhance the plant's resiliency to such water quality changes; and 3) to describe mobile/temporary water treatment options which could be rapidly implemented in the event that the FCFP cannot provide sufficient capacity to meet customer demands after a watershed fire.

8.1 CURRENT TREATMENT PROCESS

The FCFP conventional treatment process is outlined by Figure 1. Each of the treatment components are briefly described in the following sections. The description is followed by a discussion of expected water quality impacts based on the literature review and samples collected as part of this analysis in October 2018 and the implications for the treatment process.

8.1.1 RAW WATER INTAKE AND PRE-SEDIMENTATION

Raw water is collected through a diversion dam and inlet structure along Fish Creek and delivered to the plant headworks through an 18-inch gravity transmission line. Flow is first sent to a 2,400 cubic foot (ft^3) pre-sedimentation basin (rise rate = 17.3 gpm/ft^2 at 7.5 MGD, detention time = 3.4 minutes at 7.5 MGD). This structure is primarily needed during spring runoff when creek turbidity is highest.

8.1.1.1 WILDFIRE IMPACTS

/ In the event of a wildfire in the watershed, impacts to Fish Creek would include significantly higher turbidity and suspended solids as the result sediment mobilization in fire impacted areas. The nature of organic carbon in the sediment will be altered after the fire due to the combustion of the organic matter. Metals may also be mobilized in the sediment and could present water treatment challenges. Rainstorms following the wildfire will flush high sediment loads from the watershed into the creek which could build up at various areas within the creek, including in front of the FCFP intake. In addition, the loss of vegetation in the watershed could allow debris of varying sizes to be transported into the creek which could impact the operation of the raw water intake in Fish Creek in the aftermath of a wildfire. These water quality changes could directly and indirectly impact the facility's ability to effectively meet potable water demands for the City and the District.

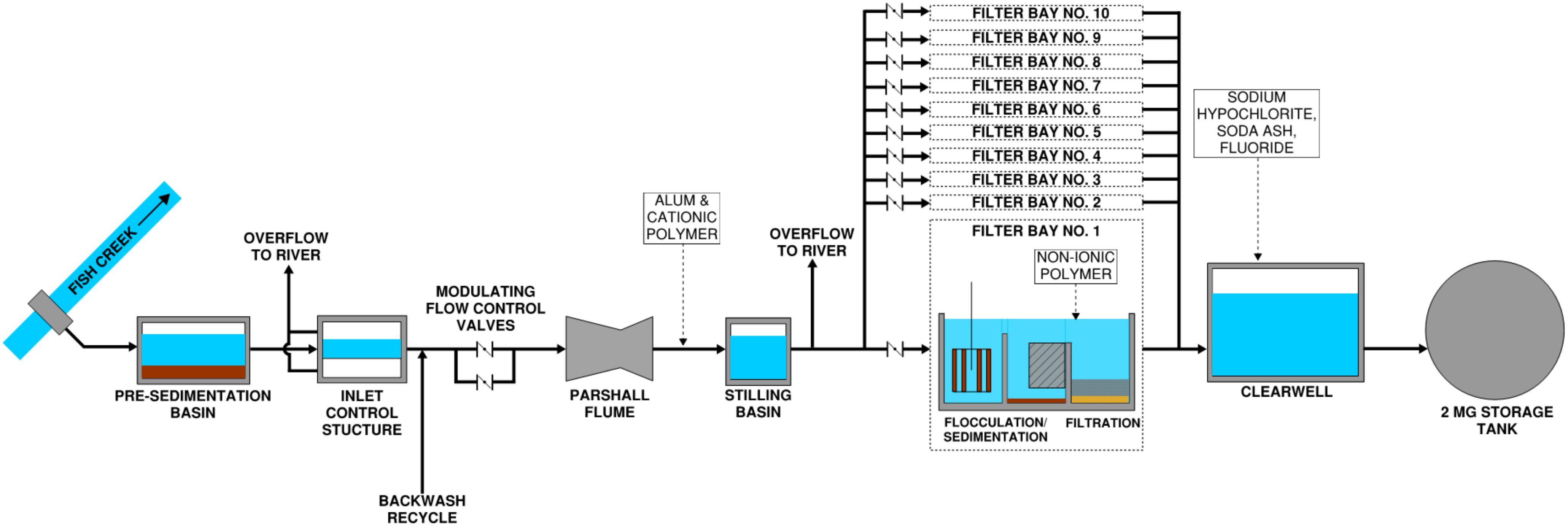

Figure 8-1. Fish Creek Filtration Plant Process

8.1.1.2 TREATMENT CONSIDERATIONS

- The previous section identified measures that can be taken to reduce sediment erosion from the landscape and potential locations for sediment basins were wildfire to occur in the watershed to preemptively remove sediment loading prior to reaching the FCFP intake. If damage from large debris is identified as a major concern, the intake structure can be hardened or armored.
- To prevent fine silt from settling out in the 18-inch raw water transmission line, the intake should be operated to provide a minimum scouring velocity of 1 ft/second (this would be achieved at a minimum plant flow of 1.2 MGD).
- The existing pre-sedimentation basin at the FCFP works well under current water quality conditions. The detention time of 3.4 minutes at 7.5 MGD would create treatment challenges under post wildfire conditions. During the summer months, 8-9 MGD is passed through the pre-sedimentation pond for treatment to account for water loss in the process while maximizing plant production capacity, which will only decrease the detention time and increase the sediment load into the treatment process. Sediment that passes the intake will eventually overwhelm the pre-sedimentation basin since it was not designed for large and prolonged sediment loading events. To enhance the settleability of high solids loads in the source water, a cationic polymer feed could be added to the raw water intake, upstream of the basin.
- To minimize the impact of solids loading on downstream processes, the solids accumulation capacity of the pre-sedimentation basin should be maximized. Operations staff has indicated that the maximum depth of solids is maintained below 3 feet before the solids are removed and disposed. Under current operation, the pre-sedimentation basin accumulates approximately 2-3 feet of solids per year. After a wildfire in the watershed, the suspended solids in Fish Creek could result in 2-3 feet of solids in the pre-sedimentation basin in just a matter of days or weeks.
- An optional approach to pre-sedimentation would be to utilize the existing backwash settling ponds as emergency pre-sedimentation basins in the event that the existing pre-sedimentation basin is overwhelmed under high source water turbidity events. Each pond has a volume of 625,000 gallons and would provide approximately 2 hours of additional detention time for raw water solids settling. This could be done in a single pond which always sits empty on standby while the other pond continues to handle plant residual streams. Alternatively, both ponds could also be utilized for this purpose, however plant residuals would then need to be sent elsewhere, such as the sewer (see Section 8.1.7.2 for additional discussion on this). With either approach, a new raw water pump and 18-inch line back to the plant inlet would need to be implemented. The suction for this new pumping scheme would need to be isolated from the existing recycle water wetwell so those streams are not blended (if both ponds are used for pre-sedimentation and residuals are sent to the sewer, the existing wetwell could be repurposed for this).

8.1.2 INFLUENT FLOW CONTROL, METERING, AND CHEMICAL APPLICATION

From the pre-sedimentation basin, water is sent through an 18-inch pipe to the inlet control structure, which has a series of adjustable overflow weirs to protect the chemical feed building from flooding. Overflow is discharged back to Fish Creek through a 24-inch pipe. Raw water is carried from the inlet control structure to the chemical feed building where a 24-inch Parshall flume measures the total influent flow. Immediately downstream of the flume, alum and cationic polymer are mixed into solution as the inlet channel discharges to the stilling basin. Influent flow control valves upstream modulate to maintain a set water level in the stilling basin, so a constant water level is provided in the filters downstream.

8.1.2.1 WILDFIRE IMPACTS

- As long as the FCFP intake and pre-sedimentation basin are properly functioning, minimal impacts are expected on the influent flow control and metering as a result of a wildfire. Chemical application will be impacted by the degree to which raw water quality is altered; this is discussed further in Section 8.1.8.

8.1.2.2 TREATMENT CONSIDERATIONS

- If plant capacity is reduced after a watershed fire, but excess flow is required to prevent silt from settling in the raw water intake pipe, the surplus can be overflowed at the inlet control structure back to the river. As previously noted, minimum flow to prevent sedimentation in that pipe is 1.2 MGD (1 ft/second scour velocity).
- The current system configuration allows for some flexibility in adding additional or alternative pre-treatment chemicals (i.e., pre-oxidant, alternative coagulant or polymer). The plant inlet systems are sized to handle an ultimate flow of 12 MGD. Thus, future expansion of the facility should take place downstream of the stilling basin (see Section 8.3 for additional details on FCFP expansion).

8.1.3 FLOCCULATION AND SEDIMENTATION

A 36-inch header takes stilling basin effluent to a series of 10 filter bays. Each filter bay consists of a flocculation tank, a sedimentation tank, and a filter tank, which operate in series as an independent train. The bays are designed to split flow evenly and with 1 filter bay out of service (or in standby), a flow rate of 0.92 MGD/filter bay is necessary to produce 7.5 MGD of finished water from the FCFP, assuming loses from sedimentation and filter wasting/washing processes. Maintaining 1 filter bay offline allows flexibility of backwashing in the event of challenging treatment conditions.

Water enters a filter bay flocculation tank though a 12-inch branch from the filter influent header. Each flocculation basin is 10,000 gallons (detention time – 15.6 minutes) and contains a single vertical paddle flocculator, which rotates at 1 rpm. A weir isolates the flocculation tank from the adjacent sedimentation tank. During normal operation, this weir is submerged.

Each sedimentation tank is 10,000 gallons and is equipped with tube settlers which have a surface area of 224 ft^2/tank (or 2.85 gpm/sf tube settler loading rate). Filter influent weirs are adjustable and are operated in the submerged condition so that all three filter bay tanks maintain a common water surface elevation. Non-ionic polymer is fed at the inlet of each filter.

8.1.3.1 WILDFIRE IMPACTS

- Postfire water quality will significantly impact the performance considerations for flocculation and sedimentation. Variability or significant increases in solids, turbidity, and organics will impact the required enhanced removal of these constituents in order to meet TOC removal and other water treatment requirements and/or goals.

8.1.3.2 TREATMENT CONSIDERATIONS

- Additional suspended solids, turbidity, and organic loading will likely increase the required doses of coagulant and polymer. Limited flocculation time challenges the FCFP's ability to form settleable floc in the sedimentation basins without significantly reducing the flow through each train (thereby increasing the flocculation and settling times). Due to the common basin configuration for each filter bay, the ability to make modifications within these processes is very limited.
- Replacing the tube settlers with lamella plates would increase the effective settling area in the basins, which would in turn reduce the turbidity loading on the filters (potentially increasing production efficiency). However, since there is limited flocculation upstream of sedimentation, the treatment benefits should be compared to the cost associated with retrofitting lamella plates in the process.
- The addition f non-ionic polymer feeds to each flocculation basin could be considered. Having the ability to feed at both the flocculation basin and the filter inlet would provide the flexibility to further tailor the treatment process based on water quality and could help to protect the filters from solids overloading by enhancing sedimentation.

