COUNTY OF BOULDER
POST-FIRE MITIGATION RESPONSE

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"A report submitted to the University of Colorado at Denver, Civil Engineering Department in partial fulfillment of the Senior Design course"

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We would also like to extend our appreciation to the County of Boulder, specifically Mike Thomas, County Engineer, and Sharla Benjamin, Project Engineer, for the opportunity to participate in the development of post fire mitigation for the Geer Canyon area.

We thank Kevin Grady, Resident Park Ranger, for his time and insight.

Lastly, we wish to express our gratitude to SEH, specifically, Erica Olsen, Project Manager, and Drew Chandler, Senior Engineer, for their guidance and support in this project.

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March 3, 2021

Mike Thomas, P.E., County Engineer
Boulder County Public Works
2525 13th St., Suite #203
Boulder, CO 80304

Re: Letter of Transmittal – Geer Canyon Post Fire Mitigation

Dear Mr. Thomas,

Team Initiate with the University of Colorado Denver's Senior Design would like to thank you for the privilege of studying the Geer Canyon watershed for the post-fire mitigation response of the Calwood wildfire.

The purpose of our involvement is to make improvements to mitigate future high debris flows and water flows through Geer Canyon to protect existing infrastructure such as the Wapiti Trail, Geer Canyon Drive, the parking lot and the water structures; as well as to ensure the continuation of the water supply to the surrounding residents. As part of our investigation, we performed a site visit on March 1, 2021 and met with the county engineer, project engineer and resident ranger, to obtain a better understanding of the terrain. We also took soil samples to analyze erosion and debris flows based on the soil types throughout the trails and Canyon. This report contains our findings, recommendations, and conclusions on ways to mitigate the Geer Canyon area after the Calwood wildfire in order to reopen this space for public use and recreation.

Best Regards,

Abril Gonzalez-Torres   Samuel Rivera   Quinten Schaffner   Andrew Riley

Shannon Lamb   Batool Shehab

I. Project Background

Many areas in the United States (US) are expected to get hotter and drier with climate change, and therefore the risk of wildfires is expected to rise. Although wildfires can be beneficial for ecosystems, where plant life and soils can adapt, they can be dangerous to humans. The population rise in the US indicates an increase in rural population and as a result, more structures are placed in harm's way: to burns and to dangerous water and debris flows that occur after the wildfire is extinguished.

In 2013, Boulder experienced significant rainfall, causing flooding, loss of life, and widespread damage to the county's infrastructure. More than 18 inches of rainfall caused 25- to 100-year flooding along Boulder's drainageways. Following the flood, the Colorado Water Conservation Board (CWCB) initiated a program to re-map the predicted 1% annual chance flood zone (100-year floodplain) of the most affected waterways (refer to Exhibit 1A), including Geer Canyon. Changes to the floodplains were made based on the Federal Emergency Management Agency's (FEMA) Preliminary Flood Insurance Rate Maps (FIRMs) for stream reaches studied by the Colorado Hazard Mapping Program (CHAMP). Geer Canyon happens to be one of such streams.

Figure 1: 2013 Boulder County Flood

Geer Canyon has a history of high-water flows and with the recent Calwood wildfire, water flows will only increase. The Calwood wildfire was sparked on October 17, 2020 from undetermined reasons based on reports from the Boulder County Sheriff's Office (BCSO). The fire was extinguished on November 14, 2020 and recorded as the largest wildfire in Boulder County history, with winds reaching up to 60 miles per hour making the damage span 10,106 acres above Geer Canyon within Boulder County, Colorado (refer to Exhibit 1B). The fire event put a portion of the county's watershed and transportation infrastructure in jeopardy. Due to this area being so extensive, this project will focus on the Geer Canyon Watershed, which includes 4,058 acres of burn area with 1,170 acres of high severity burn (28%), 1,548 acres of moderate severity burn (37%), 1,315 acres of low severity burn (32%) and only 120 acres that remained unburned (3%) (refer to Exhibit 1C).

Figure 2: Calwood Wildfire

II. Purpose

Post-fire mitigation can be difficult to design due to the variability in rainfall intensity, the severity of the fire, the soil burn severity, and how much vegetative cover is remaining. Each of these factors influence how extreme the runoff and erosion can be.

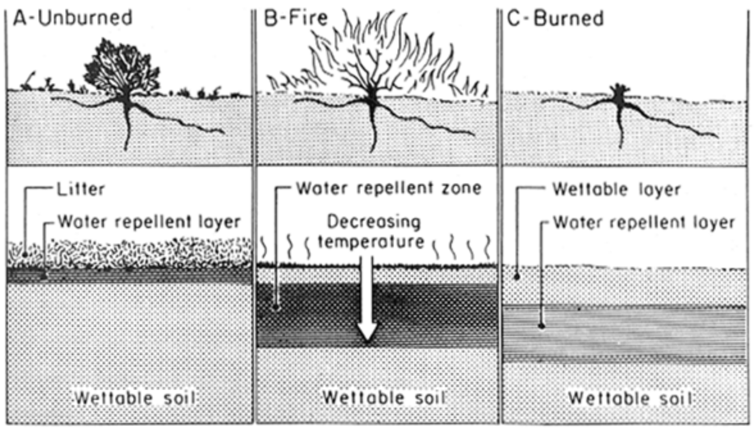

Figure 3: Soil Conditions Before, During and After Fire. (A) before fire, hydrophobic substances accumulate in the litter layer and mineral soil immediately beneath; (B) fire burns the vegetation and litter layer, causing hydrophobic substances to move downward along temperature gradients; (C) after fire, a water-repellent layer is present below and parallel to the soil surface on the burned area

