2022 Cameron Peak Fire Recovery Work Plan – Aerial Mulching & Point Mitigation

Submitted in Partnership with:

City of Greeley Colorado

City of Fort Collins

City of Loveland

Larimer County

Contents

Page No.

List of Appendices

List of Figures

Page No.

List of Tables

Page No.

Introduction

This work plan relies heavily on geospatial data to convey mitigation needs resulting from the Cameron Peak Fire. An online map with relevant layers has been generated to support this report. It can be accessed and viewed using the following link: 2022 Cameron Peak Fire Work Plan Map Series

Cameron Peak Fire

During the summer and fall of 2020, the Cameron Peak Fire burned approximately 210,000 acres of alpine forest in the Poudre River and Big Thompson watersheds (Figure 1). Exigent recovery for community needs, such as utilities, debris removal, and initial stabilization and protection, have dominated the recovery efforts during 2021 and have largely been addressed. This report focuses on a more distributed approach which leverages small improvements used in upper watershed at a variety of sites.

Wildfires affect almost all runoff processes within a watershed including infiltration, evapotranspiration, and landscape roughness, generally resulting in more rapid runoff and larger runoff volumes. This increase in runoff volumes and velocities substantially increases sediment yields (USDA, 2016). Typically, a fire-affected watershed requires 10 years to recover hydrologically from the wildfire. Because these effects are most pronounced in the first few years of watershed recovery, emergency mitigation efforts are essential to protect life, property, and valuable resources from debris flows and debris floods (Robichaud et. al., 2010).

The bulk of the Cameron Peak Fire burned on National Forest System lands (83%). Private property is typically located along the Poudre River at the outlet of burnt tributary watersheds. Because initial Federal funding efforts for mitigation were limited to private property, the implementation was focused on the downstream portions of watersheds, typically well downstream of where debris flows and floods initiate. For example, the Black Hollow debris flow, which occurred on 7/20/21, was initiated by hillslope erosion within National Forest System lands in the upper watersheds rather than slope failures (CGS, 2021). Eroded material cascaded downstream until reaching the Poudre River, killing four people and damaging adjacent infrastructure, including private property, private homes, and Colorado State Highway 14. No traditional point mitigation on downstream private property can protect these assets once the debris flow is initiated in the upper watershed.

The 2022 Work Plan utilizes two different mitigation approaches, area treatments and point mitigation, to maximize mitigation potential and watershed resiliency to high-intensity storm events. Area treatments within this report and effort will be focused on aerial wood mulch applications. Areas of high burn severity and moderate slopes provide the largest mitigation potential for aerial mulching and are the focus of this effort. Point mitigation is designed to be implemented at discrete locations along a stream or within a watershed. It is most effective when implemented in a distributed approach across small tributaries higher in contributing watersheds. The ability to implement mitigation on National Forest System lands will allow for these types of approaches to be implemented more consistently and in combination. Pairing these two mitigation strategies is likely to lead to additive benefits and improved outcomes.

Post-Fire Stream & Water Quality Impacts

The primarily objective of post-fire recovery is to reduce flood risk to life, property, and other valuable assets at risk (VAR) during the 10-year period following the Cameron Peak Fire. VARs include emergency access roads, private structures, and corresponding private utilities or infrastructure. While protection against watershed disturbances on private property can reduce the risk and impacts, area treatment and distributed point mitigation features in the upper tributary channels, mostly on National Forest System lands, will have a larger impact. This is particularly true when mitigating against debris flows initiated by hillslope erosion. These events generally occur within 2-3 years post-fire and can initiate during as little as a 2-year recurrence interval storm event (Parise & Cannon, 2011). Because these types

of debris flows initiate across an entire watershed, the approach outlined in this Work Plan is the most applicable mitigation tactic. Roadway infrastructure is the most vulnerable and proximal infrastructure being addressed with this Work Plan and mitigation effort. However, mitigation activities will support all downstream users and VARs as described later in this report.

The main secondary objective is to mitigate water quality impacts resulting from the increased sediment influx from fire-affected basins tributary to the Poudre River and Big Thompson River. Several communities, including City of Fort Collins, City of Greeley, and City of Loveland, rely on the Poudre and Big Thompson Rivers for municipal water supply. Increased sediment inputs will likely result in additional intake shutoffs, increased treatment costs, and degraded water quality for communities across northern Colorado, as seen during 2021. During 2021, all water providers were unable to treat water from post-fire watersheds for prolonged periods due to degraded water quality. In addition, increases in sediment yield can harm local fish habitat and species (Short et al., 2015). Proposed point mitigation and aerial mulch would increase sediment and debris deposition and storage within the tributaries systems to reduce these impacts to downstream systems.

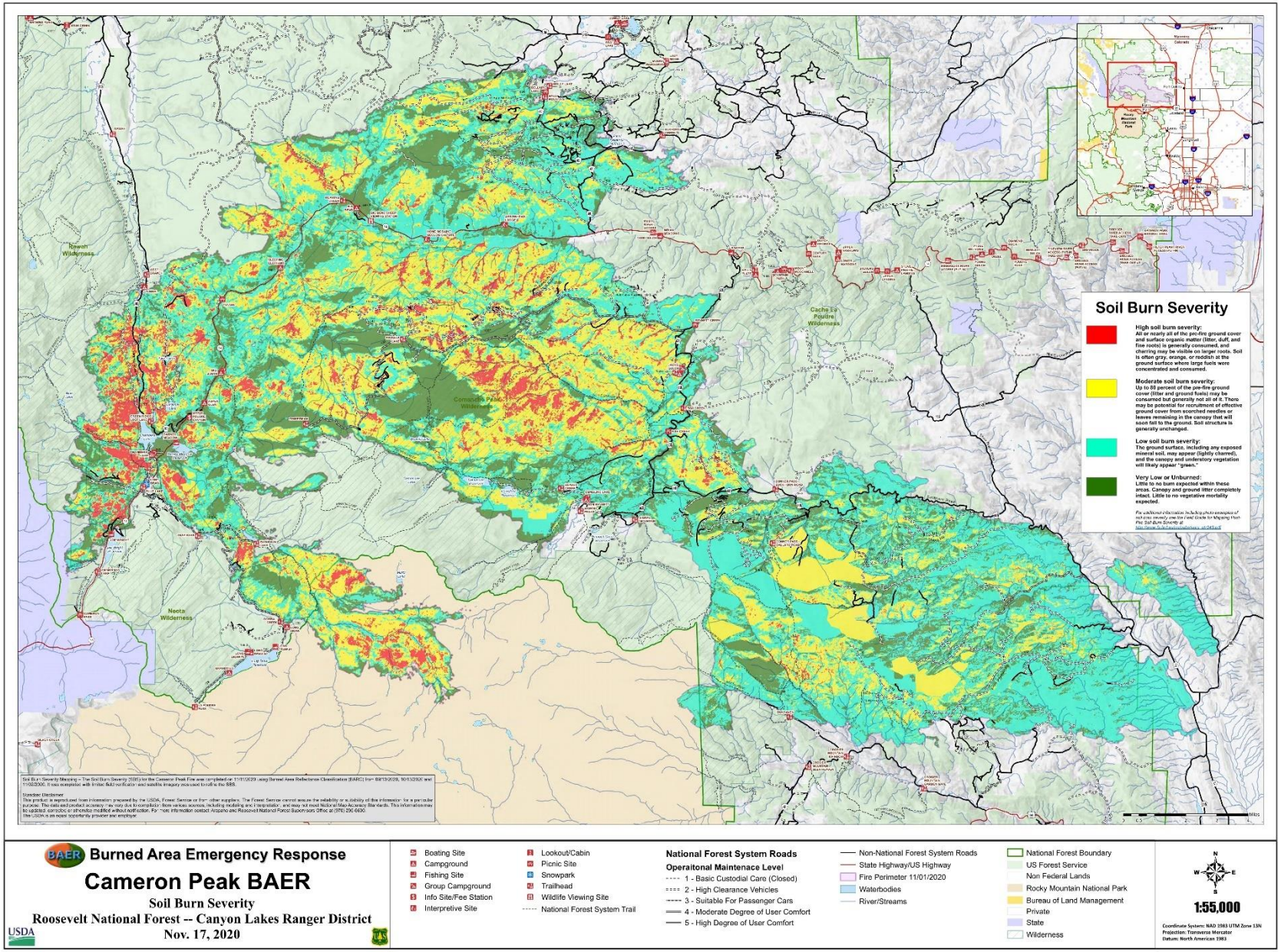


Figure 1: Cameron Peak Fire BEAR Soil Burn Severity (SBS) Map. The USFS has updated portions of the SBS mapping since the initial release. We will use the updated mapping in addition to recent aerial imagery and field verification efforts to prioritize watersheds for treatment.

The three main localized drivers of increased sediment yield to streams and large river systems post-fire are:

Hillslope Erosion to Streams – The removal of protective vegetation due to forest fires results in the destabilization of soils and soil structures (USDA, 2016). Hillslopes are stabilized and protected by a combination of forest canopies, intercepting rain drop impacts, root structures, holding soil particles in place, and forest litter, dampening sheet flow velocities. Destabilized soils are more vulnerable to increase runoff volumes caused by reduced evapotranspiration, raindrop interception, and infiltration. This increased vulnerability and runoff volume combine to create massive riling on burnt hillslopes which mobilizes sand, silt, and ash into adjacent river systems to be transported downstream. An example of hillslope erosion is shown in **Figure 2**.

Figure 2: Hillslope riling and erosion has caused local deposition in riparian environment in the Black Hollow watershed.

As mentioned previously, upland (hillslope) erosion is a common trigger for debris flows and in-channel erosion in post-fire watersheds immediately after a burn event (Parise & Cannon, 2011). Hillslope erosion of disturbed sediments creates a positive feedback loop that can build immensely powerful and destructive debris flows. During a rainfall event, fine-grained sediment is entrained in overland sheet flow. This sediment increases the density of the runoff, increasing its ability to entrain larger sediment and bulking the flows. In steep mountain watersheds, hillslope sheet flow consolidates in channels, initiating in-channel erosion and entrainment of debris. These processes continue until a debris flow threshold is crossed, at which the debris flow will continue downstream until a reduction in slope causes most of the material to fall out of suspension (Parise & Cannon, 2011). At this point, the debris flow will likely transition to a mudflow and traditional flood event that can still damage and negatively impact communities far downstream.

Stream Incision and Headcutting – As discussed previously, wildfires result in more discharge and peak flows in stream systems. Increases in flow is more pronounced in smaller systems where high-severity burn can dominate contributing areas. In addition, runoff generating events are more common after a fire causing channel heads, topographic inflection points that mark the transition from hillslope to channel flow, to migrate upstream through incision and downcutting. Downcutting can degrade and destroy valuable riparian and wetland habitat. Headcuts occur when hydraulic forces overcome surface resistance which is

Figure 3: An example of headcutting and resulting incision in a post-fire watershed.

influenced by sediment size and vegetation stabilization (Wohl, 2014). Since vegetation resistance is lost during a wildfire, headcuts are more likely to trigger and less likely to stabilize in a post-fire watershed. Headcuts result in significant sediment pulses transported downstream and may impact vulnerable habitat and infrastructure. An example of headcutting in a fire affected watershed can be seen in **Figure 3**.

Figure 4: Road damage resulting from increased runoff generate in a post-fire watershed during a 2021 summer storm event.

Roadway Drainage – The increase in runoff associated with post-fire hydrology is likely to overwhelm existing road drainage infrastructure leading to instability and increased sedimentation to creeks and riparian environments. This indirect impact is even more pronounced on National Forest System lands where lower standard roads on steeper slopes can contribute erosion into drainages. This funding will also focus on improving roads that are desired and planned for access into non-wilderness areas and stabilizing legacy roads that can increase sedimentation. An example of a washed-out road is depicted in **Figure 4**.

Impacts to Downstream Communities - These localized processes initiate significant flood events with debris and sediment that increases the destructive potential of these flows and degrades water quality for all downstream users and communities. City of Greeley could not use a total of 980 acre-feet of diverted degraded water from the Poudre River over a total of 40 days during 2021. City of Greeley Water Resources estimates $134 million dollars in additional costs associated with post-fire water quality impacts over the 10-year recovery if no mitigation is implemented in burned watersheds. Other impacted municipalities include City of Fort Collins, City of Loveland, Town of Windsor, and City of Laramie. Post-fire water quality degradation will likely lead to high maintenance costs, interrupted operations, lost revenue, higher treatment costs, and uncertainty in water resource supplies and needs.

While the most dramatic impacts to infrastructure occur directly downstream of small high burn tributary channels during high-intensity rain events, large-scale flood events are also influenced by post-burn hydrologic adjustments. In 2013, regional flooding along the Front Range was worsened along the Poudre River due to the recent High Park Fire (2012) and its impacts to the watershed. Large rain events in post-fire watersheds lead to increased peak flows which can overwhelm populations centers along the Front Range, leading to costly. Mitigation aimed at dampening the impacts and enhancing recovery are invaluable to the long-term management of burned forest and Front Range communities.

Cameron Peak Fire Mitigation Strategy

Watershed Prioritization

Small watersheds (Seventh-level or HUC14) were delineated by JW Associates with the goal of identifying and prioritizing hazards that would be targets of post-fire mitigation actions. These watersheds were analyzed and ranked based upon the following hazard components;

1. Soil Burn Severity (SBS)
2. Hillslope Erosion
3. Debris Flow
4. Road Composite

The Post-fire Composite Hazard Ranking combines the first four components by combining their rankings for each small watershed and then re-categorizing the results. The Post-fire Composite Hazard Ranking is being used as a basis for prioritizing and targeting small watersheds for post-fire treatments. The results of this calculation were ranked from 1 (lowest Post-fire Composite Hazard) to 5 (highest Post-fire Composite Hazard) to create the Post-fire Composite Hazard Ranking. Based upon this analysis, there are 34 small watersheds that received a Post-fire Composite Hazard Rank of Highest (**Figure 5**).

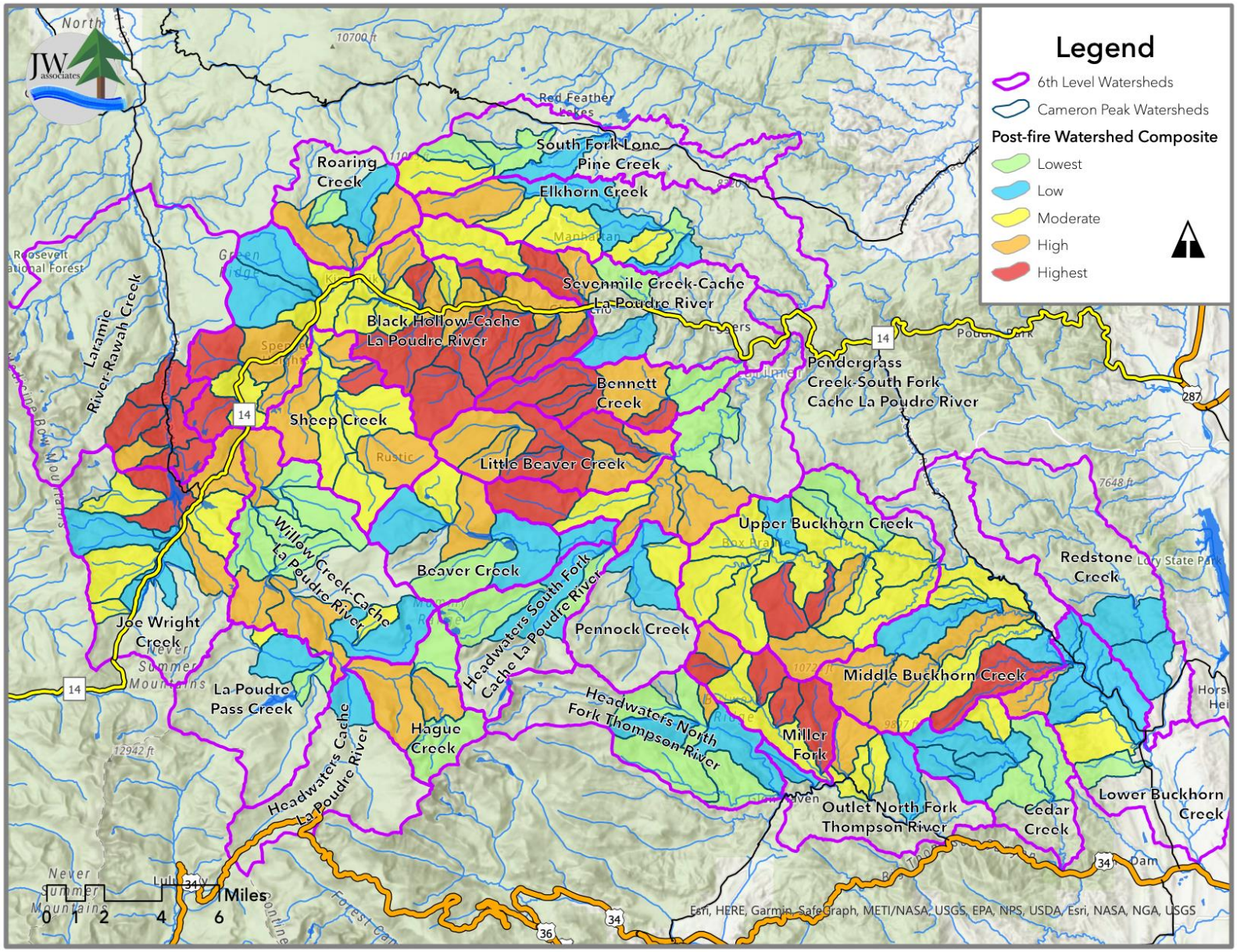


Figure 5: Cameron Peak Fire Post-fire Hazard Composite Ranking Map.