8.1.4 FILTRATION

The filters have 18 inches of anthracite (1.0 to 1.1 mm effective size) over 9 inches of sand (0.45 to 0.55 mm effective size) with several layers of underlying garnet and support gravel. Each filter has a surface area of 144 ft^2 and is rated for a maximum loading rate of 5 gpm/ft^2, however the underdrain and media manufacturer (Leopold) recommends that the system is operated at 4 gpm/ft^2. Backwash volume is estimated to be 2% of filter production, including 30 minutes of filter to waste (FTW) time per backwash cycle. The unit filter run volumes (UFRV) have been estimated at 5,600 gallons/ft^2 in the winter and 1,400 gallons/ft^2 in the summer (assuming a 4 gpm/sf loading rate and backwashing frequency of 1/day in the winter and 3/day in the summer).

8.1.4.1 WILDFIRE IMPACTS

/ The filters were deigned to handle the good source water quality which currently exists but may not be well equipped to deal with challenging water quality under postfire conditions. The additional solids expected in the source water could overwhelm processes upstream of the filters, which would result in higher solids loading on the filters. Higher doses of coagulant will also produce more solids that may be difficult to settle. The additional solids loading on the filters will result in lower filter loading rates, shorter filter runs, and ultimately a reduced overall treatment capacity for the FCFP.

8.1.4.2 TREATMENT CONSIDERATIONS

/ Replacing the filter underdrains and filter media could provide some improvement to the robustness of the filters. The clay tile underdrains could be replaced with plastic (low profile) underdrain blocks. Underdrain replacement should coincide with replacement of the filter media – the type and size of the media should be tailored for optimal filter performance. The low UFRVs estimated for current operations will be further reduced if upstream processes are not able to handle the water quality challenges that could arise after a wildfire. Lower filter loading rates and more frequent backwashing reduces overall plant production capacity.

8.1.5 DISINFECTION AND FINISHED WATER STORAGE

Filter effluent combines in a 24-inch pipe and goes to the 70,000-gallon clearwell for free chlorine disinfection and finished water chemical addition. Sodium hypochlorite, soda ash, and fluoride are added at the influent to the clearwell. Water is sent from the clearwell to the 2 MG storage tank through a 30-inch line. Both the clearwell and the storage tank are used for disinfection volume. The chlorine residual is measured at the 2 MG tank effluent. Sodium hypochlorite is typically dosed in the range of 1.8-2.5 mg/L, to achieve the free chlorine residual goal of 1.3 mg/L.

8.1.5.1 WILDFIRE IMPACTS

/ Due to the change in both the amount and nature of organic loading into the FCFP, disinfection chemistry (chlorine demand), and disinfection byproduct (DBP) formation are anticipated to be altered. The change to disinfection also depends on additional treatment processes that may be added to address the treatment challenges.

8.1.5.2 TREATMENT CONSIDERATIONS

/ Since the District and the City operate a free chlorine distribution system, additional treatment is recommended prior to disinfection to removal organics and control DBP formation.

8.1.6 FILTER WASHING

Filter wash cycles are initiated either when the headloss across a filter reaches 7.5 feet or filter effluent turbidity exceeds 0.2 NTU. The filter box is drained at the start of every wash cycle, and the sedimentation tank is drained every fifth cycle to remove accumulated sludge. A wash cycle consists of a 3-minute surface wash at 0.65 gpm/ft^2 and a 7 minute backwash; the backwash rate depends on the water temperature (15 gpm/ft^2 during summer months and 10 gpm/ft^2 during winter months). During the summer months, backwash rates are higher and filters typically have to be washed 2-3 times more frequently thereby limiting plant production to approximately 7 MGD (as reported by Operations staff and the FCFP O&M Manual). Both the surface wash and backwash pumps draw from the clearwell, which has enough storage capacity for approximately 2 consecutive filter wash cycles. Waste wash water is collected in a trough that has adjustable weir elevation and is sent to the settling ponds. After a wash cycle is completed, the filter is refilled using the backwash supply pumps. This allows the floc in the flocculation tank to not be disturbed when the filter bay is brought back on-line. Filters operate in FTW mode for 30 minutes before being brought back into service.

8.1.6.1 WILDFIRE IMPACTS

- The FCFP facility currently experiences a slight reduction in net capacity during summer months as the result of increased backwash frequency due to shorter filter runtimes, and higher backwash rates. Without additional pre-treatment, even shorter filter runtimes after a wildfire could cause a further reduction in plant capacity as the result of a filter backwash bottleneck. While the 2 MG tank and other treated water storage within the distribution system provide some buffer to meet customer demands when the plant capacity is impacted, other treated water supply options may need to be leveraged to offset this deficit.

8.1.6.2 TREATMENT CONSIDERATIONS

- Efficient backwashing and backwash waste handling will be an important tool to maintain treatment capacity during challenging water quality conditions. Current operations suggest that the backwash rates may not be sufficient to properly expand the media (20-25%). Additionally, the surface wash time should be done for 1-2 minutes when the media is fully expanded. In order to further optimize the wash process and minimize filter downtime, the FTW duration could be reduced so that just one box volume (approximately 10,000 gallons) is sent to waste before bringing the filter back on-line (assuming effluent turbidity has fully dropped).
- If improvements to the filter underdrains and media are implemented, air scour should also be considered to replace the surface wash system. This will reduce the volumes of water utilized during backwashes and improve cleaning. The media expansion during backwash should be evaluated and backwash rates should be adjusted to achieve at least a 20% bed expansion during the high rate wash. The filter to waste time should be analyzed based on turbidity spike trends and rinse to waste should also be considered in the backwash sequence as this sub-fluidized rinse step at the end of the backwash sequence removes remnant particles and reduces the filter ripening duration.

8.1.7 RESIDUALS HANDLING

Residuals are captured in the pre-sedimentation basin, the sedimentation tanks, and filter backwash processes. The pre-sedimentation basin is cleaned out annually after spring runoff has subsided; typically, 2-3 feet (600-900 ft^3) of sediment accumulate each year. The material is stockpiled on site with other residual solids for drying and eventual hauling to a landfill.

The facility has two earthen settling ponds for sedimentation tank and filter backwash waste solids, each with a volume of 625,000 gallons. They can be operated independently, in series, or in parallel. Supernatant water is decanted over the outlet weirs to the backwash return pump station where it is recycled to the head of the plant. The pond outlet weirs can be adjusted to minimize solids recycled back to the process. The ponds are cleaned once per year, typically in the late summer or early fall. Sediment from a drained basin is collected using a pump and stockpiled on site to dry and be tested before being hauled to a landfill.

8.1.7.1 WILDFIRE IMPACTS

- With anticipated higher alum and polymer doses for removal of organics and suspended solids, the rate at which sludge accumulates in the sedimentation tanks will increase, requiring those basins to be drained more frequently. Moreover, additional solids would likely carry over onto the filters, thereby reducing filter runtimes, and increasing backwash frequency.
- The increased waste volumes would decrease backwash pond retention time and impact recycled water quality. The added solids loading would also require the ponds to be cleaned out more frequently and result in greater volumes of sludge to be stockpiled, dried, and hauled away. Changes in the makeup of the solids could change the classification of the solids (due to increased Technologically Enhanced Naturally Occurring Radioactive Material [TENORM]), which could require the material to be disposed of at a more expensive landfill. The FCFP site has limited space available to spread out solids for drying, and if stacked too high, there may not be adequate drying time to send the material to a landfill before more sludge has to be removed from the pre-sedimentation basin and backwash waste ponds.

8.1.7.2 TREATMENT CONSIDERATIONS

- There is limited space available for passive solids handling technologies such as settling ponds and drying beds. In the event of a wildfire in the watershed, it is anticipated that there will be a significant increase in the amount of solids to be removed through the treatment process. It is not feasible to add additional backwash ponds or drying beds without exhausting the space currently available for future plant expansion.
- Mechanical dewatering could be considered at the FCFP as an option for solids handling in a much smaller footprint. Mechanical solids handling would consist of thickening (i.e., gravity thickener or gravity belt thickener) and dewatering (i.e., centrifuge or belt filter press). While a permanent mechanical dewatering facility could be considered for the FCFP, a mobile dewatering unit could also be utilized to dewater solids in an emergency situation without the high capital cost associated with adding the permanent infrastructure. Figure 8.2 illustrates the dewatering process for centrifuges and belt filter presses.
- As an alternative to modifying or adding solids handling on-site, residual streams could potentially be sent to the sewer. Per the FCFP O&M Manual, the sanitary sewer system for Sanctuary is a short distance away from the plant and could be extended to provide an option for backwash disposal; and, the plant currently has a domestic connection to the sanitary sewer system with infrastructure in place to connect residual streams. This type of modification would be required if both settling ponds were repurposed as pre-sedimentation basins (see Section 8.1.1.2).
- Consistent with the facility's O&M Manual, it is recommended that the City and District do a detailed solids handling analysis for the facility to better understand the current capacity of the FCFP solids handling systems and the limitations to deal with residuals under challenging source water quality conditions, prior to making any modifications.

8.1.8 CHEMICAL FEED AND STORAGE

As previously noted, the FCFP uses a variety of chemicals in the treatment process. Alum, soda ash, and fluoride (sodium fluorosilicate) are stored as dry powder. Bags are manually unloaded to a series of hoppers which drop to volumetric screw feeders below where chemicals are blended into solution and sent to their application points with a carrier water dilution system. There is one spare dry feed system which can be used for either alum or soda ash or potentially an alternate pre-treatment chemical.