In an unburned forest, the risk of soil erosion and water flow is not high because existing vegetation creates an encouraging environment for quick infiltration. After a wildfire, it is typical for soil to become hydrophobic. This is due to the hydrocarbon residue that has been created with the burn of the organic materials. This residue soaks into empty pore spaces in the soils, making the surface impervious to water, thus future waterflow brings debris and water down into draws and waterways with a higher velocity and a larger quantity. Debris flows are among the most hazardous risks of rainfall on burned hillslopes. The flows can occur with little warning and can exert great impact loads on structures in their paths. Even small debris flows can strip vegetation, block drainage ways, damage structures, and endanger human life. In the Geer Canyon area, the main section of concern for these flows is the culvert under Lefthand Canyon Drive which is where the central water supply for the residents in the area near the

Figure 4: Soil Samples Collected at Varying Burn Degrees. Left, medium burn severity. Middle, vegetation regrowth. Right, high burn severity

Calwood Fire burn is located. Sediment delivery from debris flows can “bulk” the volume of flood flows, creating an even greater downstream flooding hazard and enough sediment buildup to cut off water supply. To avoid debris and water flows from coming down so heavily, wiping away existing structures and clogging the mouth of Deer Creek mitigation structures can be strategically placed in the burn area.

Within the Geer Watershed area (refer to Exhibit 1C), Boulder County is specifically concerned about three major points of interest (POI), which are indicated by the purple stars in Exhibit 2. These were determined by the United States Forest Service Burned Area Emergency Response (USFS BAER) assessment, which was performed due to the area being property of the Arapaho-Roosevelt National Forests, and the results indicate 60 to 100% hazardous debris flows (refer to Exhibit 1D) in this burned area of the Calwood Fire. Around POI 1, on the west side of the parking lot, an existing logging road runs parallel to the channel along the draw that is perpendicular to the trail (refer to Exhibit 3A). If these two paths combine during a rainfall event, the area would become flooded as water would follow the channel direction and wipe out the parking lot and trail or these structures will become the new flow path. At POI 2, water flows are expected to rise in volume and velocity which will destroy the existing channel and trail (refer to Exhibit 3B). Lastly, at POI 3 water flows are expected to exceed existing culvert capacity (refer to Exhibit 3C). Debris at this point also has the protentional of reducing the existing culvert capacity by clogging and blocking water passage. It is likely for water to spill over the channel and onto the existing paved roadway.

Therefore, this report will examine various aspects of wildfire mitigation responses in order to provide an applicable and reliable response to prevent this occurrence. The design efforts from previous wildfire mitigation plans of various Colorado municipalities have been examined, lab tests on the soil burn severity and soil types have been performed to analyze future debris and water flow velocities, and simulations with this information have been conducted to develop a suitable design. This design includes low-, moderate-, and high-cost mitigation plans with various erosion control structures and basins to reduce the risks posed by flooding and erosion.

III. Jurisdiction Having Authority

Geer Canyon is public land and under the jurisdiction of the City and County of Boulder. Some areas around our study belong to the USFS. These jurisdictions have authority over the response of post-fire mitigation procedures. Suggestions will be provided and presented to these authorities:

Boulder County Public Works, 2525 13th Street, Boulder, CO 80304.

U.S. Forest Service, 2140 Yarmouth Ave, Boulder, CO 80301.

Colorado State Forest Service, 5625 Ute Highway, Longmont, CO 80503.

USDA Forest Service, San Isabel National Forest, 2840 Kachina Drive, Pueblo, CO 81008

Further north along the Wapiti trail, there are eagle's nests located in trees. The study is not concerned with this area because permits and different regulations are applicable due to the protected bird species.

IV. <u>Applicable Codes</u>

In post-fire mitigation procedures, there are various codes that must be considered when creating a design and plan of implementation. There are national codes, state codes, and county codes to comply with. The national codes being the first and most important regulations to comply with following the state and county codes respectively. The International Code Council, the ICC, created the International Wildland Urban Interface (WUI) code to define both general and WUI requirements after a wildfire. The state code was created by the Colorado Department of Transportation (CDOT) which is the most applicable for the points of interest in the Calwood Fire: specifying procedures for the removal of debris, of portions of present structures, and of excavation and embankment. Lastly, the Boulder County Land Use code gives the regulations of procedures following disasters and land development standards.

The codes which provided regulations and guidance in our design are as follows:

National Code - International Code Council: 2018 International Wildland Urban Interface Code

Chapter 4: Wildland-Urban Interface Area Requirements

Appendix A: General Requirements

Appendix B: Vegetation Management Plan

Appendix F: Characteristics of Fire-Resistive Vegetation

State Code - Colorado Department of Transportation:

2021 Master Item Code Book – Spec Year 05

Section 201: Removal of Debris

Section 202: Removal of Portions of Present Structure

Section 203: Excavation and Embankment

Boulder County - Land Use Code

Article 7: Development Standards

7-1100: Fire Protection

Article 14: Rubbish, Weeds and Brush, and Unsafe Structure

Article 19: Procedures Following Disasters

V. Design Considerations

To create a suitable design, there are various aspects to consider which are specific to the landscape, existing environment, and client's requests. The main consideration was to implement erosion control structures that do not need to be constructed with heavy equipment or machinery due to the limited access and rocky terrain and slope. Not only would heavy machinery not be able to access certain areas of interest, but many mitigation structures considered in the design need proper maintenance and clearing by rangers and/or small, light equipment. Frequency of clearing will be dependent on rainfall events and amounts of debris flow. Furthermore, the city engineer and project engineer, emphasized the desire for temporary mitigation structures rather than permanent. Once regrowth of vegetation occurs, soils will become pervious, thus stabilizing the amounts of debris and water running down the slopes. The design recommended is intended to prevent debris and water flow for 5 to 7 years and several structures involved will be easily removable. Due to the structures' temporary time, costs were considered to create an economical, yet effective mitigation plan.