Area Treatments – Post-Fire Mulch Mitigation

Mulching is one of the most effective post-fire treatments (Robichaud et al. 2010 and Robichaud et al. 2013) and is primarily effective at reducing hillslope erosion. It has been shown to reduce rainfall splash and surface runoff, increase soil moisture and, consequently, improve revegetation. Wood mulch has been increasingly used in as a post-fire treatment in Colorado, including after the High Park Fire (2012). Unlike agricultural straw mulch, which can bring invasive weeds and can be moved off site by wind during dry weather, wood mulch can be made from trees burned in the fire, thereby minimizing the risk of introducing any noxious plants or foreign materials. It is also less prone to being blown off-site during windy periods. Wood mulch applied in burned areas following the High Park Fire survived the 2013 Flood, where 12 inches of rain fell in two days. Wood mulch also helps promote plant and tree recovery and can enhance soil protection for several years post-fire (Jonas et al. 2019).

Mulching, shown in **Figure 6**, also reduces rapid overland flow on moderate and high burn severity soils, thereby reducing post-fire peak flows from rainfall events. Mulch used in combination with other treatments in channels or further downstream, the strategy laid out in this Work Plan, can increase the effectiveness of the combined treatments. In general, mulch is recommended to be used when there is a large percentage of a watershed that contains moderate and/or high burn severity and there is a value at risk downstream.

Figure 6: Wood Mulch Application in High Park Burned Watershed

Initial estimates of the amount and locations for mulch treatments were completed for the Cameron Peak Fire burned area. These treatments are directed at minimizing the post-fire effects on downstream VARs and water suppliers downstream of the burned watersheds. The estimates were made using the following criteria;

1. Slopes between 20-60 percent were identified in the burned area.
2. Areas identified as moderate and high soil burn severity were delineated within those slopes.
3. Polygons were created from contiguous areas from steps 1 and 2 above to identify the potential mulching areas.

Polygons were accumulated within watersheds (HUC14) that were identified as high and highest post-fire hazard.

Post-Fire Point Mitigation

As mentioned previously, point mitigation is intended to be placed at a discrete location in a stream or watershed. The location is determined by upstream burn and watershed characteristics as well as equipment access. Typically, point mitigation is proposed at locations in which the contributing watershed has been identified during prioritization efforts and the impacts are expected to threaten VARs and degrade stream habitat and water quality. Additionally, point mitigation should be employed in areas that are at risk of encroachment from downstream stream instability that will migrate upstream and degrade stream habitat, threaten VARs, or degrade water quality with mass erosion.

The prioritization between individual sites included in this Work Plan will need to be completed once site evaluations are conducted and the scope of the total funding is in place. Because the limiting factor to

work is likely to be access, this will play a large role in the final selection of mitigation sites. Other factors to be included in the next phase of prioritization will be downstream VARs, upstream valuable habitat, stream vulnerability, and stream degradation.

While this Work Plan highlights areas with potentially appropriate access and need, it is important to understand that the mitigation proposed in this report will be altered to fit each site specifically based on the geomorphic controls, upstream fire-impact, available on-site material, stakeholder inputs, and access. The concepts and mitigation techniques described below have been applied to a wide range of post-fire environments and are designed to provide decadal stability during large thunderstorm events in post-fire watersheds. The intention is to use on-site and native materials when possible and to create subtle and hidden features that function during storm events while enhancing the natural recovery.

These concepts will likely go through several phases of adjustment to satisfy the needs of the US Forest Service and private property owners impacted. Adjustments will be made based on site visits with the project team to meet the design intent and limit the impact to alpine, riparian, and forest habitat. While the planning and prioritization of these projects will take place in 2022, it is also likely that construction efforts may extend in to 2023. However, because the impact of wildfire is most pronounced in the first few years of recovery, the goal will be to complete high priority areas as soon as possible.

Point Mitigation Concepts & Features

The conceptual design for each of the features described below can be found in **Appendix A** of the submittal package. Again, these designs are likely to alter with stakeholder input and site evaluations, but the processes, goals, and intentions will remain the same.

Armored Drainage Crossing – This feature is designed to convert an existing culvert crossing to an armored ford that will also act as stabilization features for the stream system. The lack of a culvert adds resiliency to the system while offering opportunities for upstream sediment storage. A large upstream and downstream apron of rock allows for flows to overtop the feature without causing total failure to the embankment. These structures rely on imported riprap and smaller rock to limit the disturbance and impacts. Fish passage will need to be examined at each site to limit impacts to aquatic species.

Large Wood Material (LWM) Stabilization - This feature is ideal for stream stabilization in smaller tributaries or ephemeral streams. Burnt wood material that remains structurally sound will be sourced on-site during clearing. This wood is pinned together and buried several feet into the channel to slightly above existing grade to facilitate deposition. The LWM will be ballasted with boulder material sourced on-site. An example of those installed in 2021 in series is shown in **Figure 7**.

Figure 7: LWM Stabilization installation constructed in the Fall of 2021 in the CLP watershed.

Rock Stabilization – These features are intended to stabilize larger, wider tributary creeks affected by post-burn impacts such as headcutting and incision. Typically, native rock is harvested during the excavation and construction of adjacent features, including LWM stabilization or Armor Drainage Crossings. The larger boulders, if available, are to be used for the apex rocks which are subjected to the bulk of the hydraulic forces, while 9- to 24-inch material is used in the wings and splash rock of the structure. The wings of the structure slope down towards the center, consolidating flows and mitigating channel widening. A complete rock stabilization structure can be seen in **Figure 8**.

Figure 8: Rock Stabilization downstream of a fire-impact watershed. Installed during 2021 mitigation efforts.

Log Jams – Jams will be installed far upstream of most project areas to create depositional opportunities while intercepting debris. These jams will be stabilized with large rock, buried into the banks, or anchored to other standing and stable trees. They are intended to provide a key log that will initiate and enhance wood recruitment at the location of installation. These features require time to fully develop but should provide long-term habitat and channel heterogeneity. **Figure 9** shows a Log Jam installation enhanced with a temporary wattle.

Riparian Revegetation – Recovery of riparian areas is vital to the recovery of water quality. Revegetation will increase sediment accumulation and storage in fluvial systems and will accelerate watershed recovery while improving water quality (Pollock et al., 2014). Primarily, this will be accomplished through native willow harvesting and staking. In wetland areas, willow wattles or willow fences will also be installed to reverse the effects to downcutting and incision.

Figure 9: A log jam installed and enhanced with a wattle during Fall 2021 mitigation.

Road Drainage Improvements – As mentioned previously, poorly maintained roadways can increase sedimentation inputs and erosion concerns in tributary streams. Removing abandoned roads and improving desired roads can limit their impact on water quality. Armored drainage crossings and roadside swales are a part of this work. However, the main concept to be deployed in this effort are water bars. This feature consolidates on road sheet flow and conveys it across the road down slope to an armored location to reduce riling and erosion.

Hillslope Wattles – Laying approved biodegradable wattles parallel to contours is an effective way to generate several cubic feet of deposition space on vulnerable hillslopes. This concept will be used in small areas where aerial mulching is impractical. It was deployed during the Fall of 2020 in the areas surrounding Chamber Lake with success (**Figure 10**).

Figure 10: Hillslope wattles creating significant deposition and storage on vulnerable hillslopes just upstream of Chambers Lake.

Mitigation Technique	Hillslope Erosion	Stream Incision	Road & Crossing Damage
Armored Drainage Crossing		X	X
LWM Stabilization		X	X
Rock Stabilization		X	X
Log Jams		X	X
Riparian Revegetation	X	X	X
Hillslope Wattles	X		X
Road Drainage Improvements	X	X	X

Table 1: A table showing the benefits of each mitigation strategy compared with the hazards in post-fire watersheds.

2021 Funding & Mitigation Projects

The mitigation strategy described previously was deployed during the initial mitigation efforts and activities that took place immediately after the Cameron Peak Fire. Initial funding for post-fire recovery was provided from an assortment of governments including local municipalities, Colorado Water Conservation Board (CWCB), and the Natural Resources Conservation Service (NRCS). This mitigation effort focused on aerial mulching and point-based mitigation to reduce and protect against the post-fire impact to water users and private properties within or downstream of the burn area. The goals of the aerial mulching and point migration funded and completed was to reduce hillslope erosion, enhance sediment deposition, and protect VARs from flood and debris damage. Approximate total funding for the aerial mulching is $14.5 million and was completed in 2021. The total funding for the point mitigation effort

is roughly $3 million to be completed in Spring 2022. Each watershed of focus during the 2021 Mitigation is outlined in the Online Map Series (2022 Cameron Peak Fire Work Plan Map Series).

2021 Aerial Mulching

A number of targeted watersheds were partly or fully treated with aerial wood mulch in 2021. A total of 5,805 acres in 10 priority watersheds were mulched in 2021 (**Table 2**). These treatments addressed some of the top priorities for watershed protection, but substantial watershed protection needs remain unaddressed. The Poudre River Watershed was the focus on 2021 Post-Fire Mitigation because the bulk of the burn was in this watershed, and there are more water supply users impacted within the Poudre River. However, the Big Thompson also had work completed as described below:

Table 2:Priority Watersheds Treated with Wood Mulch in 2021

Watershed	Acres
Peterson Lake	219
Barnes Meadow Reservoir	226
Crown Point Gulch	426
Mineral Gulch	460
Sheep Creek	699
Bennett Creek	848
Black Hollow	1,371
Roaring Creek	802
Miller Fork – Big Thompson	406
Black Creek – Big Thompson	348
Total	**5,805**

2021 Point Mitigation

Cache La Poudre River Watershed

The 2021point mitigation efforts were successful in repairing flood damage that occurred during the 2021 monsoon season. However, these projects have yet to be tested during large flow events. The projects have successfully enhanced deposition of baseflow sedimentation and rely on mitigation techniques that have proven successful in past EWP efforts including the 2018 Spring Creek Fire Recovery and the 2013 Front-Range Flood Recovery. Additional revegetation work is planned for all the project during the Spring of 2022 to further enhance the resilience of the structures and overall recovery of the riparian areas.

The point mitigation sites complete or funded during the 2021 mitigation effort are listed below with a brief description of the work. For more information, please request and refer to the Design Report and Deliverables package prepared for the NRCS at each site and subwatershed.

- **Dry Creek (Complete 2021)** – Structure protection (**Figure 11**) and stream stabilization features were installed on private property just north of CO14 at Dry Creek. Features include log jams, flood diversion barriers, channel grading, willow staking, and woody vegetation clearing.

Figure 11: Structure & Road Overtopping Protection at Dry Creek. The area will be stabilized with native vegetation Fall 2021.

Black Hollow (In Progress 2021 & 2022) – On July 20, 2021, a debris flow occurred in this watershed because of a high-intensity rain event. The resulting deposition and damage is shown in **Figure 12**. More than half of the 13 structures were destroyed and four people were killed during this event. Large-scale stabilization and protection efforts will be implemented in late Fall of 2021 and early Spring 2022. Efforts focus on mitigating the impact of the July 2021 event and facilitating conveyance of flood flows and sediment to the Poudre River. Features included in this stabilization effort are rock stabilization, LWM stabilization, grading, and riparian revegetation. Additionally, the lower portion of the Black Hollow channel realigned during the July 2021 event and cause adverse impacts to a structure upstream of the confluence with the Poudre River. Grading and diversion barriers were used to protect this structure.

Figure 12: Black Hollow Fan following the 7/20/21 debris flow caused by a summer thunderstorm on fire affected watershed.

- **UT3 (Complete 2021) -** Structure protection, stream stabilization, roadway access protection, and diversion features were installed on private property just south of CO14 near the Fish Hatchery. Features include LWM stabilization, flood diversion barriers, diversion channels, armored crossing, willow staking, and woody vegetation clearing.

- **Sheep Creek (Norman Fry Road) (Complete 2021) -** Structure protection, stream stabilization, roadway access protection, and diversion features were installed on private property just south of CO14 near Poudre Fire House #2. Features include LWM stabilization, flood diversion barriers, diversion channels, armored crossings (**Figure 13**), willow staking, road drainage improvements, and woody vegetation clearing.

Figure 13: An Armored Drainage Crossing completed at Sheep Creek.

- **MM87 (Complete 2021) –** A small drainage just west of Black Hollow and north of CO14 has had several mudflows this year that has blocked CO14 and threatened private property. Structure protection, stream stabilization, diversion channels, and diversion features were installed on private property. Features include rock stabilization, flood diversion barriers, and diversion channels.

- **Crown Point Gulch (Construction 2022) -** Structure protection, stream stabilization, roadway access protection, and diversion features will be installed on private property just south of CO14 and west of Rustic. Features include LWM stabilization, flood diversion barriers, diversion channels, armored drainage crossing, willow staking, road drainage improvements, and woody vegetation clearing.

- **Roaring Creek (Construction 2022) -** This large drainage is home to a community of private property adjacent to its confluence with the Poudre River. Structure protection, stream stabilization, diversion channels, and diversion features are to be installed on private property. Features will include rock stabilization, flood diversion barriers, bank stabilization, and diversion channels.

- **Boston Peak Creek (Construction 2022) –** On August 1, 2021, a debris flow occurred in this watershed because of a high-intensity rain event. No structures were destroyed. However, a

large amount of material was deposited on private property and adjacent to structures. Structure protection, stream stabilization, diversion channels, and diversion features are to be installed on private property. Features implemented will include LWM stabilization, flood diversion barriers, diversion channels, road drainage improvements, and riparian revegetation.

- **Little Beaver (Construction 2022) –** A historic structure owned by City of Greeley will be protected at this site just west of Pingree Park Road. Features include flood diversion barriers and diversion channels. Additionally, wetland rehabilitation was completed in 2021 with the Coalition for the Poudre River Watershed (CPRW) to valuable wetland habitat along Jacks Gulch, a tributary to Little Beaver.

- **Fish Creek (Construction 2022) -** A large drainage with two structures in need of protection, this watershed was severely burned. Structure protection, stream stabilization, and crossing improvements will be implemented on the site. Features include LWM stabilization, flood diversion barriers, and riparian revegetation. Additionally, hand-crew mitigation was completed with CPRW along ephemeral channels in 2021.

- **Peterson Lake Road (Construction 2022) –** Crossing improvements including a trash rack and road armoring are to be constructed in the Spring of 2022 to maintain access to Peterson Lake.

- **Mainstem Poudre (Construction 2022) –** During the spring of 2022, outreach and modeling will be used to determine additional structure protection that is required to protect from potential post-fire flooding on the Poudre River. Flood diversion barriers will be primarily used to achieve the required protection. This effort will include specific areas such as Spencer Heights, Poudre Park, and other larger community in the Poudre River Canyon.

Big Thompson Watershed

The Big Thompson portions of the Cameron Peak Fire are smaller, but more densely populated with county roads. Point mitigation efforts in 2021 have focused on county road improvements, specifically in Black Creek and Miller Fork. The Retreat is a community of private homeowners that resides on Black Creek and Miller Fork which are tributaries to the North Fork Big Thompson River. Both watersheds were severely burned from the Cameron Peak Wildfire and have since seen a lot of damage resulting from post-fire increases in runoff and sediment loads. During the first year of recovery efforts, Larimer County and the Big Thompson Watershed Coalition have funded work to achieve the following goals:

- Restore access to residents along Black Creek
- Culvert upsizing and road repairs along Buckhorn Creek and Buckhorn Rd.
- Replace three major culvert crossings with larger culverts for increased capacity and adding overtopping protection to prevent future failure
- Remove minor culvert crossings along Black Creek and replace them with armored drainage crossings
- Installing debris racks at strategic locations to help protect against debris jams inside the remaining culverts.
- Installing flood barrier bags and diversion berms to help protect properties from future events
- Installing sediment catchment areas

The constructed projects have primarily focused on repairing damaged roads, culverts, and crossing along county roads and private roads maintained by the Larimer County.

Aerial mulching has also been completed in portions of the watershed to mitigate runoff and improve water quality. The combination aerial mulching on hillslopes and point mitigation in the channel will allow for a more complete recovery effort. These two mitigation approaches will likely function with additive benefits enhancing the overall function and recovery. More mulching is proposed as a large part of the

mitigation efforts for 2022 and can be reviewed in *Cameron Peak Fire 2022 Mulch Treatment Areas & Priorities.*

Need, Quantities, and Costs By Subwatershed

Initial estimates of the amount and locations for mulch treatments were completed for the Cameron Peak Fire burned area by JW Associates in 2021. These values and prioritizations will be updated along with the updates to the Soil Burn Severity (SBS) data which are occurring now in collaboration with the U.S. Forest Service. The same criteria listed earlier was used to generate the proposed 2022 aerial mulching. These treatments are directed at minimizing the post-fire effects on downstream VARs and water suppliers downstream of the burned watersheds.