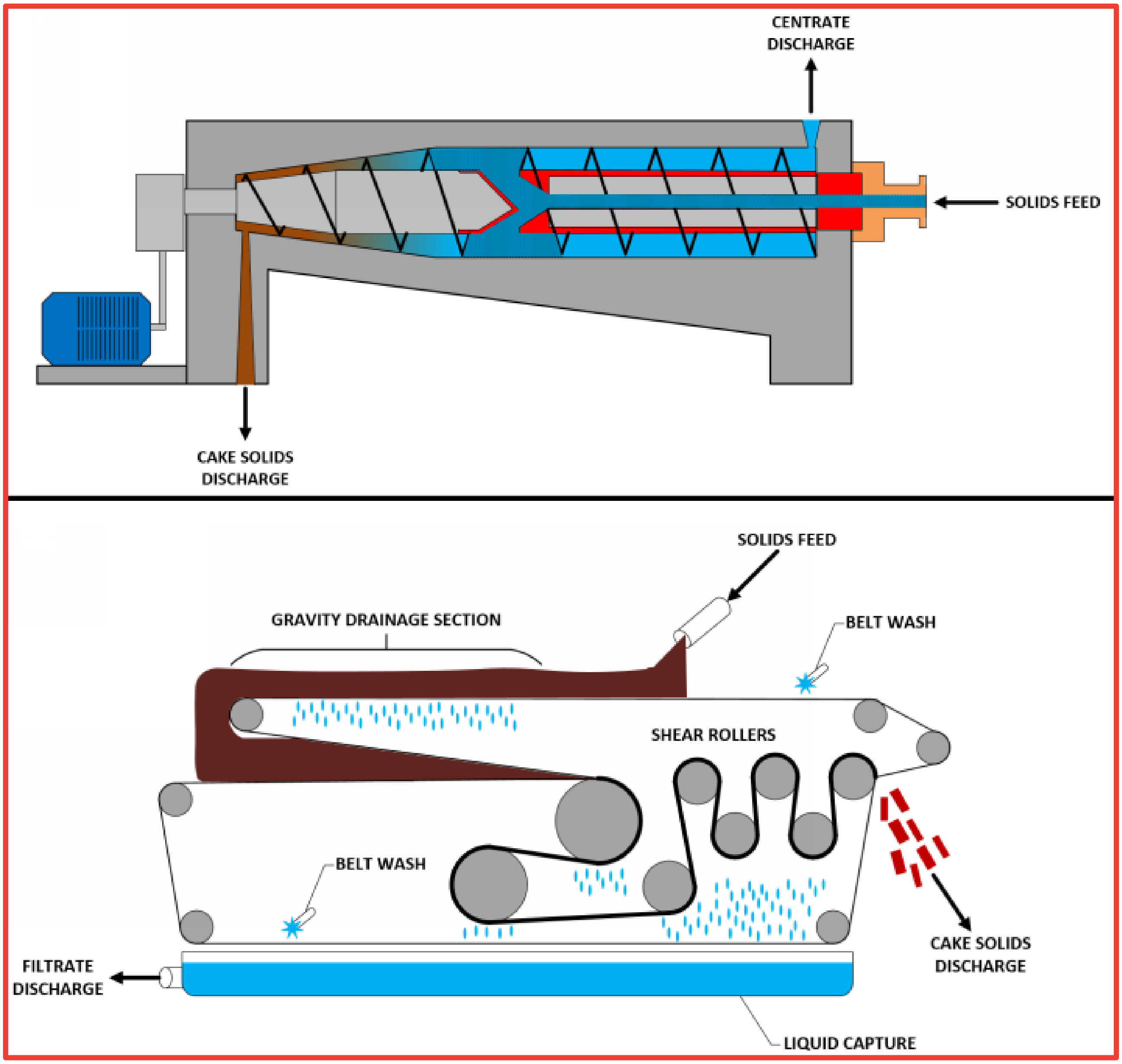

Figure 8-2. Mechanical Dewatering process for Centrifuges (top) and Belt Filter Presses (bottom).

The two types of emulsion polymers are used at the FCFP: cationic coagulant aid polymer (Nalcolyte 8100) added at the stilling basin, and non-ionic filter aid polymer (Nalclear 8170) added at the inlet of each filter tank. Both polymers are delivered neat and stored in fiberglass tanks.

Sodium hypochlorite is generated on-site using a ClorTec® system which can produce 4,320 gallons per day of solution at 0.8% strength. Three 1,200-gallon polyethylene tanks are used to store the hypochlorite solution prior to application, this volume is sufficient to operate the plant for approximately 3 days at 6 MGD. There is a 500-gallon brine tank which feeds the electrolyzer cells for hypochlorite production, and an ion exchange softening system for resin regeneration (the softeners remove hardness from dilution water upstream of the electrolyzer cells). Similar to the other dry chemicals, salt bags are manually loaded into the brine tank.

8.1.8.1 WILDFIRE IMPACTS

- In addition to higher solids loading, increased organic carbon content could create further treatment challenges by increasing DBP formation upon chlorination. To control DBPs, removal of organic matter upstream of the clearwell is critical. Under postfire conditions, the alum dose would likely need to be increased to achieve sufficient organic carbon removal and to protect the filters from excessive solids loading. The existing alum system can dose up to 54.4 mg/L at 7.5 MGD, however it is unknown if this could adequately remove organic carbon and sediment in fire impacted source water. Similarly, the cationic and non-ionic polymer doses would likely need to be increased, or the types of polymers used may need to change in order to achieve effective coagulation and filtration.
- Increased organics loads may impact chlorine demand in the clearwell. Consequently, higher sodium hypochlorite doses may be required in order to achieve the plant effluent residual goal of 1.3 mg/L. Higher disinfectant doses must be balanced with greater finished water DBP concentrations.

8.1.8.2 TREATMENT CONSIDERATIONS

- Most of the existing chemical feed systems at the FCFP would not be impacted by water quality changes, however one potential vulnerability is the alum system. As previously noted, it has the capacity to dose 54.4 mg/L at 7.5 MGD (34 mg/L at an ultimate plant buildout of 12 MGD). Under current conditions, the typical alum doses is around 12-14 mg/L. However, under post-wildfire conditions, this may not provide adequate coagulation for organic carbon removal. The spare dry chemical feed system could be used to supplement this or an alternate coagulant (i.e. aluminum chlorohydrate (ACH) or polyaluminum chloride (PACl)) could be used. The dry feed system cannot always provide a consistent, well blended solution. The cold temperature of the raw water further reduces the efficiency of blending the dry chemicals into solution (ACH and PACl can be mixed better under cold water conditions). Currently, the source water is high quality and having a variable coagulant feed does not present any challenges. However, under high sediment post-wildfire conditions this could be problematic. The source water characteristics could be quite different and zeta potential is recommended as the preferred approach for coagulant and polymer dosing. Online or bench-top zeta analyzers are available and can provide rapid feedback to optimize treatment performance.
- Replacing the existing dry feed alum system with a bulk alum storage tanks would enhance the FCFP's resiliency to wildfire water quality changes. Bulk alum provides a consistent, easy to feed solution which would be more reliable for challenging water quality. The chemical metering pumps for this system would be sized to feed a wider range of alum doses than the current dry feeders.
- If the applied polymer doses must increase as the result of water quality changes, the frequency of polymer deliveries will subsequently increase. The existing cationic and non-ionic polymer storage tanks (750 gallons and 450 gallons, respectively) likely don't need to be replaced with larger units, unless the required frequency of deliveries becomes and operational challenge. These tanks will also be able continue to be used if different types of emulsion polymers are necessary to handle challenging water quality. In order to provide the flexibility to feed polymer at higher doses under higher treatment plant flow rates, larger polymer feed pumps should be implemented.
- If sodium hypochlorite dose increases as the result of greater chlorine demand, or if sodium hypochlorite is used as a pre-oxidant (see Section 8.2.1), the existing on-site generation system would likely still be sufficient to provide enough solution for FCFP operation. The system would need to run more frequently, resulting in more frequent maintenance. Increasing the existing skid capacity may be necessary to ensure an adequate supply of sodium hypochlorite is available at all times. Along with this, a larger brine storage tank to accept bulk salt deliveries could be used to simplify system operation.
- In the event of a wildfire, jar testing is recommended to analyze various combinations and types of coagulants and polymers to meet treatment needs. Additional chemicals such as pre-oxidants, alkalinity adjustment (lime or sodium hydroxide), or corrosion inhibitors may also be considered and tested at the bench and/or full scale.

8.2 NEW TREATMENT PROCESS OPTIONS

There are several improvements which could be implemented to enhance the FCFP's resiliency to treat water in the event of a watershed fire. Some of the proposed options would be implemented upstream of filtration (pre-treatment), and others would be implemented downstream of the filters but prior to the clearwell. While pre-treatment would help to improve flocculation and sedimentation and protect the filters from losing capacity under challenging water quality conditions, post-filtration would provide additional barriers for particles and organics or micropollutants that cannot be treated through the current process. The post-filtration options would be implemented prior to free chlorine contact in the clearwell to minimize the potential for DBP formation.

Pre-treatment options which could be considered at the FCFP include pre-oxidation, roughing filters, and high rate clarification. Post-filtration treatments include membrane filtration and granular activated carbon (GAC) adsorption. Each of these alternatives is described in the following sections.

8.2.1 PRE-OXIDATION

Pre-oxidation is used to oxidize metals and organic matter prior to removal by sedimentation and filtration. A straightforward approach for this at the FCFP would be to add a raw water sodium hypochlorite feed. This is a low-cost option since the facility already has a sodium hypochlorite system. One disadvantage is that adding chlorine at higher doses to untreated water could result in DBP formation at higher doses. Also, while sodium hypochlorite is great for oxidizing organic carbon, it will not oxidize manganese unless a manganese coated media is formed, the process for which takes a long time.

As an alternative to sodium hypochlorite pre-oxidation, permanganate (sodium or potassium), chlorine dioxide, or hydrogen peroxide could also be used. Permanganate could be implemented using a series of small storage totes or drums and a metering pump feed system. It has the advantage of not creating chlorinated DBPs. However, one drawback of permanganate is that the oxidation reaction time is slower than that of chlorine and overdosing can cause water to turn pink. Hydrogen peroxide also has the advantage on not creating DBPs, however it has a high hazard classification, and building and fire codes would likely require it to be stored in a separate facility or area. Similarly, chlorine dioxide would require a separate storage facility, and can result in byproduct (chlorite) formation. Hydrogen peroxide will not oxidize manganese unless manganese coated media is formed, while chlorine dioxide is very effective at oxidizing manganese.

Another pre-oxidant option is ozone. Ozone is highly effective at oxidizing types of organic matter which causes taste and odor issues. If biofiltration is implemented, ozone would have the added benefit of increasing dissolved oxygen available for biofiltration. The main disadvantages of ozone are the high capital costs, system complexity (liquid oxygen feed, ozone generation equipment, a contact basin, ozone destruct units, and a hydrogen peroxide system for ozone quenching), relatively high energy consumption, and bromate formation. Implementing ozone at the FCFP would require a new ozone facility to be constructed on-site. Combining hydrogen peroxide and ozone (i.e., peroxone) is also a highly effective pre-oxidation strategy that can address a multitude of taste and odor compounds while minimizing the required contact time and DBP formation potential.

8.2.2 ROUGHING FILTERS

Similar to pre-sedimentation, roughing filters are used as a pre-treatment step to remove large sediment from source water. Figure 8-3 illustrates typical roughing filter design which includes a series of boxes with graded gravel as filter media. The gravel in each box gets progressively finer, thereby allowing for removal of large particles first so as to not clog the finer media downstream. Roughing filters must be cleaned periodically to remove accumulated solids. Depending on the sophistication of the system, this can either be done hydraulically with a backwash system, or manually by raking, shoveling, and occasionally replacing the media. One challenge to implementing roughing filtration at the FCFP, is that this type of system requires a large surface area, but the site has a limited amount of space available.