As of March of 2021, there were sixteen companies working on creating mulch from the dead trees in the area and each being assigned areas and dates of distribution. The mulch distribution boundaries near the site location are shown in Exhibit 1F. Although there are multiple considerations in any post wildfire mitigation plan, these were the principal concerns of the client, and therefore, were the design's foundations.

VI. Findings

A. Case History

After contacting various municipalities throughout Colorado, more information was obtained over previous mitigation efforts that have been both successful and unsuccessful for those counties. Every wildfire requires a specific mitigation response depending on the climate, topography, soil burn severity, existing vegetation, and other location-specific factors. Three different Colorado municipalities gave information regarding general recommendations and firsthand experiences in fire mitigation. These municipalities included Durango, Pueblo, and Summit counties.

Each of these counties seemed to have an overall general post-fire mitigation response which is then specialized after the fire is 100 percent contained and soil burn severity tests and reports can be created, slopes can be analyzed, and remaining vegetation can be tracked. Some of the biggest challenges these municipalities have faced are ways to stabilize the soil to prevent mudslides and degradation of water quality. After a wildfire in Pueblo, substantial amounts of debris fell into the main river and filled it with ash and dirt, diminishing the water quality and threatening fish and river life. After the 416 Fire, the environmental engineer of Durango acknowledged the rainfall data was useful in helping to predict storms and rainfall patterns but gave a broad spectrum of the likelihood of rainfall events due to the inconsistent climate, especially of rainfall, in Colorado. However, this fire was different because the fire occurred in a time where rainfalls were most frequent. Most of the mitigation structures in this case had to be placed immediately after the fire was put out. Time for planning was very limited. Mitigation included the placing of sandbags, concrete barriers, and reconstructing ditches in order to help redirect future flooding and increase the capacity of pre-existing channels. Another large concern for many counties is the threat to human life and safety, so the BAER team suggested that the best approach when dealing with flooding was to focus on area closures, warning signs, and an early warning system to notify citizens of damaging or dangerous storms nearby. Furthermore, regular areas of top priority are the wildland urban interface, WUI, which are areas located in the open space between the built environment and the natural environment. Ensuring the WUI is protected and equipped for a wildfire is a large concern for low-elevation wildfires where people live due to the mass destruction a wildfire can cause not only on existing homes and infrastructure but on human lives and safety.

The municipalities were helpful in providing general guidance over areas to focus on due to past mitigation efforts, but also made it clear that each wildfire spreads in unpredictable ways and causes various areas of concern. The design suggested in this report takes these considerations into account and provides a location-specific mitigation response which acknowledges the possible failures and setbacks these other municipalities have experienced.

B. Site Analysis

After analysis of the mountain and upper lot, three main channels for water and sediment to impact the creek and infrastructure were located. The three channels in the mountain also experienced the highest burn severity in the surrounding area. Burn severity affects the trees, ground cover, and soil composition, creating an environment for large rain events in the late spring to summer months to create large destructive flows. Previous flood damage still exists from the 2013 100 year event along with limited infrastructure and flood and sediment control measures to prevent further damage to the roads and parking lot. Already-existing sediment control structures include check dams along the road, rip rap lining the creek along the parking lot and road and a new culvert and flood capture basin.

The current project site is centered around the main area where the public interacts with the forest. All three major channels feed directly onto the road and require mitigation designs that will prevent large rocks, branches, and smaller sediment from falling and potentially damaging the parking lot and trail (refer to Figure 5). Draw 1 in Figure 5 is an area of major concern due to the fire destroying two pre-existing High Density Polyethylene (HDPE) culverts for the upper and lower section of roadway. Preoccupied with extinguishing the fire, the fire department ended up collapsing the trail after the fire had burned away the culverts. The collapsed area was partially filled with rip rap to allow water to flow over the trail in the meantime. Due to the trail's less than optimal state, getting any sort of heavy equipment to draws 1, 2 and 3, in POI 1 and 2, it will likely not be possible to install any mitigation structures to draws 2 and 3 until draw 1 is addressed.

The 2013 flood caused realignment and earthwork at POI 2, around draws 3 and 4. With the recent fire damage, the area is expected to experience large volumes of water flow. However, efforts to mitigate this volume will only be focused on draw 3 due to a bald eagle nesting grounds. Draw 5, around POI 1, is also an area of concern because of the existing logging road.