For the 2022 Point Mitigation Work Plan, areas within the Cameron Peak Fire were analyzed and conceptual designs were drafted based on experience in the area and desktop analysis. Support data sets included topographic information, soil burn severity, existing road data, and hydrology information developed by Colorado Water Conservation Board (CWCB) for the Cameron Peak Fire. The two largest hurdles for point mitigation practicality at any given site are the existing access to the location and the severity of the burn in the contributing watershed.

These areas will all need initial site investigations before a determination can be made on the exact point mitigation strategy, cost, and priority. Based on experiences in other Colorado Front Range fire mitigation, the need is likely more extensive in these areas then determinable from desktop analysis. Additionally, more sites will likely be added during investigations as needs are better characterized and prioritized in the field.

For this proposal, the areas of interest have been broken into four main regions within the Cache La Poudre and Big Thompson Watershed. These can be viewed using the 2022 Cameron Peak Fire Work Plan Map Series. These areas are each made up of several tributary watersheds that have experienced varying burn severities but are likely to need further rehabilitation and stabilization during the post-wildfire hydrologic recovery period.

Implementation Quantities & Costs

The supporting Online Map (2022 Cameron Peak Fire Work Plan Map Series) shows the exact locations of the area treatment polygons and point mitigation features, including log jams, LWM stabilization, rock stabilization, and armored drainage crossings. It also highlights areas for riparian revegetation and hillslope wattle installation. Road improvements were estimated using the total milage of existing Forest Service Roads assuming approximately a water bar installation every ¼ mile ($14,000/mi). While these are not broken down by specifically and likely won't until detail conversation with the Forest Service, estimates by region are shown in **Table 12.**

Costs used in the 2022 Work Plan were sourced from unit pricing approved during the construction phase of the 2021 Western Cameron Peak Fire EWP – City of Greeley project and the 2021 Aerial Mulching effort. Willow staking was assumed to be one stake approximately every 4 SY throughout the specified areas. Hillslope wattles were assumed to be installed at a rate of 1210 LF/acre and installations should be focused on lower portion of burnt hillslopes. Road Drainage Improvements were assumed to be $14,000 per mile of Forest Service Roads based on available GIS data. A large focus of the planning will be working with stakeholders to determine the exact condition of roadways as well as the desire to provide long-term maintenance on existing roads. The aerial mulching costs, $2,500/acre, were determined based on 2021 wood mulching operation and implementation costs.

Tables 3 through **10** provide both the quantities and costs of mulching and point mitigation in each region by subwatershed. The subwatersheds are color coded according to the prioritization rank and consistent with the Online Map Series and are:

- Lowest – Green
- Low – Blue
- Moderate – Yellow
- High – Orange
- Highest – Red

Northern CLP

The northern portion of the Cache La Poudre Watershed experienced large swaths of low and moderate burn areas with pockets of high severity burn. The major tributaries systems are Sevenmile Creek, Manhattan Creek, Washout Gulch, Swamp Creek, and Elkhorn Creek. Several subwatershed within each of these areas have been identified for mitigation. Proposed mulching locations and areas with a combination of point mitigation and aerial mulching are shown in **Table 3**. Point Mitigation features and proposed quantities by watershed are shown in **Table 4**.

Regional Values At Risk:

- **Roadways:** CO-14; CR-69; CR-68C; NF-225; NF-517.
- **Private Property:** Shambhala Mountain Center; Manhattan Community (13 structures); Elkhorn Creek Property Owners (11 structures).
- **Drinking Supplies:** City of Fort Collins, City of Greeley, Tri-Districts (North Weld, Eastern Larimer County, Fort Collins – Loveland Water District), Northern Water, Irrigation Companies, and Private Users.

Table 3: Northern CLP Region proposed aerial mulching acres in non-wilderness & wilderness areas by subwatershed, including percent burn area treatment, cost, and combination with Point Mitigation.

Northern CLP Region Watersheds	Total Mulch Non-Wilderness (acres)	Total Mulch Wilderness (acres)	Moderate & High Soil Burn Severity (acres)	Burned Area Treated (%)	Estimated Cost ($)	Point Mitigation in Combination?
Boston Peak Creek	567	0	1,012	56%	$1,417,500	Yes (2021)
Lower Upper BH - CLP	585	0	1,180	50%	$1,462,500	No
Dry Creek	235	0	481	49%	$587,500	Yes (2021)
Upper Sevenmile Creek	314	0	1,647	19%	$785,000	Yes
UT2 to BH - CLP	159	0	486	33%	$397,500	No
Totals	**1,860**	**0**	**4,806**	**39%**	**$4,577,500**	

Table 4: Proposed Point Mitigation Features in subwatersheds within the Northern Region of the CLP including cost and quantity. The unit prices reflect 2021 data.

Northern CLP Region Watersheds	Armored Crossing (EA)	LWM Stabilization (EA)	Rock Stabilization (EA)	Log Jams (EA)	Willow Staking (AC)	Hillslope Wattles (AC)	Total Cost by Subwatershed (No Road Improvements)
2021 Unit Prices	**$30,000**	**$3,112**	**$6,000**	**$1,200**	**$10,285**	**$5,445**	
Headwaters Elkhorn Creek	1 ($30,000)	2 ($6,224)	3 ($18,000)	5 ($6,000)	0 ($0)	0 ($0)	**$60,224**
Lower Manhattan Creek	0 ($0)	0 ($0)	3 ($18,000)	1 ($1,200)	4 ($41,140)	0 ($0)	**$60,340**
Lower Sevenmile Creek	5 ($150,000)	6 ($18,672)	5 ($30,000)	4 ($4,800)	4 ($41,140)	0 ($0)	**$244,612**
Swamp Creek	0 ($0)	0 ($0)	0 ($0)	0 ($0)	6 ($61,710)	0 ($0)	**$61,710**
Upper Elkhorn Creek	0 ($0)	3 ($9,336)	3 ($18,000)	1 ($1,200)	0 ($0)	5 ($27,225)	**$55,761**
Upper Sevenmile Creek	1 ($30,000)	1 ($3,112)	4 ($24,000)	3 ($3,600)	0 ($0)	0 ($0)	**$60,712**
UT5 to Elkhorn Creek	2 ($60,000)	0 ($0)	3 ($18,000)	1 ($1,200)	0 ($0)	0 ($0)	**$79,200**
Washout Gulch	0 ($0)	0 ($0)	0 ($0)	2 ($2,400)	0 ($0)	0 ($0)	**$2,400**
Totals & Feature Construction Costs	**9 ($270,000)**	**12 ($37,344)**	**21 ($126,000)**	**17 ($20,400)**	**14 ($141,550)**	**5 ($27,225)**	

Western CLP

The Cameron Peak Fire was initiated in the western portion of the Cache La Poudre Watershed. While this area of access in this region is smaller in size, it experienced large swaths of high severity burn primarily in the area surrounding Chambers Lake, including Sawmill Creek and Joe Wright Creek, the Laramie River Headwaters, Trapp Creek, and Peterson Lake.

Mulching is proposed along the Mainstem of the Poudre River, Joe Wright Creek, Tunnel Creek, Tributaries to Sheep Creek, and Twin Lakes (**Table 5**). No areas are conducive to the combination of point mitigation and aerial mulching due to the steep terrain, limited access points, and expansive wilderness areas. Several of the tributaries in the Laramie River Valley have been prioritized for point mitigation and rehabilitation using the access along Skyline Ditch and County Road 103 (**Table 6**).

Regional Values At Risk:

- **Roadways:** CO-14; Long Draw Rd.; NF-159.; CR-103;
- **Water Resource Infrastructure:** Skyline Ditch; Chambers Lake; Peterson Lake; Rawah and Lower Supply Ditch; Laramie-Poudre Tunnel
- **Drinking Supplies:** City of Fort Collins, City of Greeley, City of Laramie, Tri-Districts (North Weld, Eastern Larimer County, Fort Collins – Loveland Water District), Northern Water, Irrigation Companies, and Private Users.

Table 5: Western CLP Region proposed aerial mulching acres in non-wilderness & wilderness areas by subwatershed, including percent burn area treatment, cost, and combination with Point Mitigation.

Western CLP Region Watersheds	Total Mulch Non-Wilderness (acres)	Total Mulch Wilderness (acres)	Moderate & High Soil Burn Severity (acres)	Burned Area Treated (%)	Estimated Cost ($)	Point Mitigation in Combination?
Upper Upper BH - CLP	678	0	1,012	56%	$1,695,000	No
Twin Lakes	396	0	1,180	50%	$990,000	No
Tunnel Creek	501	0	481	49%	$1,252,500	No
Lower Joe Wright Creek	803	0	1,647	19%	$2,007,500	No
Headwaters BH - CLP	622	0	486	33%	$1,555,000	No
UT2 to Sheep Creek	0	847	1,175	47%	$2,117,500	No
Totals	**3,000**	**847**	**5,980**	**42%**	**$7,500,000** **$2,117,500**	

Table 6: Proposed Point Mitigation Features by subwatersheds within the Northern Region of the CLP including cost and quantity. The unit prices reflect 2021 data.

Western CLP Region Watersheds	Armored Crossing (EA)	LWM Stabilization (EA)	Rock Stabilization (EA)	Log Jams (EA)	Willow Staking (AC)	Hillslope Wattles (AC)	Total Cost by Subwatershed (No Road Improvements)
2021 Unit Prices	**$30,000**	**$3,112**	**$6,000**	**$1,200**	**$10,285**	**$5,445**	
Laramie Lake	0 ($0)	3 ($9,336)	0 ($0)	1 ($1,200)	0 ($0)	0 ($0)	**$10,536**
Lower Laramie River-Rawah Creek	0 ($0)	0 ($0)	2 ($12,000)	6 ($7,200)	0 ($0)	0 ($0)	**$19,200**
Lower Trap Creek	1 ($30,000)	0 ($0)	0 ($0)	0 ($0)	3 ($30,638)	0 ($0)	**$60,638**
Middle Joe Wright Creek	0 ($0)	0 ($0)	0 ($0)	0 ($0)	0 ($0)	20 ($108,900)	**$108,900**
Middle Laramie River-Rawah Creek	0 ($0)	12 ($37,344)	0 ($0)	5 ($6,000)	0 ($0)	0 ($0)	**$43,344**
Peterson Lake	0 ($0)	0 ($0)	0 ($0)	2 ($2,400)	1 ($10,285)	32 ($174,240)	**$186,925**
Sawmill Creek	0 ($0)	0 ($0)	0 ($0)	2 ($2,400)	0 ($0)	0 ($0)	**$2,400**
Two and One Half Creek	1 ($30,000)	2 ($6,224)	2 ($12,000)	1 ($1,200)	0 ($0)	0 ($0)	**$49,424**
Upper Laramie River-Rawah Creek	0 ($0)	0 ($0)	2 ($12,000)	2 ($2,400)	34 ($347,916)	0 ($0)	**$362,316**
UT1 to Laramie River-Rawah Creek	0 ($0)	2 ($6,224)	0 ($0)	1 ($1,200)	0 ($0)	0 ($0)	**$7,424**
Totals & Feature Construction Costs	**2 ($60,000)**	**19 ($59,128)**	**6 ($36,000)**	**20 ($24,000)**	**37 ($391,143)**	**52 ($283,140)**	

Southern CLP

This is the largest area of proposed mitigation within this request for funding. Tributary watersheds within US Forest Service lands include Fish Creek, Jacks Gulch, Little Beaver, Upper Sheep Creek, Bennet Creek, Dadd Gulch, and Black Hollow Creek. There are some private land areas on the eastern portion of this region including Ratville and Monument Gulch. Mulching is proposed within the Jacks Gulch, Black Hollow, Sheep Creek, Little Beaver, and Ratville (**Table 7**). Point mitigation by subwatershed is shown in **Table 8**.

Regional Values At Risk:

- **Roadways:** CO-14; Crown Point Rd.; Pingree Park Rd.; NF-259; NF-263; NF-259; NF-268; NF-139A; NF-142; NF-135; NF-350.
- **Private Property:** Ratville Community (1 structure); Monument Gulch Community (4 structures); Black Hollow Community (4 structures); Mineral Gulch Community (7 structures).
- **Drinking Supplies:** City of Fort Collins, City of Greeley, Tri-Districts (North Weld, Eastern Larimer County, Fort Collins – Loveland Water District), Northern Water, Irrigation Companies, and Private Users.

Table 7: Southern CLP Region proposed aerial mulching acres in non-wilderness & wilderness areas by subwatershed, including percent burn area treatment, cost, and combination with Point Mitigation. The green totals are indicating mulching in Wilderness areas.

Southern CLP Region Watersheds	Total Mulch Non-Wilderness (acres)	Total Mulch Wilderness (acres)	Moderate & High Soil Burn Severity (acres)	Burned Area Treated (%)	Estimated Cost ($) Non-Wilderness & Wilderness	Point Mitigation in Combination?
Lower East Fork Sheep Creek	273	0	1,484	18%	$682,500	Yes
Upper East Fork Sheep Creek	541	72	1,606	38%	$1,352,500 $180,000	Yes
Upper West Fork Sheep Creek	164	0	880	19%	$410,000	Yes
UT3 to Sheep Creek	109	26	642	21%	$272,500 $65,000	No
UT1 to Headwaters CLP	162	1,217	2,915	47%	$405,000 $3,042,500	Yes
Upper South Fork CLP River	643	28	1,562	43%	$1,607,500 $70,000	Yes
Ratville	454	0	1,006	45%	$1,135,000	Yes
Upper Bennett Creek	356	61	2,165	31% 51%	$890,000 $152,500	Yes
Middle Little Beaver Creek	161	1,194	2,233	63% 51%	$402,500 $2,985,000	No
Lower Little Beaver Creek	72	547	2,180	57%	$180,000 $1,367,500	Yes (2021)
Lower Fish Creek - Pendergrass	103	490	1,335	38%	$257,500 $1,225,000	No
Jacks Gulch	0	299	1,302	19%	$747,500	Yes
Comanche Reservoir	0	462	1,504	21%	$1,155,000	Yes (2021)
UT to Upper Little Beaver Creek	0	398	780	47%	$995,000	No
UT to Little Beaver Creek	0	683	1,080	43%	$1,707,500	No
Upper Little Beaver	0	988	1,948	45%	$2,470,000	No
Upper Fish Creek - Pendergrass	0	1,140	1,987	19%	$2,850,000	No
Lower Black Hollow	771	81	1,632	61%	$1,927,500 $202,500	Yes (2021)
Totals	**3,809**	**7,686**	**28,241**	**40%**	**$9,617,500** **$19,215,000**	

Table 8: Proposed Point Mitigation features by subwatersheds within the Southern Region of the CLP including cost and quantity. The unit prices reflect 2021 data.

Southern CLP Region Watersheds	Armored Crossing (EA)	LWM Stabilization (EA)	Rock Stabilization (EA)	Log Jams (EA)	Willow Staking (AC)	Hillslope Wattles (AC)	Total Cost by Subwatershed (No Road Improvements)
2021 Unit Prices	**$30,000**	**$3,112**	**$6,000**	**$1,200**	**$10,285**	**$5,445**	
Dadd Gulch	0 ($0)	2 ($6,224)	1 ($6,000)	0 ($0)	0 ($0)	0 ($0)	**$12,224**
Jacks Gulch	0 ($0)	0 ($0)	0 ($0)	6 ($7,200)	1 ($10,285)	0 ($0)	**$17,485**
Kyle Gulch	0 ($0)	0 ($0)	1 ($6,000)	4 ($4,800)	0 ($0)	0 ($0)	**$10,800**
Lower Bennett Creek	0 ($0)	0 ($0)	1 ($6,000)	5 ($6,000)	11 ($113,135)	0 ($0)	**$125,135**
Lower East Fork Sheep Creek	1 ($30,000)	2 ($6,224)	0 ($0)	1 ($1,200)	0 ($0)	40 ($217,800)	**$255,224**
Middle Bennett Creek	3 ($90,000)	16 ($49,792)	13 ($78,000)	10 ($12,000)	1 ($10,285)	23 ($125,235)	**$365,312**
Mineral Springs Gulch	1 ($30,000)	2 ($6,224)	0 ($0)	0 ($0)	0 ($0)	0 ($0)	**$36,224**
Ratville	6 ($180,000)	5 ($15,560)	12 ($72,000)	5 ($6,000)	0 ($0)	0 ($0)	**$273,560**
Upper Bennett Creek	2 ($60,000)	5 ($15,560)	15 ($90,000)	11 ($13,200)	3 ($30,855)	6 ($32,670)	**$242,285**
Upper Black Hollow Creek	6 ($180,000)	10 ($31,120)	2 ($12,000)	3 ($3,600)	0 ($0)	0 ($0)	**$226,720**
Upper East Fork Sheep Creek	2 ($60,000)	2 ($6,224)	2 ($12,000)	2 ($2,400)	17 ($174,845)	0 ($0)	**$255,469**
Upper South Fork CLP River	0 ($0)	0 ($0)	0 ($0)	5 ($6,000)	0 ($0)	0 ($0)	**$6,000**
Upper West Fork Sheep Creek	1 ($30,000)	1 ($3,112)	2 ($12,000)	0 ($0)	3 ($30,855)	8 ($43,560)	**$119,527**
UT1 to Bennett Creek	0 ($0)	7 ($21,784)	8 ($48,000)	4 ($4,800)	0 ($0)	0 ($0)	**$74,584**
UT1 to Headwaters CLP	1 ($30,000)	1 ($3,112)	1 ($6,000)	1 ($1,200)	0 ($0)	0 ($0)	**$40,312**
Totals & Feature Construction Costs	**23 ($690,000)**	**53 ($164,936)**	**58 ($348,000)**	**57 ($68,400)**	**36 ($373,742)**	**77 ($419,264)**	

Big Thompson

The Big Thompson was not divided additionally due to the size of the burn area and relatively limited number of fire-affected tributary watersheds. The most heavily impacted areas during the 2021 monsoon season were the private properties adjacent to Miller Fork and Black Creek. Because these areas received some funding during 2021 efforts, additional proposed sites are more limited. However, there are opportunities for mitigation implementation is Big Bear Gulch, Cascade Gulch, Fish Creek (Big T), and Sheep Creek (Big T). Additionally, teams have noticed that the burn severity in the Big Thompson may be higher than catalogued in the Soil Burn Severity map due to snow cover and difficult conditions during the analysis. This will be evaluated during site visits and may result in greater need than currently anticipated.