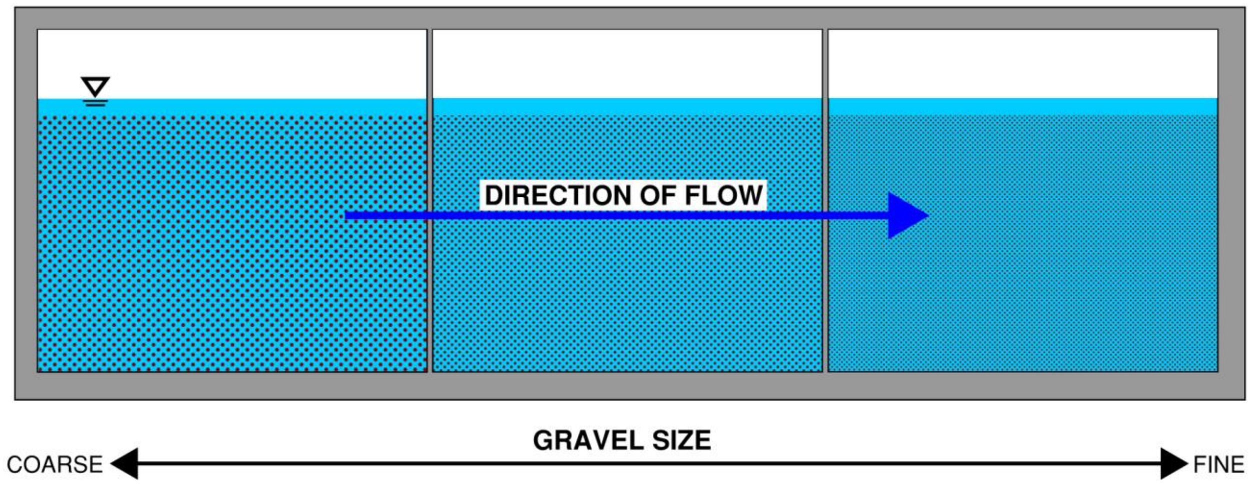

Figure 8-3. Roughing Filter Design

8.2.3 HIGH RATE CLARIFICATION

High rate clarification could be implemented downstream of the pre-sedimentation basin to provide an extra barrier for solids removal to protect the downstream processes. High rate clarification encompasses a number of different processes for sediment removal including dissolved air floatation, ballasted flocculation, or contact flocculation/clarification. These processes utilize smaller footprints than traditional flocculation/ sedimentation. While bench top and pilot studies would be required to determine which clarification process would be best utilized at the FCFP, it is recommended that ballasted flocculation be used if possible. Ballasted flocculation (Actiflo™) is a process which uses traditional coagulant and polymer flocculation with microsand addition to enhance settleability. This process is illustrated by Figure 8-4.

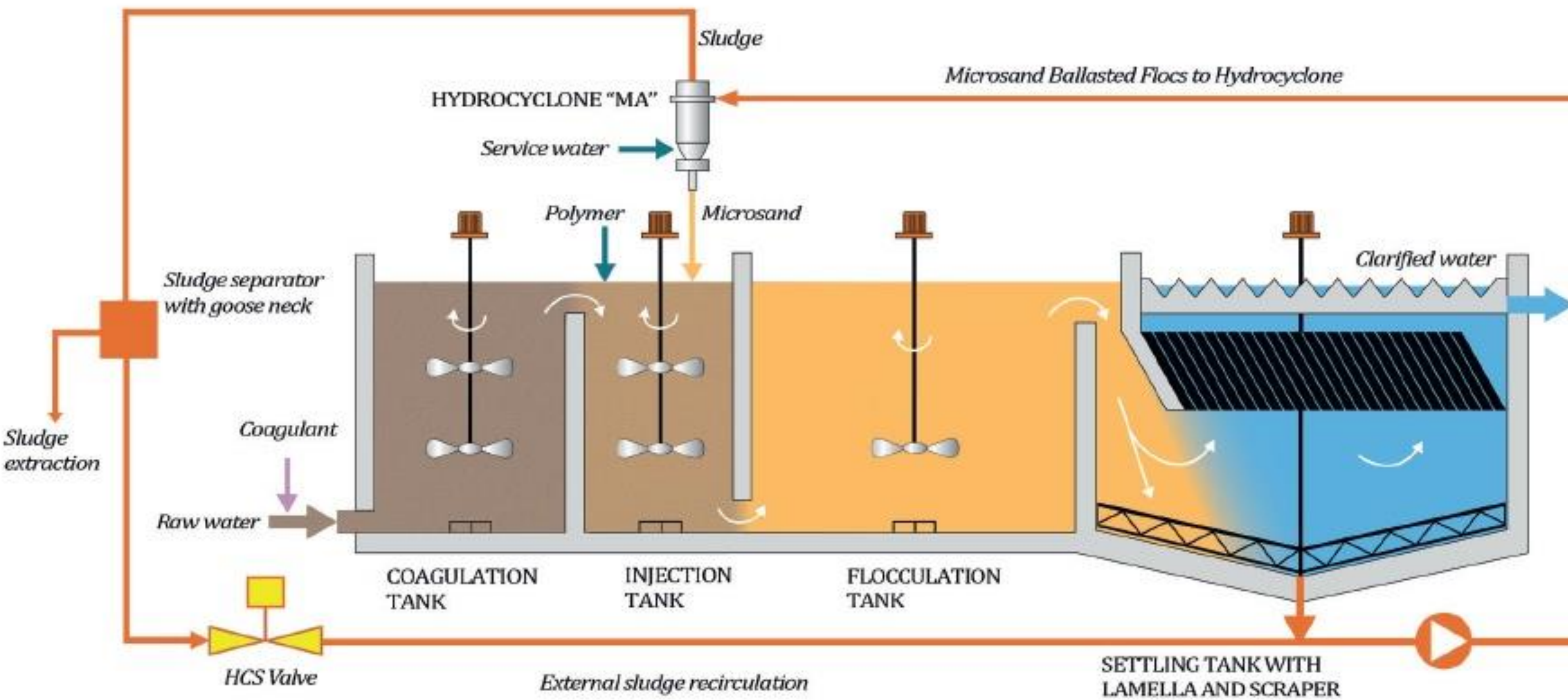

Figure 8-4. Actiflo™ (ballasted flocculation) high rate clarification process.

8.2.4 MEMBRANE FILTRATION

Addition of membranes downstream of the existing filters would help to remove fine particles carried over from the filters. Membranes have the advantage of being able to handle short-term spikes of turbidity (up to 1,000 NTU) should there be a process upset upstream under challenging water quality. Membrane filtration is a physical process wherein large molecules are strained out of solution. The size of molecules removed depends on the type of membrane. Membrane filtration would require feed pumps to provide sufficient system feed pressure (approximately 65-75 psi). Furthermore, these systems require extensive auxiliary components including backwash pumps, membrane cleaning chemical storage and feed equipment, and a method of treating and/or disposing of chemical cleaning waste streams.

8.2.5 GAC ADSORPTION

As an alternative to membranes, GAC could be implemented downstream of the filters. GAC contactors are highly effective at removing organics from water through adsorption. The main benefit of this approach is that it would reduce TOC upstream of chlorine addition in the clearwell. The GAC contactors could be operated similar to gravity filters or in pressure vessels. Because the water feed to these GAC contactors would already be filtered, headloss accumulation would be minimal and periodic backwashing would minimally impact plant production. Figure 8- 5 illustrates the GAC adsorption process.

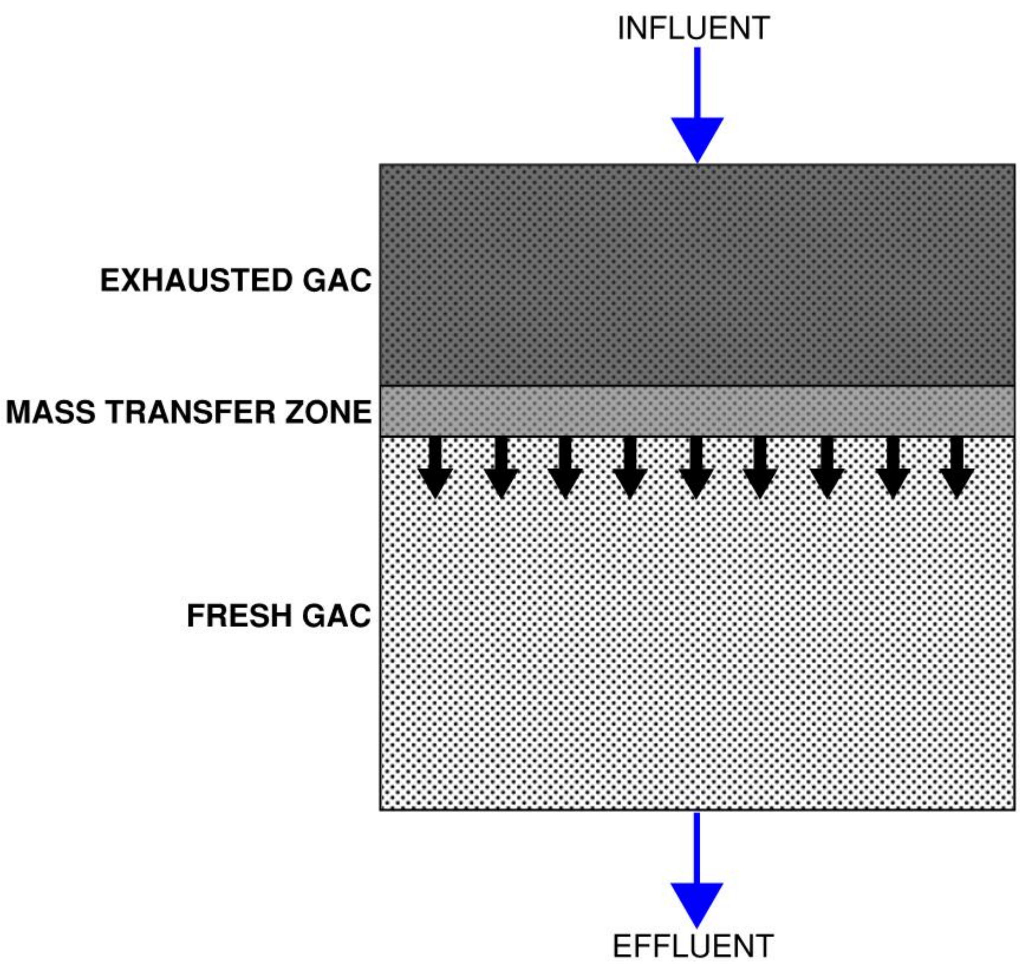

Figure 8-5. GAC Adsorption Process

8.3 PLANT EXPANSION

The proposed pre-treatment and post-filtration improvements described above would help mitigate loss of existing treatment capacity and protect against excessive DBP formation in the event of a wildfire in the watershed. In order to ensure demands can continue to be met as the City and District continue to grow, the next expansion of the FCFP should be proactively designed to be resilient to the postfire impacts to water quality that could be expected were a fire to occur in Fish Creek basin.