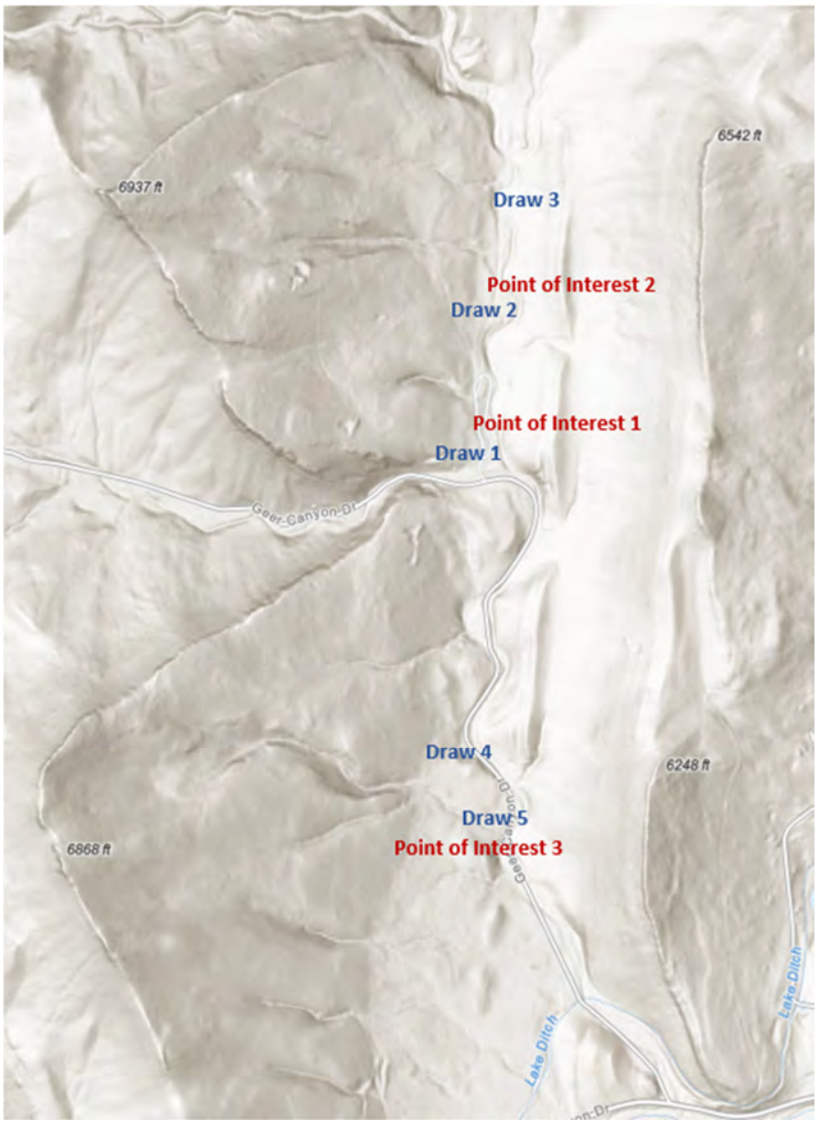

Figure 5: Geer Canyon terrain map with the main path depicted in a black line.

Most of the mitigation efforts will focus on safely transporting the water from one side of the road to the other into Geer Creek that sits on the right side of the road. Although efforts further down Geer Creek will also be considered to ensure the impact of the increased flow does not permanently damage Geer Creek mainly center around draw 3. Beyond protection of the immediate infrastructure, Geer Creek feeds a water distribution plant in the nearby area and towns. Should large amounts of debris and ash clog Greer Creek during an event, the creek will likely shut down the water facilities to nearby areas to prevent damage to water distribution systems. The current design direction is to prevent large debris from entering the system.

Designs for the flood control must consider the terrain and vehicle access. Steep slopes and rocky outcrops prevent most types of vehicles from going off the designated roads, restricting any measures at higher elevations to those built and maintained by hand. Areas that are expected to clog either due to purposeful design or natural causes would preferably be placed near the side of Greer Canyon Drive to allow for small machinery to come in and effectively unclog the systems. Any system that are installed will also need to be place near Geer Canyon Dr or the main parking lot and trail to allow equipment and supplies to enter and exit the sites.

To determine flow, the area for the catchment basin was calculated for the side of the mountain using Geographic information system (GIS) data from the United States Department of Agriculture (USDA) topographical mapping system. The same mapping data also gave the elevation of the top of the mountain and the roadway. A waterdrop analysis of the area was also performed in AutoDesk Civil3D (refer to Figure 6) that showed the longest path water would take to reach the roadway as well as the boundaries of each basin. The resulting slopes of the basin's area ranged between 16 and 25%. Selecting the larger side of the range, 25%, allows for a more conservative approach for the expected flow produced from the mountainside.

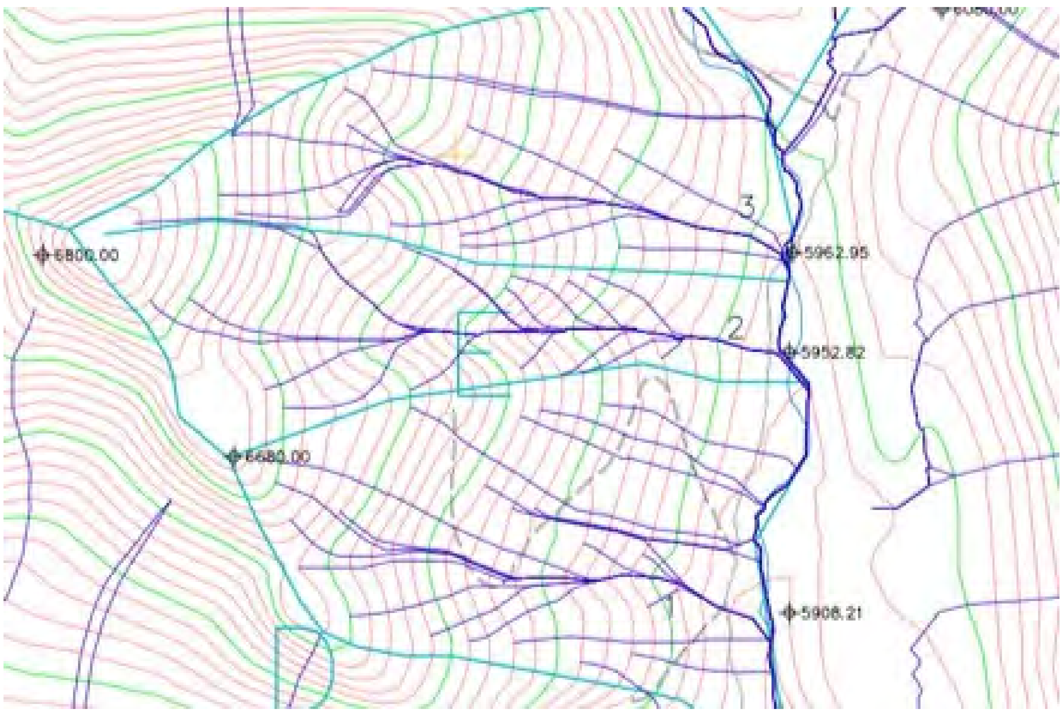

Figure 6: Geer Canyon topo map with catchment basins in light blue and water drop paths in dark blue (1-3)

The National Oceanic and Atmospheric Association (NOAA) through the National Weather Service provides maps and data on the precipitation frequency and intensity for water basins throughout the US. The NOAA ATLAS 14 Point Precipitation tool allows for local weather stations and geographical data to create precipitation frequency and precipitation intensity tables that are used for estimating rainfall events in the nearby areas for different rainfall return periods and event durations ranging from 5 minute to 24 hour events. With the precipitation intensity shown in units of inches per hour, the basin in consideration can be simplified for the Rational method of flow analysis in a basin. The assumptions of the simplification are that there is negligible infiltration into the soil, and water will run off the land and into the waterways in the catchment area.