Mulching is proposed in many different highly impacted subwatersheds (**Table 9**). Point mitigation is proposed where access allows and is intended to mitigate downstream issues (**Table 10**).

Regional Values At Risk:

- **Roadways:** Crystal Mountain Rd.; Stringtown Gulch Rd.; Big Bear Rd.; Buckhorn Rd.; Deer Path St.; Windsong Rd.; Granite Rd.; Foogy Park Rd.; Ballard Rd.; Pack Trail; Streamside Dr.; Fishermans Ln.; Miller Fork Rd.; NF-345A
- **Private Property:** Miller Fork Community (>10 structures); Drake Community (>10 structures); Buckhorn Community (>50 structures); Big Bear Community (6 structures);

Stringtown Gulch Community (4 structures); Owl Hollow Community (2 structures); Crystal Mountain Community (4 structures).

- **Drinking Supplies:** City of Fort Collins, City of Greeley, City of Loveland, Tri-Districts (North Weld, Eastern Larimer County, Fort Collins – Loveland Water District), Northern Water, Irrigation Companies, and Private Users.

Table 9: Big Thompson Region proposed aerial mulching acres in non-wilderness & wilderness areas by subwatershed, including percent burn area treatment, cost, and combination with Point Mitigation.

Big Thompson Region Watersheds	Total Mulch Non-Wilderness (acres)	Total Mulch Wilderness (acres)	Moderate & High Soil Burn Severity (acres)	Burned Area Treated (%)	Estimated Cost ($)	Point Mitigation in Combination?
Middle Miller Fork	270	0	1,218	22%	$675,000	Yes (2021)
Upper Miller Fork	521	0	1,044	50%	$1,302,500	Yes (2021)
UT1 to Miller Fork	252	0	840	30%	$630,000	No
UT2 to Miller Fork	48	0	1,041	5%	$120,000	No
UT3 to Miller Fork	258	0	553	47%	$645,000	Yes
Elk Creek	1,286	0	2,096	61%	$3,215,000	No
Headwaters Buckhorn Creek	1,507	0	2,274	66%	$3,767,500	No
Cascade Creek	1,291	0	1,818	71%	$3,227,500	Yes
UT2 to Upper Buckhorn Creek	326	0	555	59%	$815,000	No
UT4 to Upper Buckhorn Creek	391	0	852	46%	$977,500	Yes
Upper Sheep Creek	1,097	0	2,030	54%	$2,742,500	Yes
Upper Fish Creek - Buckhorn	531	0	1,723	31%	$1,327,500	Yes
Lower Fish Creek - Buckhorn	638	0	1,252	51%	$1,595,000	No
Stringtown Gulch	939	0	2,146	44%	$2,347,500	Yes
Big Bear Gulch	1,111	0	2,346	47%	$2,777,500	Yes
Totals	**10,466**	**0**	**21,788**	**46%**	**$26,165,000**	

Table 10: Proposed Point Mitigation Features by subwatersheds within the Northern Region of the CLP including cost and quantity. The unit prices reflect 2021 data.

Big Thompson Region Watersheds	Armored Crossing (EA)	LWM Stabilization (EA)	Rock Stabilization (EA)	Log Jams (EA)	Willow Staking (AC)	Hillslope Wattles (AC)	Total Cost by Subwatershed (No Road Improvements)
2021 Unit Prices	**$30,000**	**$3,112**	**$6,000**	**$1,200**	**$10,285**	**$5,445**	
Big Bear Gulch	1 ($30,000)	6 ($18,672)	6 ($36,000)	11 ($13,200)	0 ($0)	0 ($0)	**$97,872**
Cascade Creek	1 ($30,000)	2 ($6,224)	2 ($12,000)	2 ($2,400)	0 ($0)	0 ($0)	**$50,624**
Galuchie Gulch	1 ($30,000)	0 ($0)	2 ($12,000)	1 ($1,200)	0 ($0)	0 ($0)	**$43,200**
Lower Miller Fork	0 ($0)	2 ($6,224)	1 ($6,000)	2 ($2,400)	0 ($0)	0 ($0)	**$14,624**
Lower North Fork Fish Creek	1 ($30,000)	2 ($6,224)	5 ($30,000)	4 ($4,800)	0 ($0)	0 ($0)	**$71,024**
Spruce Gulch - Cedar Creek	0 ($0)	2 ($6,224)	2 ($12,000)	1 ($1,200)	0 ($0)	0 ($0)	**$19,424**
Stringtown Gulch	2 ($60,000)	4 ($12,448)	3 ($18,000)	2 ($2,400)	0 ($0)	0 ($0)	**$92,848**
Upper Fish Creek	3 ($90,000)	8 ($24,896)	5 ($30,000)	8 ($9,600)	0 ($0)	0 ($0)	**$154,496**
Upper North Fork Fish Creek	1 ($30,000)	0 ($0)	0 ($0)	0 ($0)	8 ($63,525)	0 ($0)	**$93,525**
Upper Sheep Creek	1 ($30,000)	2 ($6,224)	2 ($12,000)	2 ($2,400)	0 ($0)	0 ($0)	**$50,624**
UT to North Fork Fish Creek	0 ($0)	4 ($12,448)	1 ($6,000)	0 ($0)	2 ($20,328)	0 ($0)	**$38,776**
UT1 to Miller Fork	0 ($0)	1 ($3,112)	2 ($12,000)	2 ($2,400)	0 ($0)	0 ($0)	**$17,512**
UT4 to Upper Buckhorn Creek	1 ($30,000)	2 ($6,224)	2 ($12,000)	2 ($2,400)	0 ($0)	0 ($0)	**$50,624**
Totals & Feature Construction Costs	**12 ($360,000)**	**35 ($108,920)**	**33 ($198,000)**	**37 ($44,400)**	**10 ($83,853)**	**0 ($0)**	

Summary by Subwatershed

Table 11 shows the summary of mulching and point mitigation costs by subwatershed priority. These will likely fluctuate slightly as the Soil Burn Severity (SBS) updates are analyzed.

Table 11:Sumamry of costs by subwatershed priorities. This does not include funding for road improvements which is included in Table 13

Priority Watershed Type	Total Mulch (acres)	Total Mulching Costs	Total Point Mitigation Costs (No Road Improvements)	Total Subwatershed Costs
Highest Priority Subwatersheds	11,684	$29,210,000	$1,543,850	**$30,753,850**
High Priority Subwatersheds	8,802	$22,005,000	$1,564,821	**$23,569,821**
Moderate Priority Subwatersheds	5,968	$14,920,000	$725,021	**$15,645,021**
Low Priority Subwatersheds	567	$1,417,500	$373,273	**$1,790,773**
Lowest Priority Subwatersheds	0	$0	$125,135	**$125,135**

Summary Cost Estimates by Region

Table 12 and **13** present the summarized costs totals for each of the regions and treatment types. The total needs for aerial mulching in the Cache La Poudre Watershed is $21,695,000 in non-wilderness areas and $21,332,500 in wilderness areas. The combined total is for the Cache La Poudre is $43,027500. The total need for the Big Thompson Watershed is $26,165,000. The total need for point mitigation in the Cache La Poudre Watershed is $6,791,675 while the need for the Big Thompson is $2,604,383. Additional related projects and needs for recovery that do not fit directly into watershed treatments are listed below.

Table 12: A costs summary of proposed aerial mulching by region. The total aerial mulching costs for the Cache La Poudre is $21,695,000 in non-wilderness areas and $21,332,500 in wilderness areas. The total mulching need for the Cameron Peak Fire is $69,192,500.

Regions within the Cache La Poudre and Big Thompson Watersheds	Total Mulch Non-Wilderness (acres)	Total Mulch Wilderness (acres)	Moderate & High Soil Burn Severity (acres)	Burned Area Treated (%)	Estimated Cost in Non-Wilderness Areas ($)	Estimated Cost in Wilderness Areas ($)
Northern CLP	1,860	0	4,806	39%	$4,577,500	$0
Western CLP	3,000	847	5,980	42%	$7,500,000	$2,117,500
Southern CLP	3,809	7,686	28,241	40%	$9,617,500	$19,215,000
Big Thompson	10,466	0	21,788	46%	$26,165,000	$0
Totals	**19,106**	**8,533**	**56,695**	**34%**	**$47,860,000**	**$21,332,500**

Table 13: A costs summary of proposed point mitigation construction and design by feature and region. Total Construction Costs by Region are: Northern CLP- $1,649,724, Southern CLP- $3,596,862, Western CLP- $1,692,105, Big Thompson- $2,604,383.

	Armored Crossing	LWM Stabilization	Rock Stabilization	Log Jams	Willow Staking	Road Drainage Improvements	Hillslope Wattles
2021 Unit Prices	**$30,000**	**$3,112**	**$6,000**	**$1,200**	**$10,285**	**$14,000**	**$5,445**
Northern CLP Region	$270,000	$37,344	$126,000	$20,400	$141,550	$599,500	$27,225
Southern CLP Region	$690,000	$164,936	$348,000	$68,400	$373,742	$600,000	$419,264
Western CLP Region	$60,000	$59,128	$36,000	$24,000	$391,143	$400,000	$283,140
Big Thompson Region	$360,000	$108,920	$198,000	$44,400	$83,853	$1,134,000	$0
Total Cameron Peak Fire Construction Costs by Feature	**$1,380,000**	**$370,328**	**$708,000**	**$157,200**	**$990,287**	**$2,733,500**	**$729,629**
Contractor Mobilization (10%)	$138,000	$37,033	$70,800	$15,720	$99,029	$273,350	$72,963
Engineering Design (10%)	$138,000	$37,033	$70,800	$15,720	$99,029	$273,350	$72,963
Permitting (5%)	$69,000	$18,516	$35,400	$7,860	$49,515	$136,675	$36,482
Construction Oversight (10%)	$138,000	$37,033	$70,800	$15,720	$99,029	$273,350	$72,963
Total Costs By Feature	**$1,863,000**	**$499,943**	**$955,800**	**$212,220**	**$1,336,888**	**$3,690,225**	**$985,000**
Total Cameron Peak Fire Point Mitigation Costs							**$9,543,076**

Other Funding Needs

While the general principles of mitigating post-fire impacts are generally well known, there is a large amount of information still missing due to the remoteness of the areas these large wildfires typical impact. Data collection to assess the impact of the fire and large flood events is extremely important in

understand and mitigating the overall strain on infrastructure. Three data needs with rough costs are detailed below.

Updated Topographic/Imagery Data in Support of Design – Following disasters like fire or flood, it is important to have accurate topographic data to plan and design recovery efforts and improvements. The Black Hollow flood event on July 20, 2021 completely transformed the watershed, lower fan, and Poudre River. It was vital that funding was available and budgeted to collect data soon after this event. However, it is more effective and equally important to have accurate topography for area prior to large landscape alterations. The Geospatial Group at Ayres has compiled a proposal for a large-scale data collection effort for the entire Cache La Poudre Watershed and Larimer County. This data will be invaluable to design, future mitigation, forest management, development, and economic growth in the area of interest. The full proposal is in **Appendix B**.

Cost Estimates of Collection: $566,000-$700,000 (Price varies based on deliverables)

Tree Planting Support & Materials – Post-fire forest vegetation recovery is key to reducing the short and long-term impacts of the Cameron Peak Fire on water quality. Tree planting is a long-term restoration action that can have multiple benefits in re-establishing forest on areas that would not return to forest for a long time. Areas targeted for tree planting would be identified high hazard watersheds and locations that are far enough from live trees that they would not re-seed for decades or longer. The basic criteria for tree planting include;

1. Moderate to high soil burn severity
2. North to northeast aspects
3. More than 200 meters from live trees (seed sources)
4. Relatively gentle slopes (< 20%)

The scale of tree planting needed far exceeds the capability of growing seedlings and planting them. The costs of planting seedlings includes; collecting seeds, growing seedlings (1-2 years depending on species), transport of seedlings to the site, seedling storage pre-planting, layout of units, crews to plant, and monitoring. The expected budget for these activities is $6/seedling. That cost would cover the listed actions.

The targeted areas would be on National Forest lands, because there are current efforts underway to plant trees on private lands. It is assumed that seedlings would be planted at about 150 per acre. **Table 9** displays the expected amounts of tree planting and costs.

Year	Planting Area (acres)	Seedlings per acre	Cost per Seedling	Planting cost per year
2022	500	150	$6	$450,000
2023	1,000	150	$6	$900,000
Totals	**1,500**			**$1,350,000**

LiDAR & Bathymetry of Existing Reservoir Infrastructure – Several reservoirs in the burn area are vulnerable to sedimentation impact from post-fire watersheds. While this plan assesses mitigation of those impacts, repeat topographic data collection is likely the best tool to quantify the impacts to these basins of the hydrologic recovery of the burn area.

Several of these reservoirs are emptied on a yearly basis, allowing for the use of aerial LiDAR collection on an at least biyearly schedule to provide information on the magnitude of the impact, areas of specific concern, and potential mitigation options. These LiDAR reservoirs include Peterson Lake, Comanche Reservoir, and Hourglass Reservoir.

Additionally, two reservoirs in the burn area, Chambers Lake and Barnes Meadow Reservoir, require the collection of bathymetry data to provide a clear picture of sedimentation and potential storage loss. This data should be collected at least three times during the 10-year recovery.

Cost Estimates of Collection over 10-yr Recovery: $400,000

Cache La Poudre River Floodplain Mapping Update – The floodplain mapping and modeling along the Cache La Poudre River Canyon from just west of Laporte to the headwaters remains a Zone A with no detailed modeling or analysis. In many areas of the canyon, this model is inaccurate and does not adequately convey riverine flooding risk to property owners. This is especially true following the Cameron Peak Fire and resulting debris flows at Black Hollow and other areas that have altered the topography or realigned the river. Updating the Poudre River Floodplain Mapping should be prioritized to help planning and communication to the effected property owners.

Cost Estimates of Floodplain Mapping and Modeling Update: $1.5 million

Conclusion

The Cameron Peak Fire led to degradation of the Poudre River and Big Thompson watersheds; post-fire flooding may exacerbate these issues for the next decade. While various efforts during 2021 served to protect private property and access within the Poudre River and Big Thompson watersheds, more needs exist on National Forest System lands to provide additional protection to VARs and water quality improvements. Four regions have been identified for mitigation for 2022 within the Poudre and Big Thompson watersheds. Nearly $9.4 million is estimated to design and construct the point mitigation features discussed in this report to reduce hillslope erosion, stream incision, and headcutting, and improve roadway drainage on National Forest System lands. Many of these feature types have already been installed in the efforts in 2021 and proven successful during post-fire storm events. The total mulching need for the Cameron Peak Fire is $69,192,500; however, areas will be prioritized for mulch treatment so that the most impacted areas with VARs are treated first and in combination with point mitigation efforts. The specific implementation locations and conditions can be viewed using the 2022 Cameron Peak Fire Work Plan Map Series. These improvements will ultimately protect VARs and improve water quality for municipal, recreational, and ecological purposes. There is also the need to continue collecting data and monitoring valuable water resource infrastructure that will likely continue to degrade through each year of watershed recovery. The data collection needs are estimated to cost between roughly $600,000 and $1.2 million, but would provide research, management, and recovery benefits for an increasingly post-fire burdened US Forest Service.

References

United States Department of Agriculture. Hydrology Technical Note No. 4. Title 210: Hydrologic Analyses of Post-Wildfire Conditions. August, 2016.

JW Associates. 2021. Cameron Peak Fire - Draft Post-fire Watershed Hazards, Treatments & Targeting.

Jonas, J. L., E. Berryman, B. Wolk, P. Morgan, and P. R. Robichaud. 2019. Post-fire wood mulch for reducing erosion potential increases tree seedlings with few impacts on understory plants and soil nitrogen. Forest Ecology and Management, 453: 117567.

Robichaud, Peter R.; Ashmun, Louise E.; Sims, Bruce D. 2010. Post-fire treatment effectiveness for hill-slope stabilization. Gen. Tech. Rep. RMRS-GTR-240. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 62 p.