The FCFP's 10 filter bays currently provide a treatment capacity of 7.5 MGD, however the pre-sedimentation basin, inlet control structure, chemical feed systems, and disinfection scheme are designed for an ultimate facility expansion to 12 MGD. Additional clarification and filtration infrastructure must be implemented in order to realize this full capacity. The proposed expansion for the FCFP is outlined in Figure 8-6.

- A portion of the coagulated water from the stilling basin would be directed to new treatment train with a normal operating capacity of 4.5 MGD. The new treatment train would have a clarification process; this would be either traditional flocculation/sedimentation with plate or tube settlers or high rate clarification (see Section 8.2.3), depending of footprint and treatment requirements. The exact process to be implemented should be determined through bench scale and pilot testing.
- Four new filter trains would be used downstream of the clarification process. These would likely be larger than the existing filters. Under normal operating conditions, three filters would be operating at a time, with the fourth off-line for backwashing or in standby mode. The online filters would be designed to produce 4.5 MGD under a normal loading rate. However, if a wildfire significantly impacted source water quality and the 10 existing filter bays struggled to supply 7.5 MGD, the new filters could be operated under stressed condition to produce 7.5 MGD, resulting in no lost capacity from current conditions. The sizing of the filters will depend on the normal and stressed filter loading rates. The State requires pilot testing to be performed prior to implementation for design loading rates greater than 5 gpm/ft^2.

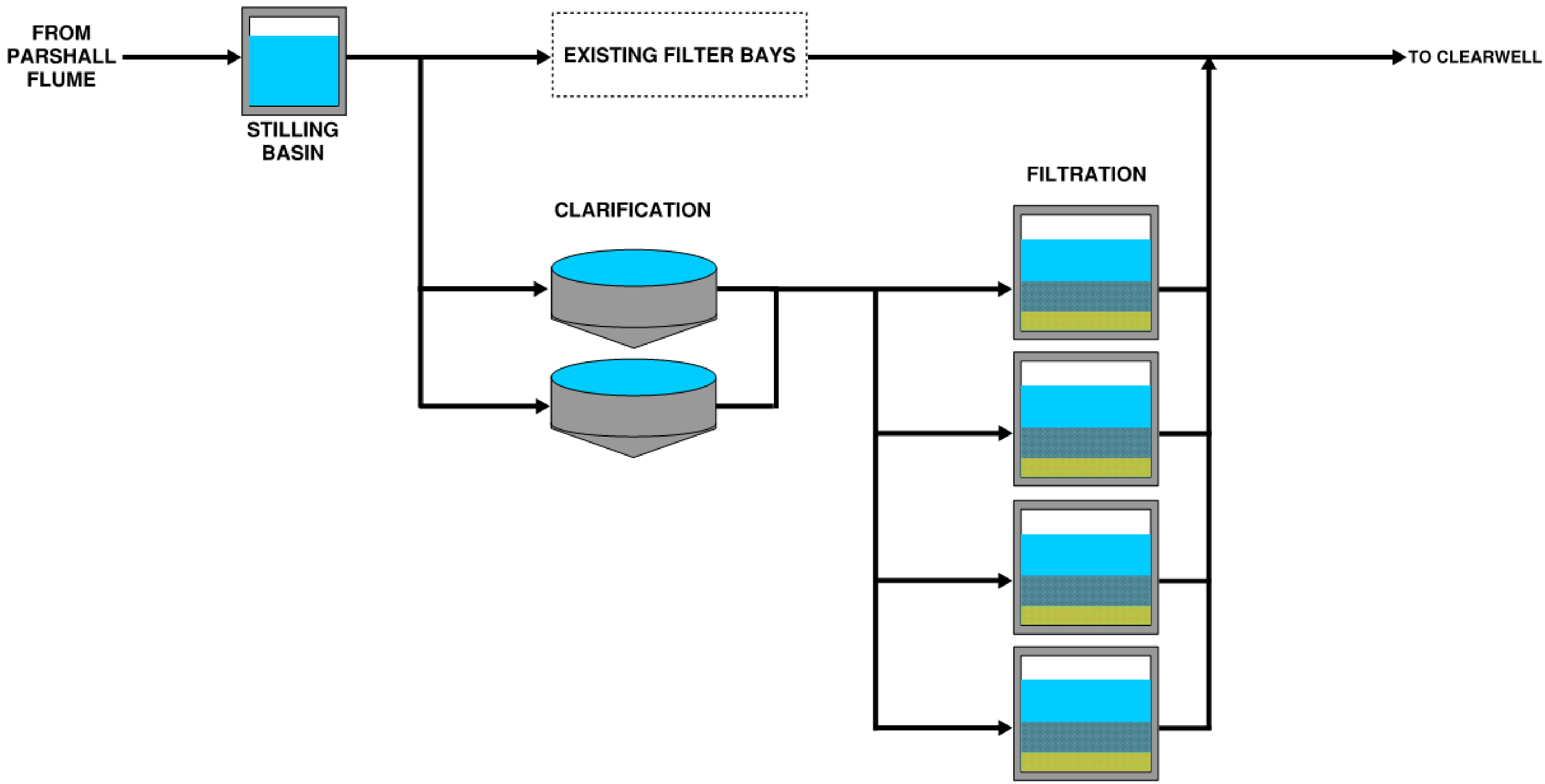

Figure 8-6. Proposed FCFP Expansion

8.4 ADDITIONAL TREATED WATER SUPPLY OPTIONS

In the event that the FCFP loses significant capacity as the result of a watershed fire, there are several treated water supply options which could be leveraged to ensure customer demands can still be met. Each of these alternatives is described briefly below.

8.4.1 YAMPA RIVER WELLS

Water supply from the FCFP is currently supplemented by a series of wells and infiltration galleries along the Yampa River. The Yampa River Well Filtration Plant (YRWFP) treats these sources to remove iron and manganese using greensand filtration, anthracite filtration, and UV and chlorine disinfection. Recent improvements to the Yampa Wellfield and YRWFP have increased the system capacity to 3.5 MGD.

Currently, this facility is only used during summer months when supplemental flow is required to meet increased demands. In the event that the FCFP partially or completely loses capacity, the Yampa system could be utilized to ensure sufficient water supply is available for base flow demands, which currently peak during the winter holiday season. Irrigation demands during the summer cannot be met by this facility alone; and, depending on the severity of FCFP loss in capacity, outdoor watering restrictions may need to be implemented or additional treated water supplies would be necessary.

8.4.2 ELK RIVER TREATMENT PLANT

The City currently owns 8 cfs of water rights on the Elk River. This source is currently undeveloped, but it is estimated that approximately 5 MGD of treated water supply capacity could be achieved from this. The treatment process for the Elk River source should consider current and future water quality scenarios. Pilot testing is required to determine the exact treatment processes and design criteria necessary for development of the Elk River as a treated water supply. Similar to the proposed FCFP expansion, the Elk River treatment plant should be designed to be resilient to water quality changes imposed by watershed wildfires with an effective clarification step upstream of filtration to ensure filters can operate at maximum loading rates.

Incorporating Elk River treatment into the City's overall treated water portfolio would help to strengthen resilience to watershed wildfires by diversifying supply options. The Elk River treatment plant could serve as a reliable backup should the FCFP experience capacity issues as the result of wildfire impacts to the watershed, and visa versa. However, this is a long-term solution that will take a number of years to fully realize. Should the FCFP be impacted by watershed fires in the near future, alternative supply options, such as mobile treatment, may be required.

8.5 MOBILE TREATMENT

If a wildfire were to impact the watershed in the near-term, mobile water treatment and dewatering units can be deployed on a temporary basis to allow the City and District to effectively meet customer treated water demands. Having agreements in already place with mobile treatment equipment suppliers and a plan for staging mobile units will allow for rapid deployment in an emergency situation.

8.5.1 MOBILE WATER TREATMENT

Mobile water treatment units could be used to supplement the City and District's existing water supplies. A number of companies such as Applied Membranes Inc., Suez, and Veolia offer trailer or shipping container mounted treatment units which can be readily deployed on-site. Depending on the quantity of supplemental water required, mobile treatment may be a single trailer containing all applicable treatment processes, or several units, each with an independent treatment process, operating in series. Generally, mobile treatment units can supply around 1-2 MGD of treated water. An example of one of these systems is shown in Figure 8-7.

Figure 8-7. Trailer Mounted Mobile Water Treatment System

The treatment process used will depend on a number of factors at the time of deployment, most importantly, the source water quality to be treated. The City will need to rely on treatment experts from these companies to determine which processes are required in a given scenario.

For potable water treatment, these systems generally follow a treatment train of sediment removal with screened filtration followed by UF membrane filtration. UF membranes are preferred for this approach because they can achieve high *Giardia* and *Cryptosporidium* removal credit, resulting in smaller required CT values which are based solely on virus inactivation. This would reduce the required disinfection volume and disinfectant dose and help to curtail DBP formation. It is important to note that, due to liability issues and State regulations, the companies providing mobile treatment units are not permitted to perform disinfection. A water treatment plant operator licensed in the State of Colorado is required to oversee this process. Depending on the logistics at the time of deployment, the effluent from the mobile treatment could be sent to the FCFP clearwell for disinfection, or some other temporary disinfection scheme to achieve the appropriate CT and disinfectant residual. Another important consideration is that these units generally do not have residual handling equipment and require that waste streams be sent to a separate handling system provided by the Utility (such as the existing FCFP settling ponds or a mobile mechanical dewatering system).

Based on sizing from Suez, one 53-foot mobile treatment trailer using UF membranes can produce 850-900 gpm (approximately 1.25 MGD). Several of these units could be used in series if flow demands exceed the capacity of a single unit. A 350 Amp, 480 VAC power supply is required to operate a unit of this size. A diesel generator or permeant power connection could be adapted for the mobile treatment skid. Some treatment systems also have the option mounted solar panels to supplement electrical power input. The proposed Suez system also requires 8-inch inlet/ outlet water connections from the raw water and to the discharging point.

In the event that mobile treatment is required in the near future, the City and District should proactively identify potential locations where it can be set up. Ideally, this would be somewhere directly adjacent to both a usable raw water supply, and a point in the distribution system where finished water can be discharged. The site should also be large enough to house at least 2-3 standard sized tractor trailers, contain some sort of system in place for handling residual waste streams produced by the treatment unit. The FCFP or YRWFP sites are the optimal locations for these units, however it would be judicious to preemptively identify several other potential locations, should those sites be unavailable.

The City and District should consider a Master Service Agreement (MSA) with Suez (or another mobile water treatment company). With an MSA in place, the contracted company would just need to be contacted in the event mobile treatment is required, and a unit(s) can be deployed on-site immediately without being slowed down by administrative timelines. The MSA would outline the scope, fee, and responsibilities for all parties should mobile treatment be utilized. Any of the companies named in this report are viable options for providing mobile potable water treatment systems, however several others exist which could provide similar services.