Anticipated flow characteristics from the Rational method for a 10 year event with a 15 minute duration in draw 1 are a volumetric flow 189 cubic feet per second, moving at a velocity of 21 feet per second. The depth of the flow will be approximately 1 foot 6 inches deep spreading out to a top width of 10 feet.

The next two draws show similar characteristics. The volumetric flow for 2 is 127 cubic feet per second moving at 19 feet per second. The depth of the flow would be 1 foot 4 inches deep and have a top width of almost 9 feet. Basin 3 will produce a flow of 171 cubic feet per second with a velocity of 21 feet per second while being 1 foot 6 inches deep.

Because these flows are all open channel flows, they are all turbulent flows, making the Reynolds number unnecessary for calculation. Instead, the critical design parameter for the flow is the Froude number. The Froude Number is the ratio between the velocity of the flow and the wave celerity. When the Froude number is higher than 1, then the flow is supercritical and scouring can occur along the bottom of the channel, at drops, and at entrances for structures such as culverts. The 3 major draws defined earlier, 1, 2, and 3, located at POI 1 and 2, all have calculated Froude numbers of 4.12, 4.01, and 4.09, which indicate extensive scouring and erosion will occur.

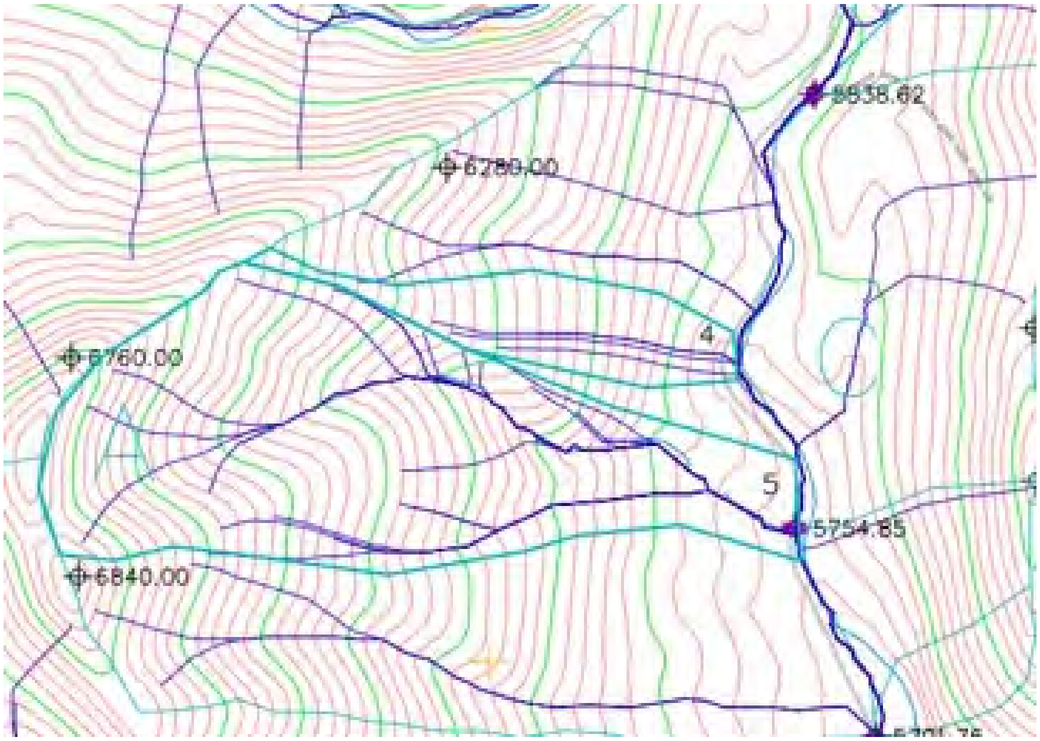

Figure 7: Geer Canyon topo map with catchment basins in light blue and water drop paths in dark blue (4 and 5)

While they suffered less burn severity than the northern draws, two more draws (refer to Figure 7) located along POI 3 also have a chance of seeing increased runoff in an intense storm event. The flow at the most northern of the two draws is expected to be around 55 cubic feet per second, which is more than double the pre-fire estimates of 18 cubic feet per second. The same pattern follows with the flow from the southern draw, which is expected to be around 101 cubic feet per second. The increase in this flow is also about 2 times the pre-fire flow, demanding action to be taken in to prevent flooding and debris from obstructing and damaging the roads.

C. Debris Analysis

High Burn

Weight of Container	316.93	g
Weight of Container + Dry Soil	940	g
Weight of Dry Sample	623.07	g

Sieve #	Diameter mm	Empty Sieve Mass g	Sieve + Soil Mass g	Soil Retained g	Retained %	Cumulative %	Passing %
4	4.75	468.17	561.94	93.77	15.05%	15.05%	78.70%
20	0.84	390.01	559.79	169.78	27.25%	42.30%	51.45%
40	0.425	356.02	423.91	67.89	10.90%	53.19%	40.55%
60	0.25	294.59	400.22	105.63	16.95%	70.15%	23.60%
100	0.15	306.11	379.43	73.32	11.77%	81.92%	11.83%
200	0.075	293.66	344.60	50.94	8.18%	90.09%	3.65%
Pan	- -	316.93	339.70	22.77	3.65%	93.75%	0.00%
				584.1			

Gravel:	15.05%	
Sand:	27.25%	
Fine:	47.79%	
D10	0.15	
D30	0.425	
D60	4.75	
Cu	31.6667	>15
Cc	0.25351	

Table 1: Sieve Test for High Burn Soil Collected from Site

Soil samples were collected at the site to confirm hydrophobicity. Although BAER analysis state debris flows to be 60 to 80% probability at the draws of interest (refer to Exhibit 1D) amount of sediment erosion was unknow. Knowing the type of soils being delt with, provide inputs for soil texture and rock content like seen in figure 8.