Robichaud, P.R., S.A. Lewis, J.W. Wagenbrenner, L.E. Ashmun, and R.E. Brown. 2013. Post-fire mulching for runoff and erosion mitigation. Part I: Effectiveness at reducing hillslope erosion rates. Catena, 105: 75–92

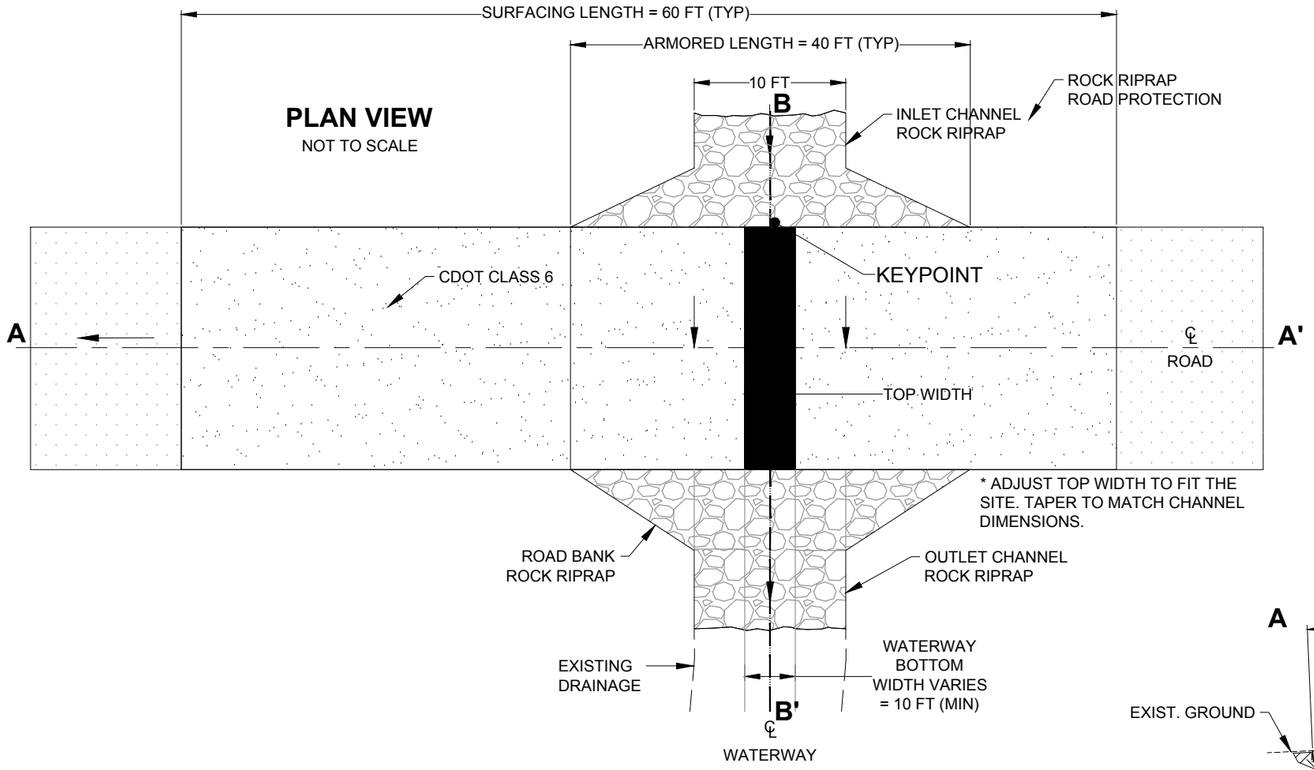
Burn Area Emergency Response (BAER) Report Cameron Peak Fire. Arapaho Roosevelt National Forest. United States National Forest. December 15, 2020.

Larimer County Parcel Data. Larimer County GIS Data Download. Larimer County, Colorado. Downloaded on 12/18/20.

Parise, M. & Cannon, S.H., 2011, *Wildfire impacts on the processes that generate debris flows in burned watersheds*. National Hazards. March, 2011.

Appendix A

2022 Cameron Peak Fire Mitigation Design Concepts



ARMORED DRAINAGE CROSSING DETAIL

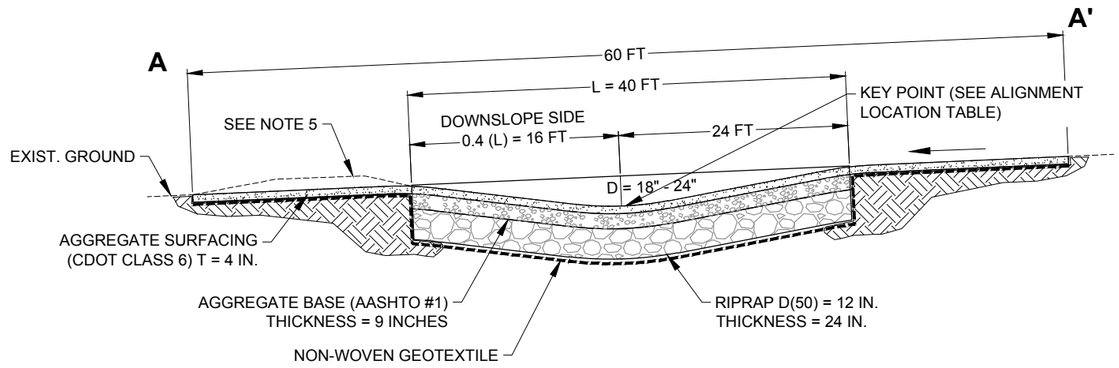
NOT TO SCALE

TYPICAL ROLLING DIP ROCK FORD

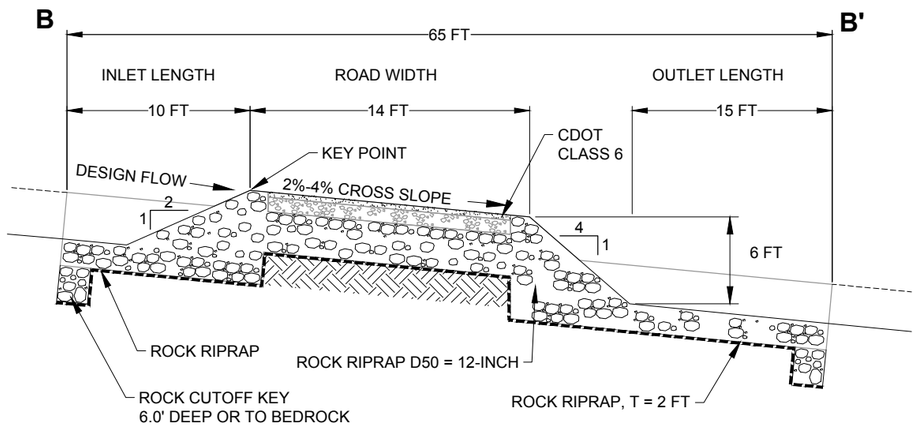
TYPICAL AT-GRADE ROCK FORD

CONSTRUCTION NOTES:

1. THIS DETAIL CAN BE USED WITH OR WITHOUT A CULVERT.
2. COORDINATE FIELD ADJUSTMENTS WITH THE ENGINEER.
3. THE DOWNHILL SIDE OF ROAD MAY NEED BUILT UP TO PREVENT WATER FROM FLOWING DOWN THE ROAD.
4. DIMENSIONS MAY VARY BASED ON SITE CONDITIONS. FIELD ADJUSTMENTS MUST BE APPROVED BY ENGINEER.



ROLLING DIP ON CONSTANT GRADE ROAD - PROFILE (A - A')



DRAINAGE CENTERLINE CROSS-SECTION (B - B')

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Date

Revisions

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

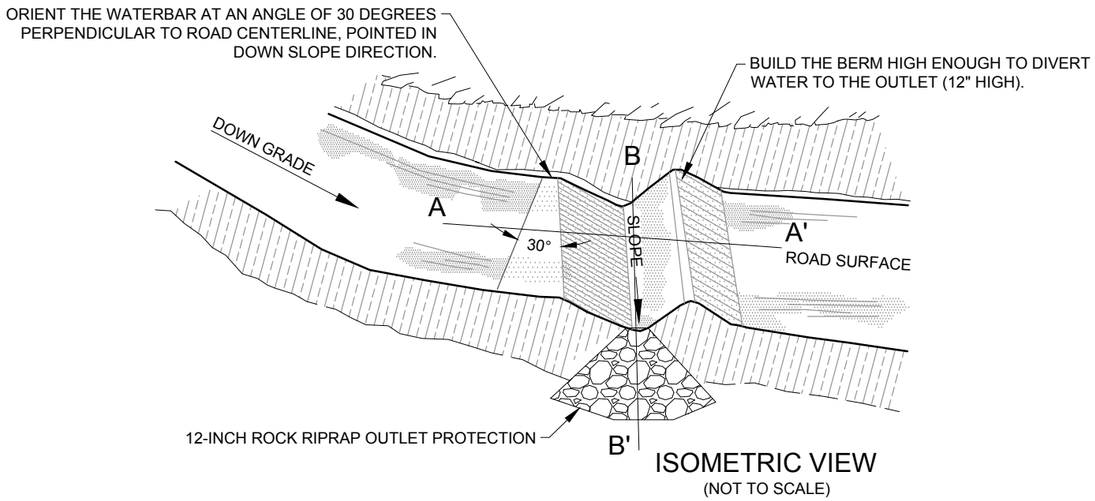
ARMORED DRAINAGE CROSSING

Project Mgr.	ABA
Designed By:	CHB
Drawn By:	RBR
Approved By:	WDR
Date:	06/08/2021

PROJECT NO.
36-4705.03

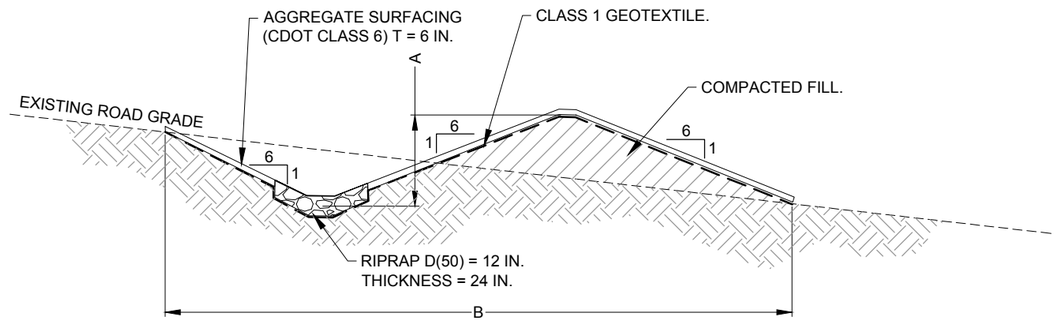
DRAWING NO.
D01

SHEET 8 OF 24

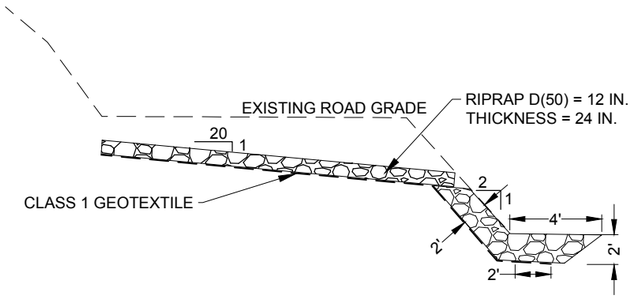


ISOMETRIC VIEW
(NOT TO SCALE)

Note to Engineer: Armor the bottom of dip with rock and Class I Drainage Geotextile fabric.



A-A' PROFILE VIEW
(NOT TO SCALE)



B-B' PROFILE VIEW
(NOT TO SCALE)

TABLE 2. WATERBAR DIMENSIONS

	A	B
TYPE 1	1 FT	12 FT
TYPE II	2 FT	24 FT
TYPE III	3 FT	36 FT

NOTES:

1. IF THE ROAD HAS A DRAINAGE DITCH, EXTEND THE WATERBAR TO INTERCEPT THE RUNOFF.
2. WATERBARS MUST BE INSPECTED AFTER ANY PRECIPITATION EVENT THAT MAY CAUSE EROSION.
3. START WATERBARS AT THE INTERSECTION OF THE ROADBED AND CUT SLOPE. EXTEND THE WATERBARS THE ENTIRE WIDTH OF THE ROADBED.
4. WATERBARS MUST HAVE FREE-FLOWING ARMORED LAYOUTS
5. COMPACTED FILL MUST BE NATIVE MATERIAL COMPACTED TO 95% PER AASHTO T 99 OR SAND, SANDY-GRAVEL, AS APPROVED BY THE ENGINEER