8.5.2 MOBILE DEWATERING

In addition to mobile water treatment equipment, the City and District should also develop an MSA with a mobile dewatering vendor. Parker Ag Services and McDonald Farms are two options in Colorado that provide residuals dewatering and hauling services. Similar to mobile water treatment, dewatering equipment requires a power supply, water connection, access for residuals trucks, and space for the dewatering equipment.

8.6 SPECIFIC RECOMMENDATIONS & OPINION OF PROBABLE COSTS

Specific recommendations for water supply infrastructure and operational improvements for the near-term are shown in Table 8-1; mid-size/range and large-scale, long-term improvement recommendations are shown in Table 8-2. Cost range estimates were provided to help inform high-level decision-making but will vary depending on actual design criteria and whether some projects are contracted out or self-performed by the District and/or City.

Table 8-1. Water Supply Infrastructure Improvement Project Recommendations

Project/ Action Item	Specific Recommendations	Operational Benefits	Estimated Cost
Near Term Action Items			
Intake Protection	Update the plant intake on Fish Creek. This include adding instrumentation for real time monitoring of changing water conditions, re-orienting inlet to reduce the potential for sediment intake, armoring the structure, install trash rack to protect from large debris and adding an automated isolation valve at the intake.	Provide rapid indication of challenging water quality to help operations adjust treatment at the plant and/or automated isolation. Prevents large debris from damaging downstream equipment, or otherwise creating blockages in the raw water inlet line.	$30-300k (upper end depends on the extent of physical modifications)
Residuals Management	Clear out residuals from pre-sedimentation basin and settling ponds prior to fire season.	Maximize available capacity of these basins. Establish disposal location and pricing for planning/budgeting.	TBD
	Provide line item in the annual budget for solids disposal.	Regularly removing solids from the site maximizes the available capacity of the existing system to dewater solids should significant sediment loads be sent to the plant as the result of a watershed fire, or other extreme event (such as a flood).	TBD (based on costs from previous line item)
	Test current residuals stockpiled on site and monitor new TENORM legislation to determine how close current sediment concentrations are to the current and proposed limits.	Having a historical TENORM profile for plant residuals allows for baselines to be established so that the impact of future water quality changes can be accurately measured and managed.	$5,000
Mobile Treatment	Enter into a Master Services Agreement with a mobile water treatment vendor.	No direct benefits for current operations. However, having these elements in place will ensure that mobile treatment can be rapidly deployed in the event that the FCFP loses capacity after a watershed fire.	N/A
	Develop a detailed implementation plan for mobile treatment. At a minimum, the plan should include provisions for a staging location, power supply, raw water intake, treated water discharge to the distribution system, disinfection, and residuals handling.		N/A
	Coordinate approvals for mobile treatment with CDPHE.		N/A
Mobile Dewatering	Establish an annual standby contract with a mobile dewatering unit supplier.	No direct benefits for current operations. However, having this in place will streamline deployment of mobile solids dewatering if needed. Mobile dewatering may also be required in the event that mobile water treatment is needed after a watershed fire (see above).	Unknown
Testing Equipment	Purchase an online or bench-top unit for measuring zeta potential.	Zeta provides a rapid and reliable method of determining particle charge. This can be used during jar testing to determine the optimal coagulant and polymer doses to use under changing raw water quality conditions and to develop a zeta profile through the treatment process which can be used to readily diagnose process upsets.	$40,000-$60,000
Filter Improvements	Replace the clay underdrains with plastic underdrain blocks.	Allows the gravel media layers overlying the underdrains to be eliminated and additional filter media to be utilized, thereby improving filter performance.	$350,000
	Replace media in all filters, with first priority given to the oldest filters.	Improves filter performance and increases run time between wash cycles.	$500
	Eliminate filter surface wash system and replace with an air scour system.	Improves filter washing, resulting in cleaner filters at the end wash cycles which allows for longer run times between wash cycles. Reduces the amount of water used during filter washing, thereby increasing plant net capacity.	$250

Table 8-2. Water Supply Infrastructure Improvement Project Recommendations, Continued.

Project/ Action Item	Specific Recommendations	Operational Benefits	Estimated Cost
Mid-size/range Improvements			
Intake Hydrocyclone	Evaluate addition of a hydrocyclone at the Fish Creek intake.	Removing sand and grit before entering the intake pipeline to the plant will reduce the solids loading on the pre-sedimentation pond and downstream treatment challenges.	TBD
Cationic Polymer Feed	Add cationic (coagulant aid) polymer feed to the raw water intake upstream of the pre-sedimentation basin.	Provides flexibility to improve the performance of the pre-sedimentation basin during high turbidity events so as to prevent excessive solids from carrying over into the downstream treatment processes.	$50,000-$150,000
Non-ionic Polymer Feed	Add non-ionic (filter aid) polymer feeds to the flocculation basins.	Provides flexibility to improve sedimentation basin performance by adding long chain polymers to produce larger, more settleable flocs.	$50,000-$150,000
Bulk Alum Tanks	Replace dry feed alum system with bulk alum storage tanks and size metering pumps to feed a wider range of doses than the current system.	Simplifies O&M requirements compared to the dry feed system (no manual unloading of bags). Provides a more reliable and predictable dosing solution. Allows operators to manually adjust coagulant dose in real time when water quality changes. Provides the ability to switch to a different coagulant in the future.	$2000,000-$500,000
Large Scale, Long-Term Improvements			
New Pre-treatment Options			
Pre-sedimentation	Convert the existing settling ponds to pre-sedimentation basins. In order to return the flow to the head of the plant, the recycle pumps and pipeline would need to be replaced with a larger capacity system to account for returning up to the full plant treatment capacity. This approach would also require implementing a system for discharging treatment process residuals to the sewer.	Provides an additional 4 hours of pre-sedimentation time to remove solids from raw water. Moves all solids handling processes off-site (to the waste water treatment facility).	$100,000-$300,000
Pre-oxidation	Add a raw water pre-oxidant system. Options include chlorine, sodium permanganate, chlorine dioxide, or ozone.	Improve metals and/or organics removal and oxidation of taste and odor compounds (depending on the pre-oxidant).	$100,000 – $ 1.5 M (highly dependent on pre-oxidant)
Roughing Filters	Install roughing filters upstream of the pre-sedimentation basin.	Removes large particles and debris upstream of the pre-sedimentation basin. Helps mitigate solids carryover into the downstream treatment processes.	$1 M
High Rate Clarification	Implement high-rate clarification (i.e., ballasted flocculation). The process could be upstream of the flocculation basins or could be the selected pre-treatment process included as part of a plant expansion project.	Capable of handling high (and variable) solids loading from raw water in a relatively small footprint. Would reduce stress on the existing flocculation and sedimentation processes during high turbidity events.	$3-5 M
New Post-Filtration Options			
Membrane Filtration	Install low pressure membranes downstream of the existing filters, prior to sending water to the clearwell.	Provides additional particle removal barrier. Will also provide a pathogen barrier for Cryptosporidum and Giardia.	$6-10 M
GAC Adsorption	Implement GAC adsorbers downstream of the existing filters, prior to sending water to the clearwell.	Provides additional TOC removal prior to free chlorine disinfection, to control DBP formation. Could also support maintaining chlorine residual throughout the distribution system.	$4-8 M
Treatment Capacity Expansion			
FCFP Expansion	Expand the capacity of the FCFP by adding a new treatment train consisting of either traditional flocculation/sedimentation or high rate clarification, followed by granular media filtration. The new processes should be designed to treat 4.5 MGD under normal conditions but have the flexibility to treat up to 7.5 MGD in the event that the existing filter bays experience a significant loss in treatment capacity. Note that filter loading rates higher than 5 gpm/sq ft require pilot testing before implementation.	The plant will be built out to its ultimate planned capacity of 12 MGD. In the event that the existing treatment train loses capacity, the new treatment train will be able to match the facility's current capacity. The facility expansion should be designed with operational flexibility and process redundancy and resilience.	TBD
New Elk River Plant	Develop the Elk River Treatment Plant Master Plan to include considerations for treatment capacity, process options, costs, and schedule. Perform bench-top and pilot studies to determine the treatment design criteria.	Addition of a new facility that draws from an alternate water source will provide redundant capacity for the City and Districts to supply water to the system in the event of a Fish Creek watershed wildfire.	TBD

9 IMPLEMENTATION STRATEGY & ACTION PLAN

The Fish Creek (CWP)^2 built upon existing relationships between local, state, and federal partners to develop a cross-jurisdictional watershed protection plan for Steamboat Springs' water supply drainage that focuses on proactive management to preserve and enhance water quality. The involvement of all parties was critical to this first step toward mitigating wildfire hazards within Steamboat Springs' water supply system. However, without continued collaboration between the City, District, Routt County, CSFS, RNF, YVSC, and other key partners, there is the risk that this planning effort will become a "shelf document" that does not ultimately provide the value of protecting the water supply and critical infrastructure.

Successful, sustainable collaboration requires commitment and leadership. One of the outcomes of the 2019 inaugural Routt County Wildfire Hazard Mitigation Planning Roundtable and Conference is the establishment of the Routt County Wildfire Council. It is suggested that Fish Creek (CWP)^2 implementation become a priority for the newly established council, with the City's Water Resource Manager and the District's General Manager as leads to facilitate the implementation process and monitor and evaluate outcomes. The fundamental concept is to maintain the momentum created by this planning process in order to facilitate movement into the implementation phase. Ideally, with support from the City, District, and project partners, the Wildfire Council will ultimately continue the efforts of the Core Team and guide the decision making process in the future.

The outcome of the Fish Creek Basin (CWP)^2 will be defined by the ability of the City and District, to successfully work with local, county, state, and federal partners to implement plan recommendations. Both the fuels management and sediment/ hydrologic control project opportunities described in Section 7 will rely heavily on partnerships with land/ resource managers, along with private landowners, and their ability/ willingness to implement plan recommendations. The identified education/ outreach and continued collaboration project opportunities described in Section 7 will rely on partnerships with a broad range of stakeholders. The only set of recommendations for which implementation is directly within City and District jurisdiction are the water supply system infrastructure/ operational improvements; these recommendations described in Section 8 should be considered very high priority, including the development of water supply redundancy that is currently underway.

Decisions makers with the City and District need to evaluate the level of risk in the long term to their water supply, to determine capital investments in improvements to FCFP and the development of water supply redundancy. While much can be done to address and reduce the risk to Steamboat Springs' water supply watershed, wildfire and postfire hydrologic impacts will remain a threat in the Fish Creek basin even if all feasible recommended fuel management treatments are implemented. Unfortunately, generally speaking, some of the areas with the highest hazard risk, are the least operable from both effectiveness and access perspectives. It is up to the decision makers to determine what level of residual risk is acceptable, and balance that with the costs of capital investments in the water treatment system and developing water supply redundancy. Based on the results of the wildfire risk assessment, implementing water treatment recommendations and/or developing alternative water supplies appears to be warranted.