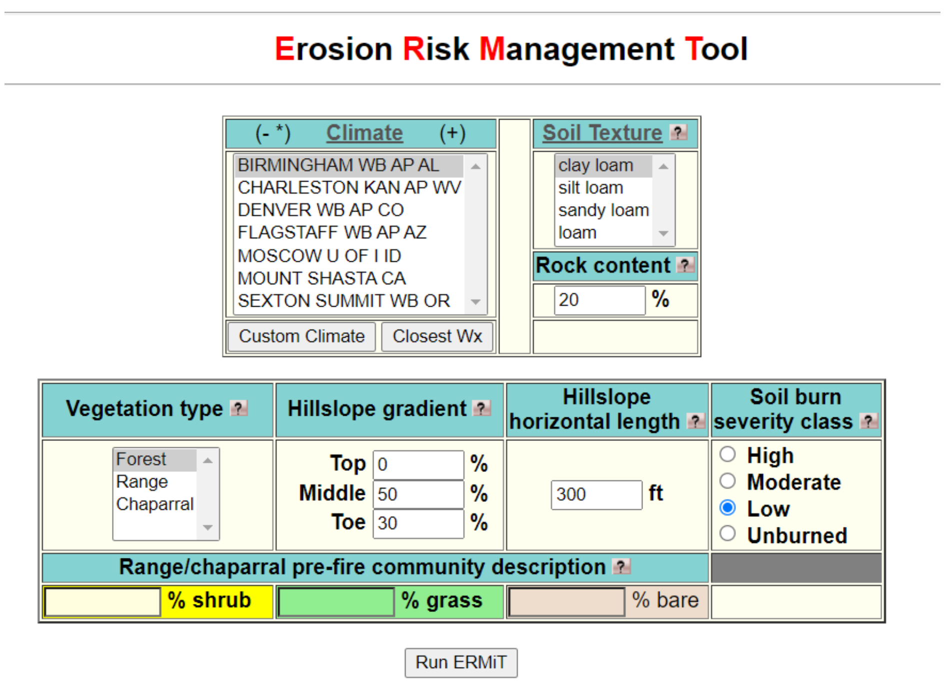

Figure 8: Online Erosion Risk Management Tool

The size of rocks that can be carried in the channels during a 10 year storm event was calculated to be between 4 inched and 6 inches in diameter. This follows a rule of thumb for sediment transport in a channel:

$$Sediment\ Diameter = Q_d * S \qquad \text{(eq. VI - C1)}$$

Where S = slope of the channel in (ft/ft) and Q_d = flow depth (ft)

Debris and soil erosion estimates were obtained using the Erosion Risk Management Tool published by the USFS. The Erosion Risk Management Tool (ERMiT) is a web-based application that uses Water Erosion Prediction Project (WEPP) technology to estimate the amount of sediment erosion that could occur for the first 5 years after a fire (refer to Exhibit 4O). The estimates are calculated as probabilistic terms over different inputs that include burn rate, forest vegetation, soil properties, and hill slopes, as well as whether other erosion treatments have been put in place such as mulching, seeding, and straw waddle barriers.

To get the sediment debris for the upper basins at POI 1 and 2, inputs of 23% for the hillslope, sandy loam soil texture, a high soil burn severity and a maximum hillslope length of 1000 feet were used. The actual hillslope lengths vary and are all over 3,300 feet long but the parameters in the application only allow for a maximum of 1000 feet. With all other factors being accurate and the actual hillslope being 3 times longer than the design slope, the estimated soil amounts were calculated to be less than 2 times the amount given by the application.

In the first year after the fire, with no mulch treatment of the slopes, at the 20% probability level, 13.39 ton/acre of sediment is expected in the discharge from a rain event. This amount drops to 4.89 tons/acre with a 0.5 ton/acre of mulch applied to the surface. This output can be extrapolated to all three major draws at POI 1 and 2 due to the similar terrain, soil, and burn severity for the section of the mountain.

VII. Recommendations

A total of 6 different structures have been proposed to help guide the flow of the various draws, to help mitigate the erosion of the park's trails, roads, and parking lot, and to protect the park infrastructure from large debris items and potential clogs of essential drainage structures. The structures include an armored drainage crossing, debris deflectors, debris racks, Reinforced Concrete Pipe| (RCP) culverts with headwalls, flood barrier bags, and grouted riprap along draw channels. These structures are recommended to be placed at differing locations based upon ease of access for equipment, effectiveness of the structure at specific locations, and the needs of drainage control and erosion mitigation at the specific locations (refer to Exhibit 3D for general map of structure locations). Below is a more detailed technical analysis of each structure and how they were designed and utilized for erosion mitigation and drainage purposes.

A. Armored Drainage Crossing

An armored drainage crossing is recommended to be placed at POI 2 at the middle draw found in basin A (refer to Exhibit 3F for location). The proposed drainage crossing is located here due to the non-existent drainage structure in this location. The crossing will help guide the flows into Geer Creek. Without an effective drainage structure, flows have the possibility to end up flowing parallel to and down the trail, leading the flow towards the northern parking lot and causing erosion to both the trail along the way and the parking lot. With the installment of a drainage crossing at this draw, water can then flow over the trail to the nearby creek while decreasing the probabilities of negative impacts of erosion to the trail. The other draws within the two main basins of the mitigation efforts have existing drainage structures in place, so the drainage crossing placement at this specific draw was made with those factors in mind.