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Date
Revisions

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

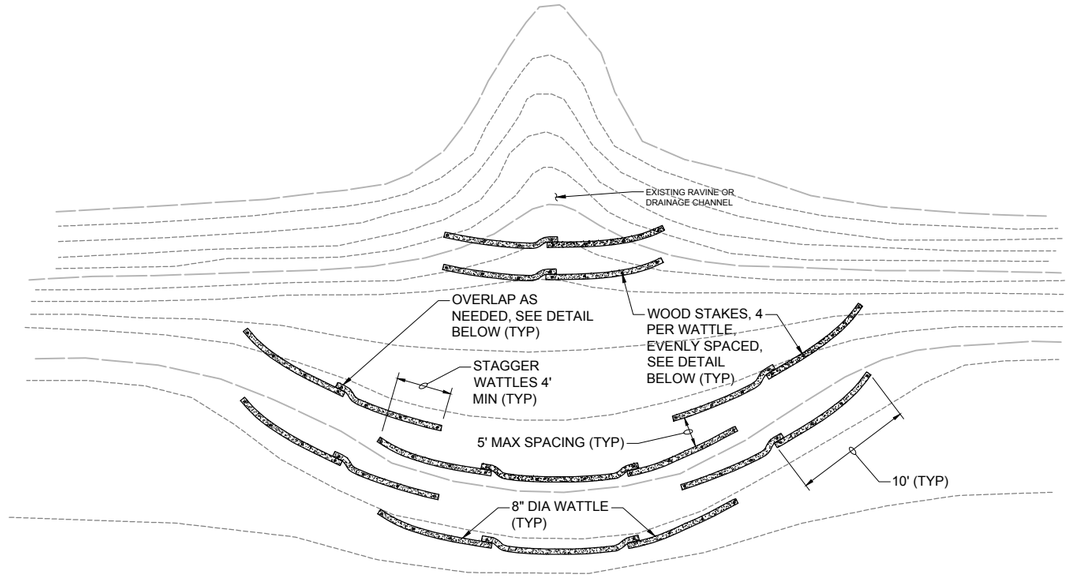
WATER BAR

Project Mgr: ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

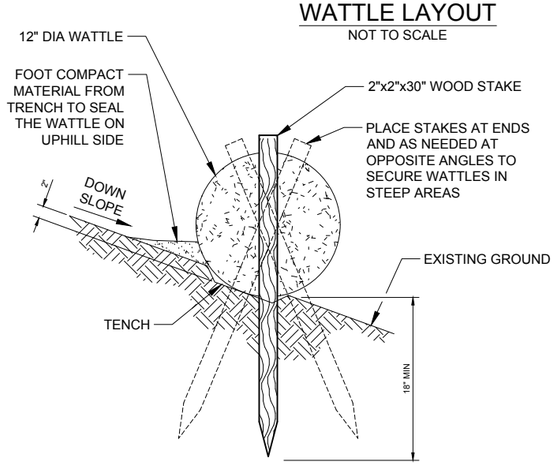
PROJECT NO.
36-4705.03

DRAWING NO.
D02

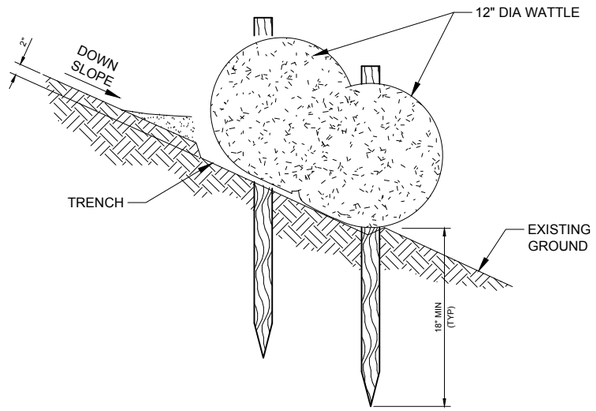
SHEET 10 OF 24



WATTLE LAYOUT
NOT TO SCALE



STAKE DETAIL
NOT TO SCALE



WATTLE OVERLAP DETAIL
NOT TO SCALE

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Revisions	Date

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

HILLSLOPE WATTLE
INSTALLATION & LAYOUT

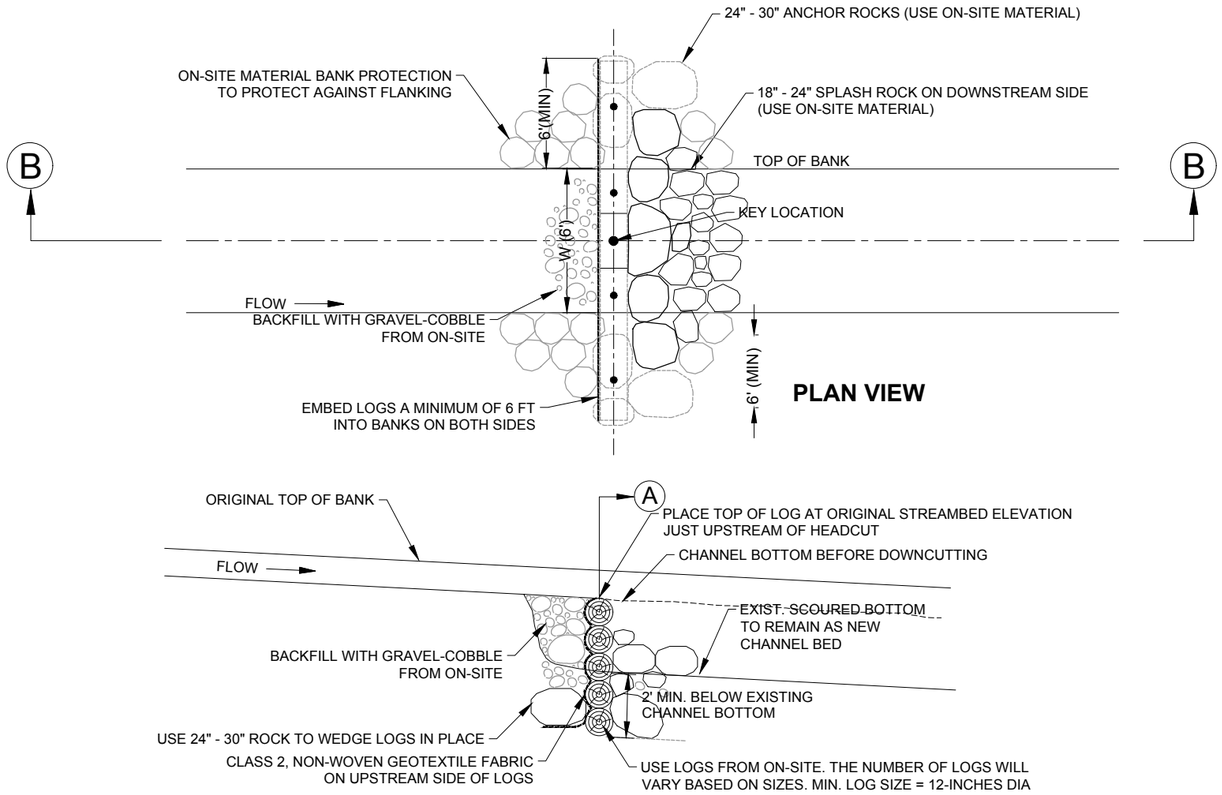
Project Mgr. ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

PROJECT NO.
36-4705.03

DRAWING NO.
D03

SHEET 9 OF 24

Drawing Name: I:\36\01_PROPOSALS AND MARKETING\GREELEY WATER RESOURCES 2022 POST-FIRE MITIGATION\DWGS\36-4705.03 SHEEP CREEK DETAILS.DWG Wednesday, October 27, 2021 11:53 AM By: BARRY, COLIN



NOTES:

1. ALL ROCK WILL BE SOURCED ON-SITE USING NATIVE BOULDERS AND COBBLE.
2. MINIMUM LOG DIAMETER IS 16 INCHES. MAY USE FEWER LOGS WHEN LARGER DIAMETER LOGS ARE AVAILABLE. THE REQUIRED NUMBER OF LOGS IS AS REQUIRED TO MEET TOP ELEVATION AND MINIMUM EMBEDMENT INTO STREAMBED.
3. USE STRAIGHT LOGS, UNIFORM DIAMETER, FREE OF ROT, DISEASE OR INSECT DAMAGE. USE LOGS FROM ON-SITE WHEN AVAILABLE.
4. FIELD ADJUST BASED ON ENGINEER APPROVAL TO MEET SITE-SPECIFIC CONDITIONS.
5. WHEN NEW CHANNEL BANKS ARE CONSTRUCTED, PROTECT THE DISTURBED SLOPE WITH EROSION CONTROL FABRIC, SEED, & MULCH. SEE SEPARATE DETAIL FOR EROSION CONTROL FABRIC.

LARGE WOODY MATERIAL (LWM) STABILIZATION

NOT TO SCALE

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Revisions | Date

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

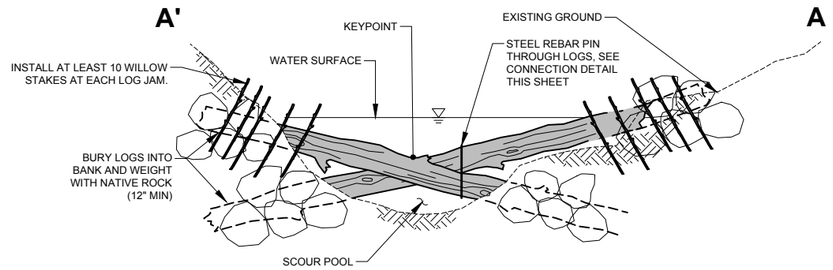
LARGE WOOD MATERIAL (LWM) STABILIZATION

Project Mgr. ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

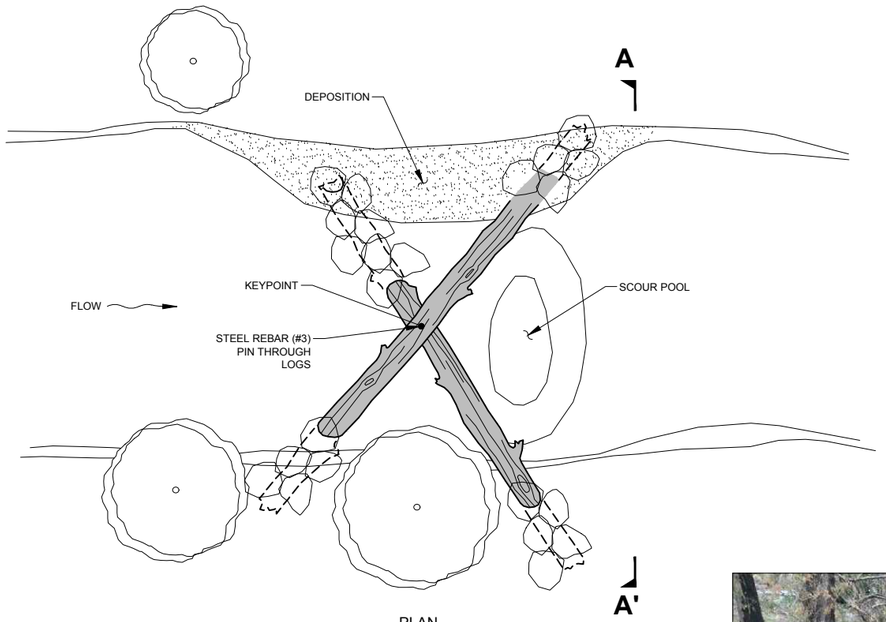
PROJECT NO.
36-4705.03

DRAWING NO.
D04

SHEET 13 OF 24



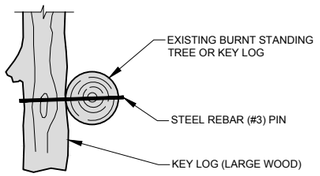
SECTION



PLAN

LOG JAM - BANK TIE-INS DETAIL OPTION 1

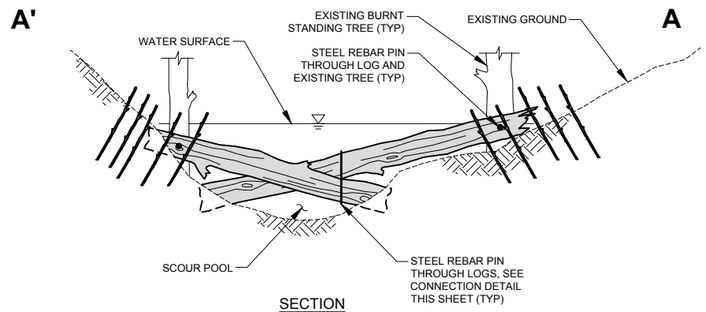
NOT TO SCALE



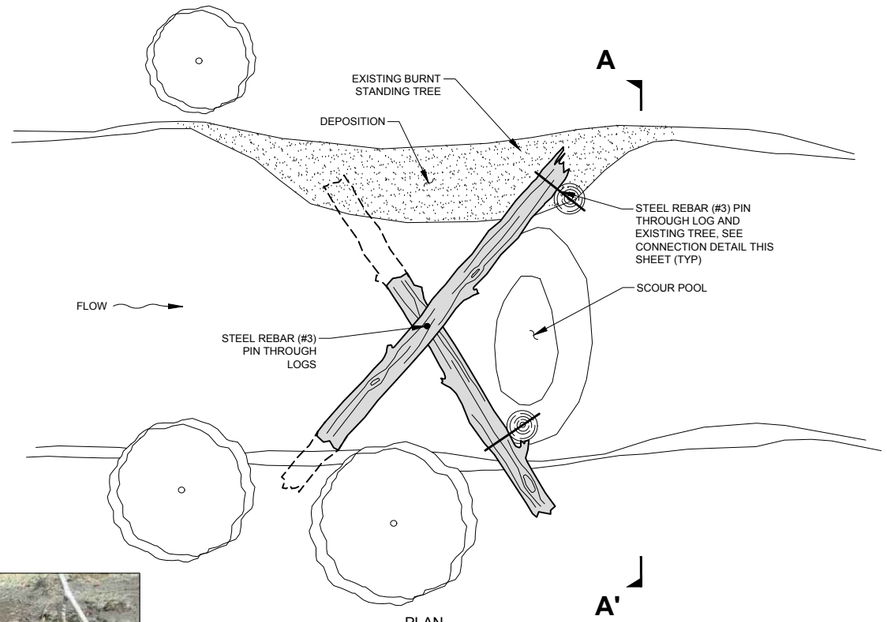
KEY LOG TABLE		
MIN LOG DIAMETER (IN)	BANKFULL WIDTH	
	0 TO 15FT	15FT TO 30FT
	MIN LOG LENGTH (FT)	
16	20	43
18	16	36
20	13	30
22	10	26
24	10	23
26	10	20

CONNECTION DETAIL

NOT TO SCALE



SECTION



PLAN

LOG JAM - BANK TIE-INS DETAIL OPTION 2

NOT TO SCALE

NOTES:

1. PLACE CUTTINGS UPRIGHT WITHIN THE LOG JAM/ROCKS ON THE BANKS PRIOR TO BACKFILL SUCH THAT AT LEAST $\frac{2}{3}$ OF THE CUTTING IS BELLOW THE GROUND SURFACE AND AT LEAST A PORTION BELOW THE GROUND SURFACE AND AT LEAST A PORTION OF THE CUTTING IS BELOW THE WATER TABLE. BACK FILL OVER AND AROUND CUTTINGS AS CAREFULLY AS POSSIBLE.
2. IF INCISION IS EVIDENT IN THE AREA, PLACE NATIVE ROCK ON THE UPSTREAM SIDE IN THE CHANNEL TO MITIGATE.

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Date

Revisions

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

LOG JAM - KEY LOG
INSTALLATION

Project Mgr. ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

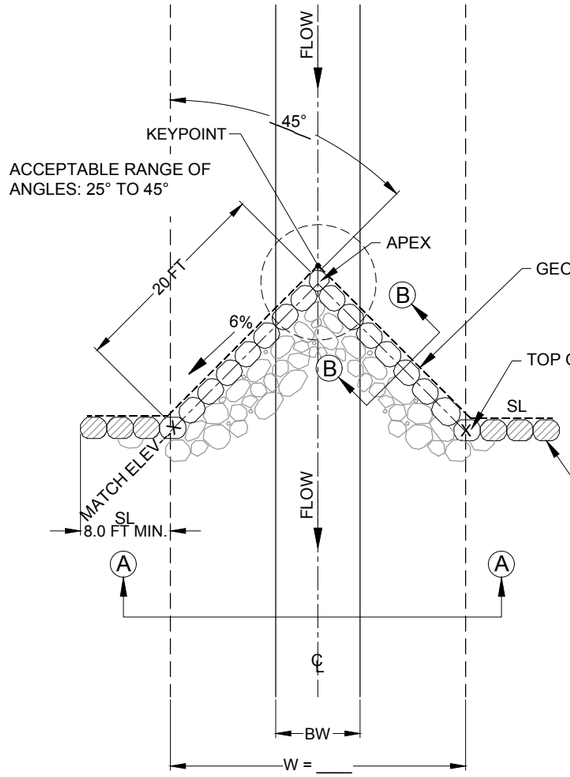
PROJECT NO.
36-4705.03

DRAWING NO.
D05

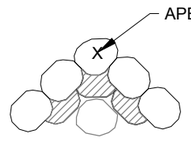
SHEET 14 OF 24

ROCK STABILIZATION STRUCTURE

(NOT TO SCALE)



PLAN VIEW

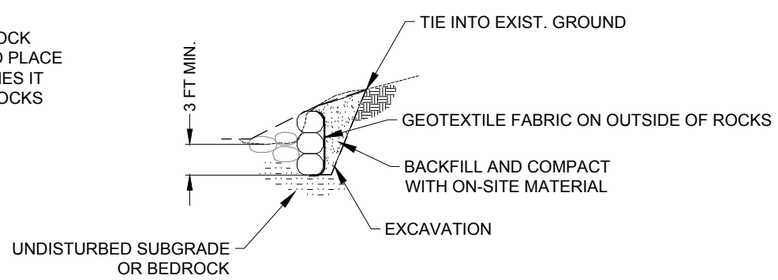


SELECT AN APEX ROCK THAT WEDGES INTO PLACE SO THE FLOW PUSHES IT TIGHTER TO ARM ROCKS (SEE NOTE 7)

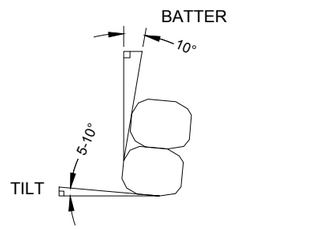
APEX ROCK DETAIL

THE TOP OF ARM ELEVATION IS HIGHER THAN THE APEX BY 6% TIMES ARM LENGTH. IF THE ARM IS 20 FT LONG, THE TOP OF THE ARM WILL BE 1.2 FT HIGHER THAN THE APEX.

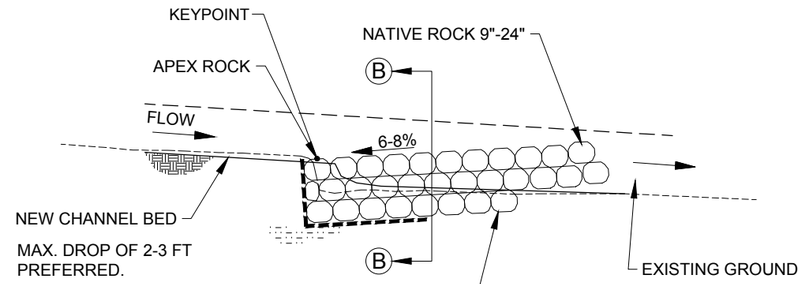
EXTEND ROCK CUTOFF SILLS INTO COMPACTED EARTH PERPENDICULAR TO FLOW DIRECTION. MINIMUM LENGTH OF 8 FEET OR TIED INTO OTHER STABLE FEATURE, SUCH AS A LARGE TREE, ROCK OUTCROP, OR HUGE BOULDER.



SECTION B-B

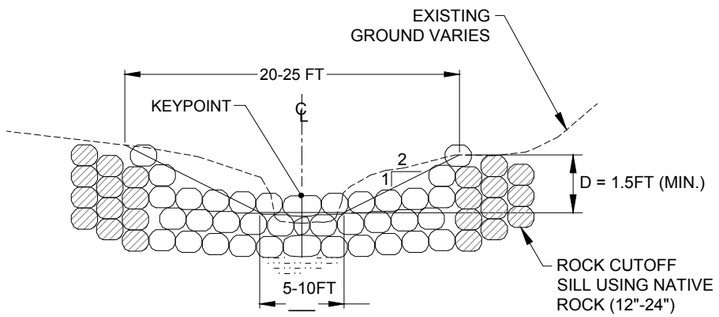


DETAIL OF VANE ARM SHOWING BATTER AND TILT BACK INTO THE BANK.