Tables 9-1 and 9-2 summarize the implementation strategy and action plan and prioritize measures to implement within the watershed before, during, and after a wildfire event to protect the critical drinking water-supply infrastructure and watershed health, along with recommended actions/ improvements to prepare FCFP to respond to postfire hydrologic and water quality impacts. Actions to be taken before a fire occurs are shown in Table 9-1; Table 9-2 shows the actions recommended during and after wildfire occurrence.

Table 9-1. Implementation Strategy and Action Plan Recommendations – Before a Fire Occurs

Timing	Project/ Action Item	Description	Benefit
Before a fire occurs			
Immediate action can be taken			
	Water Supply System Improvements	Complete near-term action items	FCFP better equipped to address postfire water quality conditions
		Plan for mid-size/range improvements	FCFP better equipped to address postfire water quality conditions
		Evaluate and determine course of action for large-scale, long-range improvements	Water Supply Redundancy
	Establish Routt County Fire Council	Continue to collaborate with key stakeholders to support integrated wildfire preparedness planning, partner on mitigation projects, and coordinate outreach efforts.	Routt County Wildfire Council can serve as the integration point to carry (CWP)[2] recommendations forward, with the City's Water Resource Mgr. and District's GM representing the watershed/ supply.
	Fish Creek Basin WUI Designation	Secure WUI designation for Fish Creek basin if required for HRFA eligibility	HFRA eligibility to streamline permitting
	Permitting Collaboration	Identify permitting requirements and HRFA opportunities for projects in RNF	First step in accomplishing projects in RNF; grant funding eligibility
	Funding Program Investigation	Investigate key funding programs for preemptive watershed wildfire protection and postfire watershed restoration and connect with program liaisons to identify requirements, deadlines, etc. Work with partners to ensure eligibility requirements for grant programs are met before they are needed. Plan for need to secure rehabilitation & restoration funding.	Funding for preemptive mitigation projects; Connections established before emergency; Prepared to "hit the ground running" if a fire occurs
	Informational Campaign	Place informational signs at trails and campgrounds and in the neighborhood	Reduce the change of ignitions by increasing public awareness of the risks wildfire poses to water supply and encourage responsible behavior in the watershed.
		Watershed Walks - work with Yampatika to incorporate discussion of wildfire and drinking water impacts in their watershed walks.	
		Messaging on Web Map Interfaces (WMIs) and trail information webpages	Reach recreational users where they access information about trails/ conditions
		Work with Chamber of Commerce and area vendors to place informational material in hotel rooms/ resorts	Establish partnerships with vendors and reach visitors.
	Volunteer Days	Work with YVSC and key stakeholders to organize volunteer days in the watershed (could be used to facilitate treatments along trails).	Encourage a sense of ownership/ responsibility and accomplish cleanup projects
Require groundwork but should be able to initiate in 2020			
	Rain Gauge Installation	Partner with NWS to install a rain gauge in the upper watershed.	High resolution precipitation data in the basin will help to characterize watershed response to precipitation events pre-fire; this will help refine post-fire modelling efforts.
	Treatment Plant	Create defensible space using Zone concept.	Protect critical infrastructure from approaching fire
	Sanctuary Neighborhood	Evaluate and complete recommendations from Fish Creek Sanctuary CWPP.	Reduce risk of fires in and originating from community, FireWise certification
	Maintain/Enhance Riparian Corridors	Assess, monitor, and maintain wetlands and riparian corridors in the upper watershed.	Understand baseline conditions and be alerted to detrimental impacts that could reduce effectiveness of wetland/ riparian areas to buffer wildfire/ postfire impacts.
	Maintain/Enhance Upland Forests	Assess/ monitor upland forest condition; reconstruct basin fire history; monitor ASCC/ CSFS long-term study of high elevation spruce-fir forest management in a changing climate.	Understand baseline conditions and potential fire intervals to inform long-term management decisions.
Require Permitting, expect 1-2-year delay unless it can be linked to an existing project (i.e. Buffalo Pass Rd or Ski Resort*)			
	Steamboat Ski Resort*	Complete hazard tree removal components of Pioneer Ridge and Pony Express projects; evaluate/ complete Burgess Creek CWPP project recommendations within Ski Area.	Reduce risk in critical areas at basin's southern border.
	Road Treatments*	Evaluate/ maintain existing fuels treatments along roads; if needed, treat vegetation 100ft on each side of road; clear or chip dead and down fuels, thin trees to increase crown spacing. Prune remaining trees; mow herbaceous plants.	Minimize potential for ignitions to spread along road corridors.
	Campgrounds/ Trailheads	Evaluate/ maintain fuels reduction projects at campgrounds and trailheads. If needed, conduct pruning/ hazard tree removal	Minimize potential for ignitions to spread in areas of high use.
	Trail Treatments	Evaluate/ maintain existing treatments along trails. Where needed, prune trees on either side of trail (width determined by trail type); cut and move dead/ down trees away from trail.	Some trails can be used as fire breaks against an oncoming fire; less work to improve and strengthen fireline.

Table 9-2. Implementation Strategy and Action Plan Recommendations – During and After Fire Occurrence.

Timing	Project/ Action Item	Description	Benefit
During a fire event			
	Incident Command Liaison	The Incident Command (IC) liaison will convey information from the risk assessment to IC if a fire does occur in the watershed. Since Steamboat Springs Fire Rescue (SSFR) would either be IC (for fires within the fire protection district) or the point of contact for IC (first on scene and initial IC, then transfer command to partners for fires on public lands), SSFR is the most appropriate entity to serve as the liaison for the (CWP)².	This will help ensure that the identified areas of concern will be included at "values at risk." GIS developed for (CWP)² can also help inform response.
After a fire occurs			
Immediately following wildfire; dependent on actual postfire conditions and BAER assessment			
	BAER Support	If a wildfire occurs in Fish Creek basin, a BAER team will rapidly evaluate the burned area and prescribe emergency stabilization treatments, including mulching, reseeding, slash spreading, erosion barriers, grade stabilizers, check dams, debris/sediment basins, culvert upsizing, channel armoring, etc.	Postfire emergency assessment and watershed stabilization led by USFS
		City/ District can support BAER by having local suppliers of erosion control materials (i.e. wood straw, wood shred) and a memorandum of understanding in place to help with spreading of materials, and/or organizing volunteers. Data generated from this report and the recommendations below can be used to help expedite the response.	City/ District coordination with BAER team leaders; values at risk identified; BAER process can maintain treatments for up to 3 years following fire and help identify long-term recovery and restoration needs.
		BAER teams coordinate with NRCS Conservation Districts, other agencies, and counties that assist private landowners in preparing for postfire impacts to ensure assessments address downstream users. NRCS' EWP program funds stabilization on private lands.	NRCS supports postfire emergency assessment and stabilization on private lands; coordination with BAER expedites process.
	Treatment Plant Protection	Construct diversion channel or temporary berm for the northeast drainage on the backside of the building to protect FCFP buildings and ponds from flooding and debris.	Protect Treatment Plant buildings and ponds from flooding and debris
	Fish Creek Reservoir	Sediment Basins at the inflows to Fish Creek Reservoir.	Capture sediment and debris upstream of the reservoir.
	Long Lake Reservoir	Sediment Basins at the inflows to Long Lake Reservoir.	Capture sediment and debris upstream of the reservoir.
	Roadway Crossing Improvements	Roadway Crossing Improvements along 310 at the 2 tributaries to Long Lake Reservoir and 2 tributaries to Fish Creek Reservoir.	Maintain access to reservoirs.
	Sediment basins at locations with good geometries	Locations with good geometries for sediment basins installation were identified: on Fish Creek, downstream of Long Lake; North Fork Fish Creek, and Unnamed Tributary to North Fish Creek.	Depending on actual location of a fire within the watershed, installing control structures in these locations could capture some sediment/ debris before it reaches the FCFP intake.
	Fish Creek Bridge	Work with Routt County OEM to monitor flood effects at bridge.	Pedestrian safety and large debris that can cause issues downstream

10 MONITORING AND EVALUATION

The Implementation Strategy and Action Plan identifies and prioritizes actions to implement within the basin before, during, and after a wildfire to protect Steamboat Springs' water supply. This section describes how the community can accomplish, and document progress toward achieving, the following goals of the $(CWP)^2$:

- A more wildfire resistant landscape in the watershed;
  - Recommendations include evaluating/ maintaining/ enhancing: natural features that can serve to mitigate wildfire and postfire impacts, upland forest condition and emerging silviculture strategies, existing fuels reduction projects along high use corridors (i.e. roads and trails) and recreational areas (trailheads and campgrounds), as well as accomplishing fuels treatments identified in previous CWPPs (Fish Creek Sanctuary and Burgess Creek) that can buffer the basin from fires originating in the community.
- Timely and effective implementation of postfire hydrologic/ sediment controls in the watershed if a damaging fire does occur;
  - Recommendations are focused around supporting the USFS led BAER process, which provides emergency assessment and stabilization for burned National Forest System lands. While the majority of recommendations are for actions that would be taken after a wildfire (hence, are dependent on actual fire location/ conditions), there are actions that can be taken before a fire to support BAER efforts (e.g. rain gauge installation, sourcing erosion control materials) and prepare for long term recovery/ restoration.
- Community and guests that are educated about where their drinking water comes from and the threat of wildfire to their water supply, and are responsible recreational users of watershed;
  - Recommendations to inform and engage the Steamboat Springs community and its guest are centered around a mounting a public relations campaign (in collaboration with partners) that will reach recreational users of Fish Creek Basin and around organizing volunteer days to accomplish projects and encourage a culture of stewardship in the watershed.
- Coordinated preemptive mitigation (including outreach), wildfire response, postfire emergency stabilization, and watershed recovery and restoration;
  - Recommendations regarding coordination/ collaboration are included to facilitate and prioritize working together with partners to achieve the goals of the $(CWP)^2$. Coordination and collaboration are foundational to accomplishing preemptive mitigation and outreach projects, and critical for ensuring a timely and effective wildfire and postfire response.
- Water supply system resiliency.
  - Recommendations to improve water supply system infrastructure/ operations are the only set that do not rely on collaboration with partners. Moreover, these directly support Steamboat Springs City Council's goal to "identify and implement strategies to promote water supply resiliency," and should be considered very high priority. Actions have been prioritized by what can be accomplished in the near, mid, and long-term and include supporting the development of water supply redundancy that is currently underway.