To design the armored drainage crossing, a trapezoidal shaped channel was utilized to mimic a more natural look that would tie in nicely with the trail it would be placed across. The design parameters for the drainage crossing include a 10 ft channel bottom width, 10 ft/1 ft side slopes on each side of the crossing, a longitudinal slope of 10% for the channel bottom, a Manning's n coefficient of 0.025 due to existing soils and surface conditions, and a design discharge of 173 cubic feet per second that needs to be met or exceeded. Table 2 provides a visual of the parameters and a typical cross section of the type of trapezoidal channel used for the armored drainage crossing:

DESIGN CONDITIONS:			
Bottom Width	B =	10	ft
Left Side Slope	Z1 =	10	ft/ft
Right Side Slope	Z2 =	10	ft/ft
Mannings n	n =	0.025	
Longitudinal Slope	S =	10%	ft/ft
Flow rate	Q =	173	cfs

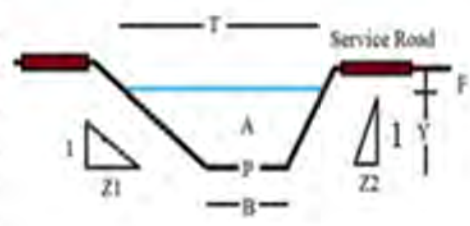

Table 2: Setup for Armored Drainage Crossing Calculations

The armored drainage crossing will be a total length of 30 feet, with the 10 foot bottom width being made of compacted soil riprap to help mitigate the erosion of the channel bottom. The riprap will have a total depth of 2 feet starting at the middle of the channel bottom and will be laid flat for the 30 foot width of the bottom and the slopes and tieback into the tops of the slopes at each side. The riprap channel will also extend 5 feet past the trail on either side to prevent the erosion of the trail at the inlet and outlet side of the crossing. To help the crossing neatly tie back into the trail, an earth filled berm was designed to be installed on the downside part of the crossing at the top of the left side slope, with a 5-foot flat top before the berm begins to go downhill at a 10% slope and meeting back up with the existing 5% slope of the trail. There will also be a small 6 inch installment of the existing compacted gravel material used for the trail to be laid over the berm and the crossing so that the drainage crossing integrates naturally as a part of the trail system. Refer to Exhibit 5 S-1 for detail drawings of the armored drainage crossing.

With the design parameters mentioned previously in mind, calculations of the various hydraulic properties of the drainage crossing were made. Manning's formula was utilized to calculate these different hydraulic properties. With a 10% side slope on each side, as well as a 10 foot bottom width, maximum flow conditions included a 1 foot flow depth with a total top width of 30 feet as well as a flow area of 20 square feet. These various drainage crossing properties resulted in a wetted perimeter of 31 feet, a hydraulic radius of 0.664 feet, and a hydraulic depth of 0.667 feet. These hydraulic properties for the drainage crossing allowed for a maximum allowable flow rate of 286.26 cubic feet per second with a flow velocity of 14.31 feet per second and a Froude number of 3.09, which indicates supercritical flow. The high Froude number essentially entails a shallow, fast moving flow which is to be expected with such a shallow flow depth and high flow rate. Also, with such a large maximum flow rate allowable for this drainage crossing, the drainage crossing has far surpassed the recommended flow rate of 173 feet per second needed for efficient drainage of a 10 year storm event that it was designed for. Table 3 contains the final design data and values of the different hydraulic properties of the crossing. Below are the Manning's formulas used:

$$A = BY + ZY^2 \qquad \text{(eq. VII – A1)}$$

$$P = B + 2Y\sqrt{1 + Z^2} \qquad \text{(eq. VII – A2)}$$

Where P = Wetted Perimeter (ft)

$$R = \frac{A}{P} \qquad \text{(eq. VII – A3)}$$

Where R = Hydraulic Radius (ft)

$$V = \frac{1.486}{n} R^{2/3}\sqrt{S_x} \qquad \text{(eq. VII – A4)}$$

Were V = Cross section normal velocity (ft*sec), n = Manning's roughness, and

Sx = Channel bottom slope

$$U = \frac{K}{n} R^{2/3} S^{1/2} \quad \text{(eq. VII – A5)}$$

U = Flow Velocity in (ft*sec), K = constant (1.486) (ft*sec), and S = Channel slope

$$U = UA = \frac{K}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2} A = \frac{K}{n} A^{5/3} P^{-2/3} \sqrt{S} \quad \text{(eq. VII – A6)}$$

$$T = B + 2ZY \quad \text{(eq. VII – A7)}$$

Where T = Top Width (ft)

$$D = \frac{A}{T} \quad \text{(eq. VII – A8)}$$

Where D = Hydraulic Depth (ft)

$$F_r = \sqrt{\frac{Q^2 T}{g A^3}} \quad \text{(eq. VII – A9)}$$

Where Fr = Froude's Number, Q = Flow Rate $\left({ft^3}/{sec}\right)$, and g = Acceleration due to gravity $\left({ft^2}/{sec}\right)$

A = Flow Area (ft^2), B = Bottom Width (ft), Y = Flow Depth (ft), Z = Side Slope

(Some variables in these equations are not shown in the data within Table 3)

Flow Depth Y ft	Flow Area A sq ft	Top Width Top ft	Wetted P-meter P-meter ft	Hy-Radius R ft	Hy-Depth D ft	Flow Velocity U fps	Flow rate Q cfs	Froude Number Fr
1	20	30	30.100	0.664	0.667	14.31	286.26	3.09

Table 3: Final Design Data

The armored drainage crossing could have the flow depth reduced along with a decrease in maximum flow rate and velocity capacity by shortening the side slope horizontal lengths, but with 10 feet horizontal lengths the drainage crossing ties back into the trail much more subtly. With such a large flow rate capacity, the armored drainage crossing should have no issues in allowing water to drain safely and efficiently across the trail in storm events much larger than a 10 year, 14 minute duration event.