PROFILE VIEW

(ALONG CENTERLINE OF CHANNEL)



SECTION A-A

(VIEW UPSTREAM)

NOTES:

1. THIS STRUCTURE IS USED AS A SEDIMENT TRAP AND STABILIZATION AGAINST INCISION ON EPHEMERAL & PERENNIAL STREAMS
2. THE SPLASH ROCK DISSIPATES ENERGY TO REDUCE EROSION ON THE CHANNEL BED. USE SCRAP ROCK SALVAGED ON-SITE ROCK FOR SPLASH ROCK.
3. THE MINIMUM EMBEDMENT DEPTH SHALL BE INTO CONSOLIDATED, UNDISTURBED SUBGRADE, NOT LOOSE SEDIMENT DEPOSITION. IF BEDROCK IS ENCOUNTERED MIN. EMBEDMENT DEPTH CAN BE REDUCED WITH APPROVAL FROM ENGINEER.
4. THE ENGINEER MAY ADJUST THE ARM LENGTHS AND SLOPES TO MATCH THE ACTUAL SITE CONDITIONS. THE RECOMMENDED SLOPE ON THE ARMS IS 4% TO 8%.
5. USE GEOTEXTILE FABRIC AS DESCRIBED IN THE SPECIFICATIONS AND BY DETAIL. PLACE GEOTEXTILE BEHIND THE ARM (UPSTREAM SIDE), DRAPED FROM TOP OF ROCK STRUCTURE TO BOTTOM OF FOOTER ROCK AND EXTEND A MINIMUM OF HALF THE TRENCH BOTTOM WIDTH. TRIM EXCESS OR VISIBLE FABRIC.
6. THE APEX BOULDER IS THE EQUIVALENT OF A KEYSTONE IN AN ARCH STRUCTURE. PLACE IT SO IT IS WEDGED IN PLACE BY THE FORCE OF THE WATER. IT SHOULD BE THE LOWEST BOULDER.
7. PLACE THE ROCKS TO INTERLOCK TOGETHER AND HAND CHINK ANY LARGE VOIDS WITH ROCK THAT WILL NOT DISLODGE DURING HIGH FLOWS.
8. USE THE EXCAVATOR BUCKET TO DUMP ("WASH") WATER ACROSS THE BACKFILL TO CONSOLIDATE IT.

Xref ..\Images\WdR_Stamp_08-06-21.dwg

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Date

Revisions

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

ROCK STABILIZATION

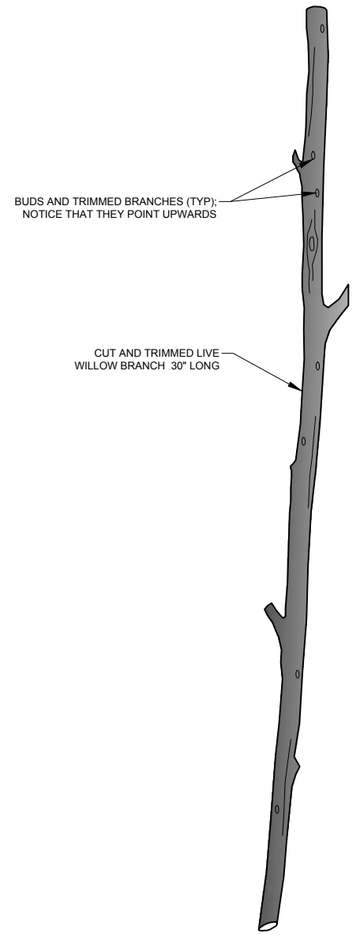
Project Mgr. ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

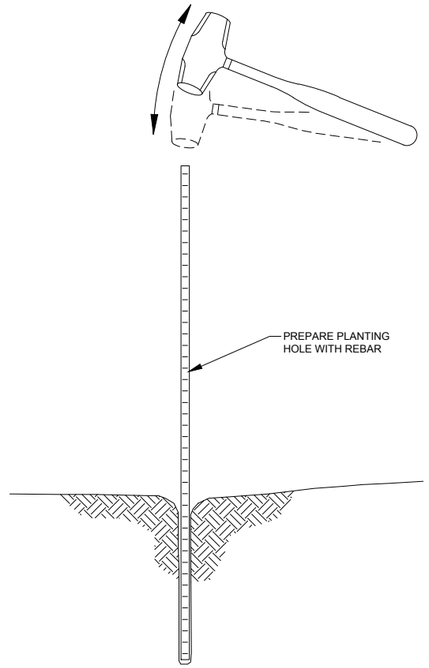
PROJECT NO.
36-4705.03

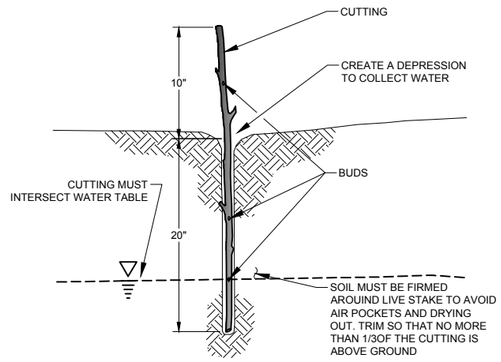
DRAWING NO.
D06

SHEET 16 OF 24

Drawing Name: I:\36\01_PROPOSALS AND MARKETING\GREELEY WATER RESOURCES 2022 POST-FIRE MITIGATION\DWGS\36-4705.03 SHEEP CREEK DETAILS.DWG Wednesday, October 27, 2021 11:53 AM By: BARRY, COLIN







NOTES:

1. SPACE EACH STAKE 2' TO 4' APART

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Revisions | Date

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

WILLOW STAKE
INSTALLATION

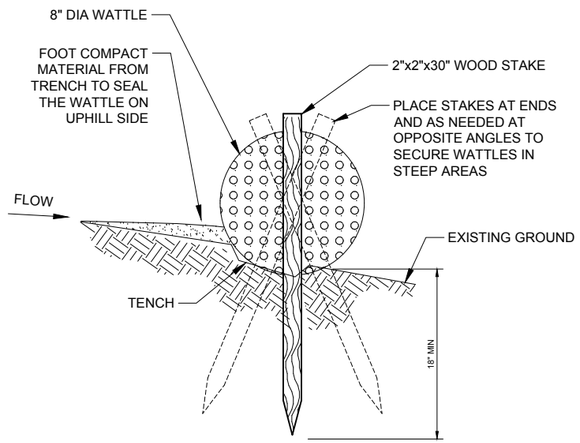
Project Mgr: ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

PROJECT NO.
36-4705.03

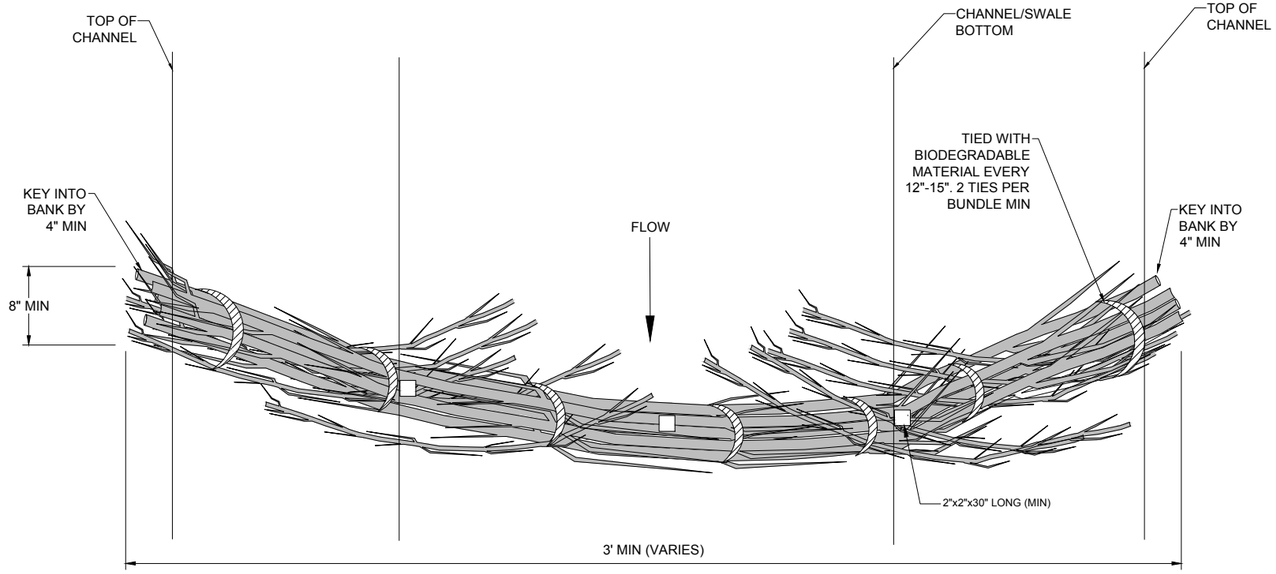
DRAWING NO.
D07

SHEET 11 OF 24

Drawing Name: I:\36\01_PROPOSALS AND MARKETING\GREELEY WATER RESOURCES 2022 POST-FIRE MITIGATION\DWGS\36-4705.03 SHEEP CREEK DETAILS.DWG Wednesday, October 27, 2021 11:53 AM By: BARRY, COLIN

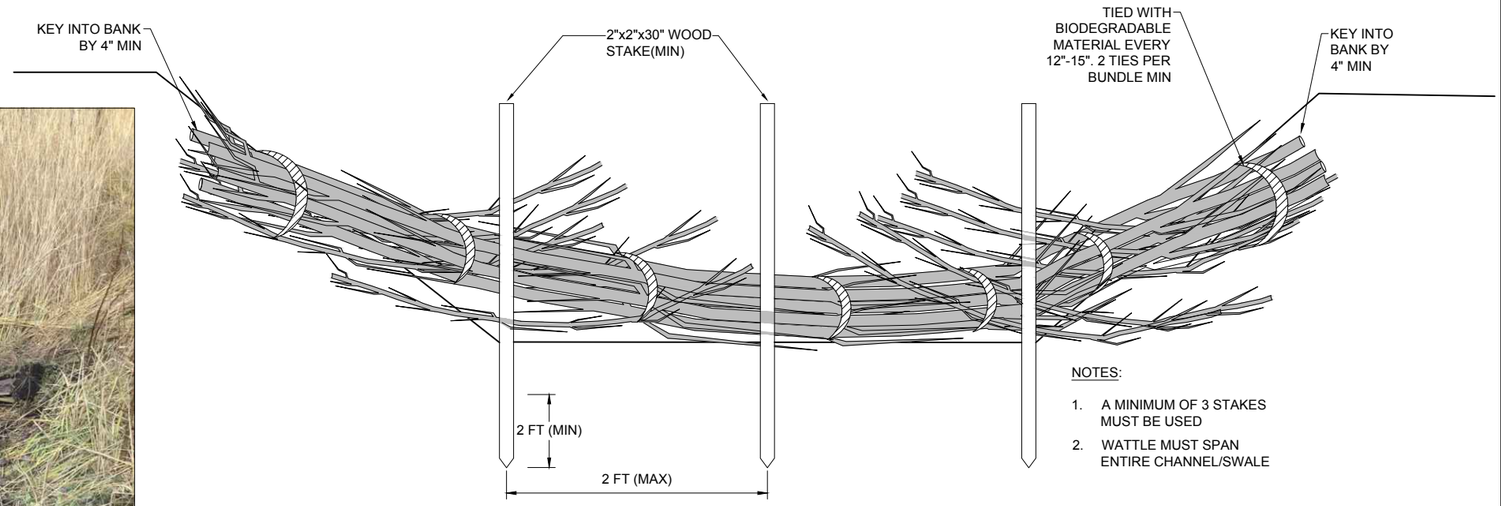


STAKE DETAIL
NOT TO SCALE



PLAN

WILLOW WATTLE INSTALLATION
NOT TO SCALE



CROSS SECTION

NOTES:

1. A MINIMUM OF 3 STAKES MUST BE USED
2. WATTLE MUST SPAN ENTIRE CHANNEL/SWALE

ONE INCH - IF NOT, SCALE ACCORDINGLY

AYRES
3665 JFK Parkway
Building 2, Suite 100
Fort Collins, CO 80525
(970) 223-5556

Revisions | Date

WEST CAMERON PEAK FIRE
(GREELEY) EWP
SHEEP CREEK SITE
CITY OF GREELEY, COLORADO

WILLOW WATTLE - FASCINE BUNDLE

Project Mgr. ABA
Designed By: CHB
Drawn By: RBR
Approved By: WDR
Date: 06/08/2021

PROJECT NO.
36-4705.03

DRAWING NO.
D08

SHEET 16 OF 24

Appendix B

CPRW LiDAR Collection Proposal – Larimer Co & Cache La Poudre Watershed

January 6th, 2022

Shayna Jones
Post-fire Mitigation & Recovery Program Manager
Coalition for the Poudre River Watershed
320 E. Vine Drive, suite 317
Fort Collins, CO 80524 USA

Re: CPRW Lidar Collection and Processing

Dear Ms. Jones:

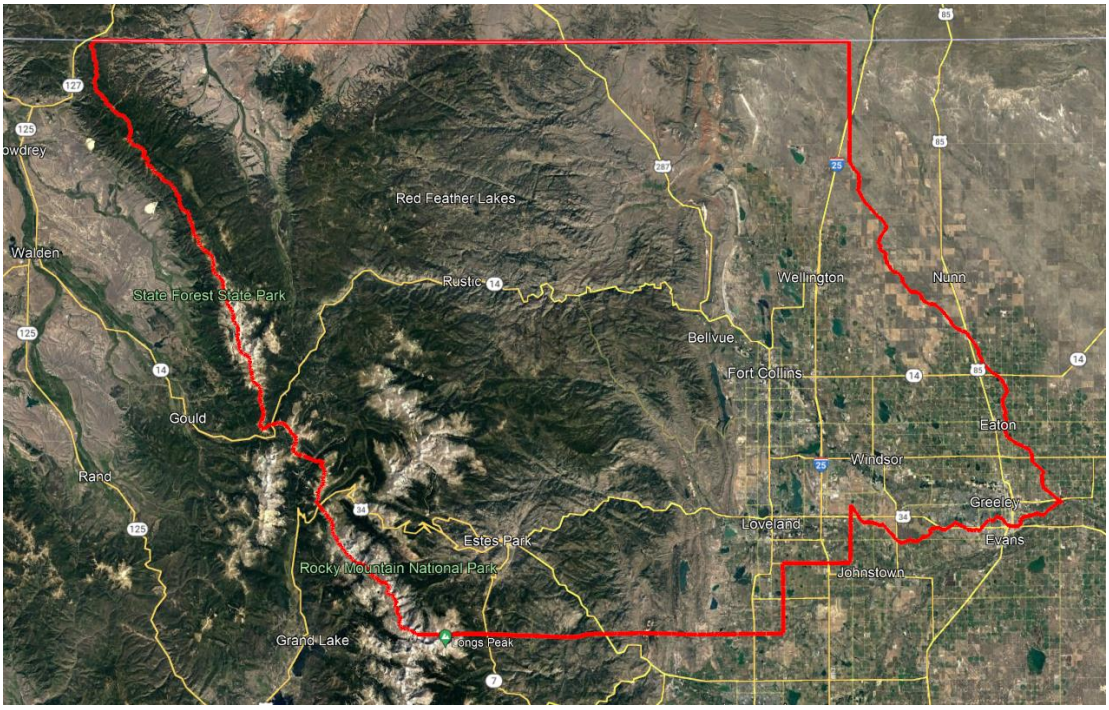
Thank you for the opportunity to submit a proposal for mapping services for the CRPW Lidar project in Larimer and Weld Counties, Colorado. This letter describes our proposed approach and fees for collecting and processing high density Lidar across project area. Ayres Associates appreciates the necessity for accuracy and expedited schedules for your project, and we present this proposal with a commitment to give your project high priority in our production schedule.

Proposed Scope of Service

For this project, we propose to utilize high density aerial Lidar to derive a project wide digital elevation model and classified point cloud. As a general overview of the project, Ayres will acquire Lidar in the Spring and Summer of 2022 using a calibrated Lidar sensor to support a detailed terrain model over approximately 2,925 square miles covering the Poudre River Watershed.

Project Area

Aerial Lidar will be captured for the project area shown below. Lidar will be collected and processed for a total of 2,925 square miles



Lidar Acquisition and Processing

Ayres understands that the proposed Lidar project calls for the development of high accuracy topographic mapping and above ground modeling across the project area. The Lidar data collection will be done using a low altitude fixed wing aircraft equipped with an advanced Lidar sensor and with airborne GNSS/IMU system for accurate georeferencing. The Lidar point cloud will be captured in the Spring - Summer of 2022 during leaf-off state, and when clouds or haze are not present between the aircraft and the ground, and when snow levels have melted to an acceptable level.

For the Lidar acquisition, QL1 Lidar will be collected at 8 points per square meter and will achieve QL1 vertical accuracy Lidar Base Specifications, which equates to 10 cm RMSEz on level or uniformly sloped non-vegetated ground.

The raw lidar point cloud will be calibrated and classified according to the base classification scheme listed below. All collected Lidar points will be retained in the point cloud according to these classifications. High vegetation and building classifications will also be included using automated routines. The point cloud will be in LAS v1.4 format.

Lidar Base Classification Scheme:

- Class 1: Processed, but unclassified
- Class 2: Bare-earth ground
- Class 5: High Vegetation
- Class 6: Buildings
- Class 7: Low Noise
- Class 9: Water
- Class 17: Bridge Decks
- Class 18: High Noise
- Class 20: Ignored ground (breakline proximity)

Breaklines will be collected to constrain the hydro features, a process called hydro-flattening. Ayres will collect additional hydro breaklines to be used in creation of bare earth Digital Elevation Model (DEM) and contours. Hydro-flattened breaklines will be compiled for ponded water that is 2 acre or greater and double line streams that 20 feet in width or greater. A bare earth digital elevation model (DEM) for the project area will be generated from the processed lidar data at a 1-ft pixel resolution and will support the generation of contours at 1-foot contour intervals.