The watershed risk assessment and identification of project opportunities relied heavily on the involvement of the Core Team, and this will also be critical for moving the identified projects and actions forward. The establishment of the Routt County Wildfire Council during the course of the Fish Creek $(CWP)^2$ development provides an opportunity to integrate project recommendations into the larger Routt County planning effort while maintaining vital partnerships. With the City's Water Resource Manager and the District's General Manager as leads to facilitate the implementation process, the Routt County Wildfire Council should become the new "home" for the Fish Creek $(CWP)^2$. This will allow for alignment with concurrent efforts and avoid creating new layers of management and responsibility. For example, Routt County is planning to update its CWPP with guidance from the Wildfire Council; this effort can be leveraged to make progress toward evaluating/ accomplishing Fish Creek Sanctuary and Burgess Creek CWPP projects that can buffer the basin's southern border from wildfire.

It is anticipated that that the Routt County Wildfire Council will require support during its initial development; and, the City and District should dedicate resources towards these early efforts to ensure the Council comes to fruition and that $(CWP)^2$ recommendations are championed. Education and outreach projects should be initiated right away to lay the foundation for both collaboration towards accomplishing, and public acceptance of, fuels management activities on private land and/or previously permitted projects can be achieved more quickly (i.e., FCFP, Sanctuary Neighborhood, Ski Resort), Accomplishing the permitting and funding investigations will be important for facilitating the next steps of actual project implementation, particularly for fuels mitigation projects within RNF. While working with the USFS to understand existing RNF roads and trails projects can identify if/ how they may be leveraged to provide additional wildfire protection in the watershed.

Evaluation should consider progress made toward the overall goals of: wildfire resistant landscape, postfire preparedness, educated community/ guests, coordinated mitigation, and water supply system resiliency. What that progress looks like will depend on the level of complexity, capacity of project lead, number of partners, etc., for a specific project. Updates on progress made towards achieving each goal should be provided on at Routt County Wildfire Council meetings on least an annual basis. For each project opportunity, the lead organization should provide information on what actions have taken place, or (for more complex projects with multiple partners) more general ideas on how it will be implemented. Regular updates will allow for the flexibility consider new/ changing resources, funding opportunities, local champions, and community priorities. Progress updates should be tracked by the City's Water Resource Manager and District's General Manager and summarized in an annual report for the Steamboat Springs City Council and MWW Board.

A comprehensive update of the Fish Creek (CWP)2 should occur at least every ten years and include a robust community and stakeholder engagement process, along with an evaluation/ update of each of the major components. The City and District should begin to evaluate this need in 2028 and incorporate suggestions for needed changes from the Routt County Wildfire Council and other stakeholders/ community members. For the ten-year update, the City and District should also work with the CWCB to understand current State priorities, Colorado Water Plan initiatives, and available funding sources and requirements. Based on direction from these groups, recommendations for updating the $(CWP)^2$ should be made to City Council, MWW Board, and the Routt County Wildfire Council, with the City to coordinate identifying partners for matching funds and submitting grant applications. A comprehensive plan update may be warranted in the interim due to extenuating circumstances such as a wildfire. severe pest infestation, prolonged drought, or other event that dramatically alters conditions in the watershed and/or provides new funding resources for mitigation, emergency stabilization, and/or long-term recovery and restoration.

Finally, it will be important to share project successes and outcomes with the greater community. The City of Steamboat Springs should lead communication of updates on the plan's implementation with stakeholders and the public over time through means such as: annual report provided to City Council and MWW Board and shared with stakeholders; presentations at community events and to boards of partner organizations upon request; information posted on the City's website; and updates shared through traditional and social media.

REFERENCES

Andrews, P.L., Bevins C.D., and Seli, R.C., 2008. "BehavePlus Fire Modeling System, Version 4.0, User's Guide," *General Technical Report RMRS-GTR-213WWW*, US Forest Service, Washington, DC.

Bradshaw, L. and E. McCormick, 2000. "*FireFamily Plus User's Guide, VERSION 2.0*, General Technical Report," *RMRS-GTR-67WWW*, US Forest Service, Rocky Mountain Research Station, Ogden, UT.

Cannon, S.H., 2006. "An Inter-Agency Collaboration for Developing Decision Tools: How the U.S. Geological Survey Works with the National Weather Service to Issue Warnings for Postfire Flash Floods and Debris Flows," prepared by the US Geological Survey, Reston, VA.

Cannon, S.H., Gartner, J.E., Rupert, M.G., Michael, J.A., Rea, A.H., and Parrett C., 2010. "Predicting the probability and volume of post-wildfire debris flows in the intermountain western United States," *Geological Society of America Bulletin* 122, 127–144.

Finney, M., 2006. "An Overview of FlamMap Fire Modeling Capabilities," *Fuels Management—How to Measure Success: Conference Proceedings*, RMRS-P-41, Portland, OR, March 28–30, pp. 213–220.

Gartner, J.E., Cannon, S.H., Santi, P.M., and DeWolfe, V..G, 2008. Empirical models to predict the volumes of debris flows generated by recently burned basins in the western U.S. *Geomorphology* 96, 339–354.

Gartner, J.E., Cannon, SH, and Santi, PM, 2014. "Empirical models for predicting volumes of sediment deposited by debris flows and sediment-laden floods in the transverse ranges of southern California," *Engineering Geology* 176, 45–56.

Hohner, A., Webster, J., Cawely, K., Rosario-Ortiz, F., and Becker, W., 2018, "Wildfire Impacts on Drinking Water Treatment Process Performance - Development of Evaluation Protocols and Management Practices ," *Water Research Foundation – Project Number 4590*, Water Research Foundation, Denver, CO.

Keeley, J.E., 2009. "Fire intensity, Fire Severity, and Burn Severity: A Brief Review and Suggested Usage," *International Journal of Wildland Fire*, Vol. 18, pp. 116–126

Meyer, D.F. and D.L. Berger, 1992. "Flood and Related Debris Flow Hazards in the Genoa Quadrangle, West-Central Nevada," *Open File Report 1992-02*, Nevada Bureau of Mines and Geology, Reno, NV.

Montgomery and Buffington, 1997. "Channel Reach Morphology in Mountain Basins," *Geological Society of America Bulletin*, Vol. 109, pp. 596-611.

Murphy, S.H., Writer, J.H., McCleskey, R.B., and Martin, D.A., 2015. "The Role of Precipitation Type, Intensity, and Spatial Distribution in Source Water Quality after Wildfire," *Environmental Research Letters*, Vol. 10, No. 8.

Napper, C., 2006. *Burned Area Emergency Response (BAER) Treatments Catalog,* Watershed, Soil, Air Management 0625 1801—SDTDC, US Forest Service, San Dimas Technology & Development Center, USDA Forest Service, San Dimas, CA.

Parrett, C., 1987. "Fire-Related Debris Flows in the Beaver Creek Drainage, Lewis and Clark County, Montana," *US Geological Survey Water-Supply Paper 2330*, US Geological Survey, Reston, VA.

RESPEC and Anchor Point, 2017. *Buffalo Municipal Watershed Wildfire Hazard Mitigation Assessment*, prepared by RESPEC, Rapid City, SD. and Anchor Point Group, Inc., Boulder, CO, for the Wyoming Water Development Commission.

RESPEC and Anchor Point, 2017. *Cheyenne Municipal Watershed Wildfire Hazard Mitigation Assessment*, prepared by RESPEC, Rapid City, SD. and Anchor Point Group, Inc., Boulder, CO, for the Wyoming Water Development Commission.

Rust, A.J., Hogue, T.S., Saxe, S., and McCray, J., 2018 "Post-fire water-quality response in the western United States," *International Journal of Wildland Fire*, https://doi.org/10.1071/WF17115.

Scott, J.H. and R. Burgan, 2005. *Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model*, General Technical Report, RMRS-GTR-153, US Forest Service, Rocky Mountain Research Station, USDA Forest Service, Fort Collins, CO.

Smith, H.G., Sheridan, G.J., Lane, P.N.J., Nyman, P., and Haydon, S., 2011. "Wildfire effects on water quality in forest catchments: A review with implications for water supply'" *Journal of Hydrology, 396, 170–192.*

Staley D.M., Negri, J.A., Kean, J.W., Laber, J.L., Tillery, A.C., and Youberg, A.M., 2016. "Updated logistic regression equations for the calculation of post-fire debris-flow likelihood in the western United States," *US Geological Survey Open-File Report 2016–1106*.

Staley D.M., Tillery, A.C., Kean, J.W., McGuire, L.A., Pauling, H.E., Rengers, F.K., and Smith, J.B., 2018. "Estimating post-fire debris-flow hazards prior to wildfire using a statistical analysis of historical distributions of fire severity from remote sensing data," *International Journal of Wildland Fire*, 27, 595–608.

Tillery, A.C. and J.R. Haas, 2016. "Potential post-wildfire debris-flow hazards –A pre-wildfire evaluation for the Jemez Mountains, north-central New Mexico," *US Geological Survey Scientific Investigations Report 2016–5101*.

US Geological Survey and USDA Natural Resources Conservation Service, 2013. *Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD), Chapter 3 of Section A, Federal Standards, Book 11, Collection and Delineation of Spatial Data, Techniques and Methods 11-A3, Fourth Edition*, US Geological Survey, Reston, VA, and USDA Natural Resources Conservation Service, Reston, VA.

Van Wagner, C.E. 1977. "Conditions for the Start and Spread of a Crown Fire," *Canadian Journal of Forest Research*, Vol. 7, No. 1, pp. 23–24.

Wildland Fire Leadership Council, 2016. "LANDFIRE," *landfire.gov*, retrieved September 2018, from *http://www.landfire.gov/index.php*

APPENDIX LIST

The following electronic datasets are provided as appendices to the Fish Creek (CWP)^2:

- **Appendix A: Digital Library**
  - The digital library contains all of the reports and planning documents compiled for the review of background information and listed in Section 3.
  - The digital library includes additional reference material on postfire impacts, including:
    - BAER process summaries and guidance documents;
    - The postfire water quality impacts/ treatment literature review and summary;
    - Water chemistry impact predictions, literature review scaling factors, and MWW October 2018 sampling results.

- **Appendix B: Geodatabase & KMZ Package**
  - Geospatial datasets generated for the Fish Creek (CWP)^2 and spatial background data that pertain to the study area were compiled and an ArcGIS geodatabase format. Geospatial layers include datasets related to hydrology, geology, soils, topography, fuels, land use, and land management, as well as all spatial data generated for the Watershed Risk Assessment.
  - Additionally, all maps contained in this report were projected in Google Earth and exported as a KMZ package. The KMZ package can be viewed in Google Earth without the need for specialized GIS software/ licenses.

- **Appendix C: Modeling Files**
  - Modeling files include tabular files of USGS debris flow and HEC-HMS model input datasets , and results, and the debris flow model sensitivity analysis and composite hazard ranking.

- **Appendix D: Meeting Materials**
  - All meeting materials including presentations, maps, and sign-in sheets, along with the public outreach brochure are included to support future outreach efforts.

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