Lidar Ground Control

Ayres will use the airborne GNSS/IMU data collected at the time of flight. We also will use COCORS data collected during the flight from nearby permanent base stations to calibrate the raw lidar data. Additionally, Ayres will perform all ground control survey necessary across the project area that will be used to validate and calibrate of the raw lidar data. The ground control calibration survey does not include any independent testing on various landcover types.

Deliverables

In summary, final deliverable products will include:

- Classified point cloud, LAS v1.4 format
- Automated classification of high vegetation and buildings (classes 5 and 6)
- Hydro flattening breaklines (20-ft streams and 2-acre ponds), ESRI shapefile format
- Bare earth DEM (1-ft pixel)
- 1-ft contour dataset (topologically cleaned)
- Intensity imagery, GeoTIFF format
- Digital Surface Model (DSM) of first returns
- Tile schematic, ESRI shapefile format

Additional lidar derivative datasets for consideration (not included in Proposed Fees):

- Bare earth point cloud – class 2 points only
  - Bare earth point clouds in .las format version 1.4 will be created from the Lidar class 2 points.

- 2D building outlines generated from building points
  - Once the Building Classification is performed, Ayres can extract two-dimensional building outlines from the Lidar data. Compiling building outlines from Lidar utilizes points collected from roof surfaces and classified as buildings. These points are then processed through modeling software which employs edge-detection macros to determine the outside extents of buildings. The result is that the building edges are compiled without horizontal displacement.
  - A degree of manual and automated editing will be necessary to help clean up areas where dense vegetation partially obscures buildings. However, limited editing will be applied elsewhere. In order to take advantage of the economic benefits of this approach, the output will be primarily the result of a semi-automated process and constrained to the ability of the Lidar data's ability to detect and geometrically define building detail.

- Tree canopy polygons from high vegetation points
  - Once the Vegetation Classification is performed on the Lidar, extraction of two-dimensional contiguous high vegetation polygons can be performed on the data. Using a series of algorithms and semi-automated extraction techniques, we are able to identify contiguous stands of trees to extract vegetation polygons from the Lidar. This method can be more efficient and cost effective than traditional photogrammetric compilation.
  - Ayres will use the Lidar point clouds to produce a representative 2D layer for a project-wide forest canopy. In order to take advantage of the economic benefits of this approach, the output will be primarily the result of a semi-automated process and constrained to the ability of our algorithms to detect and geometrically define the canopy detail from the Lidar classified data.

- Culvert collection and hydro-enforced DEM
  - The Base Project Lidar DEM will be hydro flattened but not hydro-enforced. To hydro enforce the DEM, Ayres will collect culvert locations using the Lidar. The culvert lines will then be draped to the Lidar point cloud, and the lowest elevation will be applied to the line to create a 3D breakline. We will use the 3D breaklines to reclassify the ground points and cut the DEM, allowing modeled water to flow through the culverts, rather than dam against road banks and other digital dams.
  - The hydro-DEM useful for hydrography modeling and land conservation planning across the project area. The deliverables include a hydro-enforced project-wide DEM in grid or Geotiff format and culvert locations in shapefile format.

- Cloud hosting (Amazon S3) and account management
  - Ayres can provide a cloud-hosting solution for the Lidar point cloud files. This solution helps solve the challenge of making a large amount of geospatial data readily available for project partners to download. The cloud-hosting service will maximize the datasets usage and value to the project partners and ease the burden of data requests on you and your staff.
  - Ayres will streamline the efficient uploading of data into the cloud. We will use Amazon S3 services for storing and hosting your geospatial datasets through our corporate account. Under the cloud hosting services, Ayres will:
    - Create CPRW specific buckets for holding data in Amazon S3 cloud
    - Upload the requested Lidar datasets directly into the proper buckets
    - Properly name and format data files for easy understanding of downloads

        - Provide CPRW and project partners with a spreadsheet that has unique URL's for each data tile
            - This is used to point at the data tiles from the public facing map application
        - Manage Amazon S3 account and pay monthly invoices on behalf of CPRW
        - Track usage and inform the project partners when downloads are approaching their limit for the year
    - The proposed fees area not-to-exceed lump sum amounts that are estimated for one year of service. The cloud-hosting services are contracted annually via an amendment to our existing geospatial services Contract. A new amendment will be required to maintain the links once the original amount has been expended. Ayres will work with CPRW to determine a contracting period for cloud-hosting and may contract for more than one year at a time if need be.

      Cloud-hosting of 2022 Lidar datasets:

Cloud storage up to 2 TB and 500 GB/month download:	$ 2,500.00
Initial data set-up and account management (Year 1):	$ 7,300.00
2022 Annual Cloud-Hosting Budget Total:	$ 9,800.00
2 TB cloud storage and 500 GB/month download capacity:	$ 2,900.00
Annual account management:	$ 2,000.00
2023 Annual Cloud-Hosting Budget Total:	$ 4,900.00
2 TB cloud storage and 500 GB/month download capacity:	$ 3,300.00
Annual account management:	$ 2,200.00
2024 Annual Cloud-Hosting Budget Total:	$ 5,500.00

- Interactive Lidar Online Viewer
    - Ayres will utilize the 2022 Lidar to develop an online interactive webmap service by optimizing, hosting and storing Lidar derived data layers in ArcGIS Online. We will create a customized web application and provide you with a link to access the online interactive viewer. The interactive webmap will have tools for measuring, basemap selection, and toggling data on and off. The interactive Lidar online viewer is a web browser-based application which will run in current versions of Microsoft Edge, Google Chrome, Mozilla Firefox, and Safari 11 and later.
        - According to ESRI's current guidance, we recommend using the latest versions of Google Chrome or Mozilla Firefox. Microsoft Edge and Safari 11 and later work, however these two do not have WebGL implementation and may not operate as well.
    - Ayres will process the 2022 project area Lidar to into formats compatible with ArcGIS Online. Data layers will be uploaded and hosted in the Ayres' ArcGIS Online account. Ayres will create a customized 3D web application for the project area. When the service is completed, all items will be set for public sharing.
        - Potential Viewing Layers:
            - Slope shade bare earth layer
            - Shaded relief bare earth layer
            - Hillshade bare earth layer
            - Elevation surface layer from Lidar DEM
            - Hydro-enforced DEM
            - Ground lidar point cloud
            - High vegetation lidar point cloud layer
            - Building lidar point cloud layer
            - 1-foot topographic contour layer

- Ayres will provide technical maintenance services for hosted data layers, web scenes and web applications needed for the Ayres Lidar Online service. Data storage fees from ArcGIS Online will be administered by Ayres and are included in the maintenance program. This service is based on ESRI technology and architecture. Ayres is not responsible for changes that ESRI makes to its ArcGIS Online functionality or tools.
- The proposed fees area not-to-exceed lump sum amounts that are estimated for one year of service. The Interactive Lidar Online Viewer services are contracted annually via an amendment to our existing geospatial services Contract. A new amendment will be required to maintain the Online Viewer once the original amount has been expended. Ayres will work with CPRW to determine a contracting period for cloud-hosting and may contract for more than one year at a time if need be.

  Interactive Lidar Online Viewer:

Initial web application set-up and account management:	$ 34,500.00
2023 Annual account maintenance and management:	$ 12,500.00
2024 Annual account maintenance and management:	$ 13,200.00

Proposed Schedule

Ayres will perform the proposed services according to the following schedule:

- Lidar acquisition: will occur in Spring-Summer of 2022, as weather and ground conditions permit.
  - The Eastern Front-Range portion of the project area would be collected earlier in the Spring, as ground conditions permit.
  - The Western Mountains portion of the project area would be collected as ground conditions permit and when snow levels have melted to an acceptable level as determined by CPRW staff and Ayres.
- Lidar Processing: final deliverables will be delivered within 3 months of completion of Aerial Lidar Collection and Survey Ground Control Collection.

Proposed Fees

We will perform the above services for the following **lump sum** fees:

Aerial Lidar Collection, Processing, Survey (2,925 sq miles):	$	506,000.00
Hydro Breaklines (20-ft streams and 2-acre ponds):	$	38,000.00
1-ft contour dataset (topologically cleaned):	$	22,000.00
Classification of High Vegetation, Buildings (class 5 and 6):	~~$~~	~~13,500.00~~
*Included at no cost with base project	$	0.00
Intensity Imagery from Lidar (GeoTIFF):	~~$~~	~~4,000.00~~
*Included at no cost with base project	$	0.00
Digital Surface Model (DSM) of first returns:	~~$~~	~~15,500.00~~
*Included at no cost with base project	$	0.00
Total Lump Sum Fees:	**$**	**566,000.00**

Additional Lidar derivatives **lump sum** fees:

Bare Earth Point Cloud- Class 2 points only:	$	5,000.00
2D building outlines generated from building points	$	49,000.00
Tree canopy polygons from high vegetation points	$	42,000.00
Culvert collection and hydro-enforced DEM	$	108,000.00
Cloud hosting (Amazon S3) and account management (Year 1)	$	9,800.00
Year 2	$	4,900.00
Year 3	$	5,500.00
Interactive Lidar Online Viewer	$	34,500.00
Year 2	$	12,500.00
Year 3	$	13,200.00
Total Lump Sum Fees for Additional Lidar derivatives:	**$**	**284,400.00**

I hope that we have provided the information you require to proceed with your project. In the event that you require additional information or clarification of any issue, please feel free to contact me at 414-467-8891.

Sincerely,

Ayres Associates Inc

Tyler Kaebisch
Project Manager – Geospatial Services
Direct: 414-467-8891
KaebischT@AyresAssociates.com

Appendix C

Aerial Mulching Specifications

Wood Mulch Technical Specifications

Using the soil burn severity assessment and other data treatment polygons were identified that are located in areas that are in "high" and "moderate" burn severity classes with slopes that range from 20 to 50 percent. The purpose of these post-fire treatments are to provide adequate cover on treatment areas within the Cameron Peak Fire to reduce erosion and sedimentation that may affect water quality, infrastructure and lives of the citizenry located within, adjacent, or down slope of the fire perimeter.

Aerial Mulch Specifications

Cover Purpose: The mulch material shall vary in size to allow interlocking to provide the most resistance to water runoff, soil erosion and wind removal.

Wood Shred Size and Composition: The size shall consist of a relatively even composition of smaller and larger length strands. At least 70% of the total wood shred volume will have stubble lengths of 4-8 inches typical, have less than 1" diameter and have minimal fines. It is recommended that a horizontal grinder be used on trees and a tub grinder be used for the resulting slash. A screen of 2-4" will be used to meet the desired specifications. Wood shred shall be covered during transportation and when staged to prevent material from blowing around on site.

Source Material: Burned trees from within the burned area would be preferred for generating wood mulch material. There are limited private lands in the burned area and use of burned trees from National Forest Lands is not currently permitted. However, there are some log decks from fire suppression actions that have the potential to be used. The project sponsors will also continue to work on permitting the use of trees from National Forest Lands.

Aerial Mulch Application Specification:

Targeted Areas: The contractor will mulch 100% of the targeted acres (See additional notes on aerial and broadcast application). Targeted areas are delineated on the treatment map. These polygons have not been field verified and will likely change somewhat after that verification work has been completed. The field verified polygons will be available before the project implementation begins.

Wood Shred Cover: Application rate is anticipated to be about 4 tons/acre. The objective is to attain a coverage rate of at least 70% of the soil surface with an evenly distributed interlocking wood shred, within each delineated polygon identified on the treatment map. Because wood shred moisture content may vary (e.g. live versus dead trees) application rate (tons/acre) may vary to achieve the desired cover of 70%. The helicopter netting will be small enough such that the vast majority of the mulch will not fall through and be lost in flight.

Additional Notes on Aerial and Broadcast Application: Maintain consistent contact with mulching vendor project manager and the pilot to ensure that targeted areas are being met efficiently. Avoid dropping mulch in drainages and over areas covered with substantial rock cover (greater than about 50%) since large rock cover adequately protects the soil from accelerated water erosion. A certain amount of pilot

discretion is recognized to be necessary while in the air to determine appropriate application within the treatment areas. Field inspectors will be made aware of this pilot discretion.

Aerial Mulch Cover Material Assessment Protocol:

Wood Shred Size and Composition: The material will be screened through an appropriately sized sampling screen (1/2" – 1" opening) needed to meet the size specifications with no more than 30% of any sample comprised of fines less than 1" diameter by volume. All samples with a proportion of "fines" greater than 30% will be considered not acceptable per the material specification. See Additional Notes on Material Specification and Quality Assurance below.

Methodology: The methodology described below will be used to assess the adequacy of the cover material.

1. Draw two lines inside a five gallon bucket with a permanent marker: The first line is drawn 2/3 up from the bottom of the bucket which represents 3.3 gallons; this is the sample volume. Draw the second line at the 1.0 gallon level to demarcate the 30% "fines" sample threshold.

2. With the bucket, collect mulch (material specification sample) to the upper (3.3 gallon) line, noting where the sample was taken from: site/pile identifier, horizontal (i.e. northwest corner, center, etc.) and vertical (i.e. Top, middle or bottom) locations within the pile.

3. In a continuous motion pour and shake the collected material on to the 1/2" - 1" sieve, which is 3 feet above a tarp (or something that effectively catches the material). Agitate the sieve. Material that falls through the sieve is a fine that does not meet the specification. When done, set the wood shred that did not fall through the sieve aside for further assessment if necessary.

4. Pour the sieved "fines" back into the bucket, and level the contents to make an even plane of fines at the bottom of the bucket. If the "fines" exceed the 30% mark (1.0 gallons, lower line) of the bucket after being leveled, then the sample does not pass.

Additional Notes on Material Specification and Quality Assurance:

Note where all the material specification samples are taken from, e.g. bottom or top, front or back. In the event that material samples fail for wood shred, consider several alternatives before the entire lot or individual pile is rejected.

If material is consistently just below the minimum specification from any given sample location, consider mixing the pile prior to testing additional specification samples. Eventually, either repeat or rescreen and discard enough "fines" from the pile so the specification is met.

If material still does not meet the minimum specification, consider mixing in new additional material that meets the minimum specification and retest.

For wood shred, ensure that the setting in the grinder is consistently producing the specified material. If the out feed conveyor is able to articulate and it is feasible, consider aiming the conveyor out feed into the wind to further separate fines from the specified material.

Application Assessment Protocol (Cover Assessment Considerations)

Due to the difficulty of the terrain, the time and effort required to gain access to the areas will be intensive. As a result more time will likely be taken to gain the sample points than to actually collect the data. Therefore, it will be advantageous to collect enough data to safely infer the variation of cover within a single treatment polygon. The confidence in data results should constitute no more than "a preponderance of evidence" that the coverage was applied to specification.

All treatment polygons will be given a generalized total cover estimate from afar, either from vantage points or aerial imagery. Additionally, at a minimum, a random sample of a subset of treatment polygons will be selected for a quantitative assessment using line point transects. The NRCS reserves the right to inspect every treatment polygon.

Cover will be estimated and documented utilizing a 100 point step transect. A cover point will be assessed every other step by the inspector to estimate post treatment percent cover of wood shred mulch. A mark on the inspector's boot will insure consistency. The only time the inspector looks down at the boot is when recording the hit. Transects will be randomly located within treatment polygons via randomly selected transect starting points (identified by a GPS waypoint or mark on a treatment map). Transects will be paced on a random bearing in a straight line. The minimum sampling density will be 1 transect per 100 acres or polygon. The inspector, at their discretion, can do 2 more transects from the same starting point with in the polygon if it is not clear that the application has met the 70% criteria. Pictures of the transect will be taken at the time of cover measurement. All transect information will be recorded on the approved inspection form and signed and dated by the inspector. If the 70% criterion is not met, the inspector will notify the vendor representative of the deficiency. The vendor representative will notify the contractor and the contractor will take corrective action as soon as flight and ground operations permit. A timely follow up inspection will occur on the deficient treatment area to insure mulching operations are not unduly impeded.

For sites that cannot be accessed due to landowner permissions or terrain limitations, a visual estimate will have to be employed. This may be from a vantage point or via flights on a helicopter. Please note though, color of wood shred can vary greatly depending on species and whether it is dead/heavily charred, resulting in mistaken "low" estimations of cover across the treatment polygon. Visual inspections from the air or vantage points will also be noted on the approved inspection form. Therefore, all effort will be made to access the polygons on the ground to perform the step point transect method of determining percent cover. The vendor representative will attain load tickets for every treatment polygon to verify that sufficient mulch material has been applied. Vendor representative will provide load tickets to the inspectors on a daily basis. Load tickets will be compared to documented, and attached to the inspection form. NRCS will do a second level review of the inspection form and sign off on the form to insure that the objectives of the mulching have been met per polygon.

Prior to the closing of a staging area and movement to a new staging area all treatment polygons will be signed off by NRCS as being adequate through the second level review process.

The inspectors will consist of trained NRCS, City of Greeley, City of Fort Collins, Coalition for the Poudre River Watershed, JW Associates, and other qualified personnel.

Wood Mulch Source Material

Wood to be mulched for this project can be transported into the sites. However, there will likely be some opportunity to use burned trees (see below) as mulch source materials. These trees would need to be removed before or during the mulching operations. The amount of material available has not been determined.