B. Grouted Riprap

A riprap apron is proposed to be used as energy dissipation. The equations for riprap design in Chapter 9 of the Urban Drainage Criteria Manual Vol.2 were used for this study (refer to Exhibit 4M for calculations). The purpose of the grouted riprap along the draw channels is to mitigate the risk of loose debris items getting caught in the flows, flowing down the draws, and damaging the drainage structures and park/trail infrastructure. The grouted riprap will also help to control and dissipate the flow velocities, allowing the debris flows to slow down and pose less of a hazard before reaching the drainage structures, trails, and roads.

Figure 9: Example of Grouted Riprap in 416 Fire Mitigation

Grouted riprap will be installed at a single draw at POI 3, based upon ease of access for the necessary equipment needed as well as the park and trails' infrastructure at the high risk of debris flows that could cause adverse effects (refer to Exhibit 3H for location of the grouted riprap). For example, POI 1 was looked at for placement of grouted riprap, but type VH is the recommended grain size for the expected flows. Type VH riprap is typically 24 inches in diameter, weighing from 35 to 3,500 pounds (refer to Table 4). Since POI 1 is at the mouth of Wapiti Trail, moving massive equipment would be very difficult. Type L, 1.3 to 160 pounds in weight, riprap was determined to be suitable for POI 3. Since this channel is near the paved roadway and significantly less heavy material is needed, construction of this type of structure is feasible. To find sizing, the equation below and table 5 were used (refer to Exhibit 4M for calculations).

$$d_{50} = \frac{0.023Q}{Y_t^{1.2} D_c^{0.3}} \qquad \text{(eq. VII – B1)}$$

Where Q = design discharge, Y_t = tailwater depth, and D_c = diameter of circular culvert

Pay Item		Percent of Material Smaller Than Typical Stone[2]	Typical Stone Dimensions[3] (Inches)	Typical Stone Weight[4] (Pounds)	
	Stone Size d50[1] (Inches)				Type
Riprap	6	70-100 50-70 35-50 2-10	12 9 6 2	85 35 10 0.4	VL
Riprap	9	70-100 50-70 35-50 2-10	15 12 9 3	160 85 35 1.3	L
Riprap	12	70-100 50-70 35-50 2-10	21 18 12 4	440 275 85 3	M
Riprap	18	100 50-70 35-50 2-10	30 24 18 6	1280 650 275 10	H
Riprap	24	100 50-70 35-50 2-10	42 33 24 9	3500 1700 650 35	LH

[1]d50 = nominal stone size
[2]based on typical rock mass
[3]equivalent spherical diameter
[4]based on a specific gravity = 2.5

Table 4: Standard CDOT Gradations for Rock Riprap

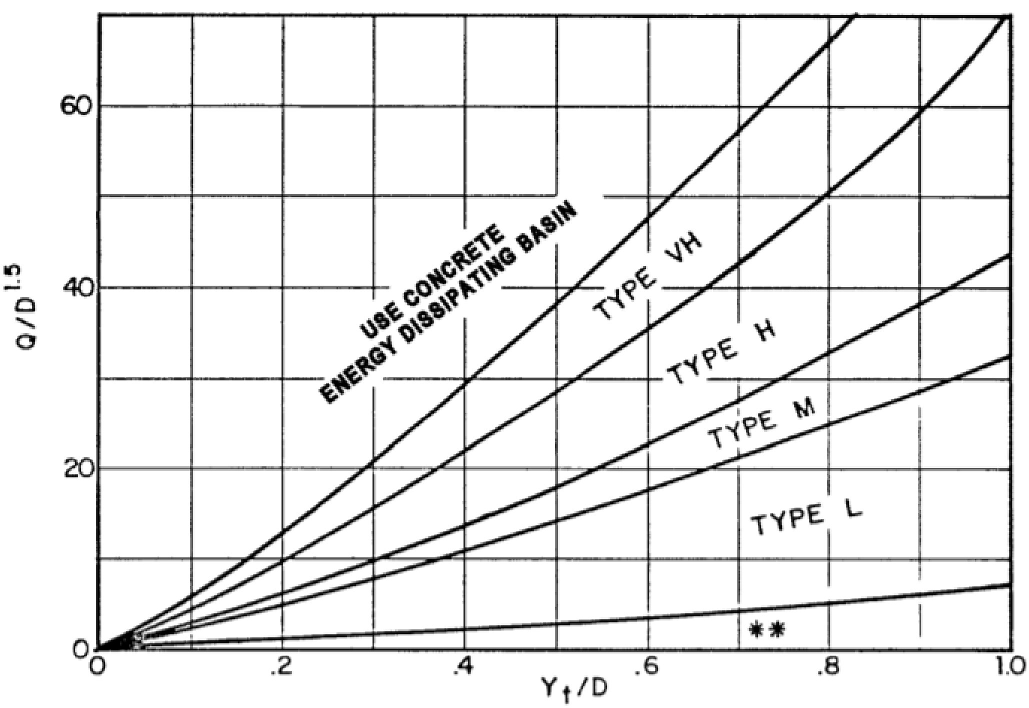

Table 5: Urban Storm Drainage Criteria Manual Volume 2
Riprap erosion protection at circular conduit outlet

Channel is expected to be grouted about 13 feet uphill from the existing roads and drainage structures. Length upward is based on equipment arm length as terrain becomes steeper further up the draw.

C. Culverts

Culverts are recommended to be placed at POI 1, where the draw drains under the trail leading to and leaving from the northern most parking lot (refer to Exhibit 3E for location). Pre-fire two HDPE culverts existed under the trail and road but melted and collapsed during the fire. In designing two new culverts, several factors had to be kept in mind such as aesthetics, size, materials, and flow capacities of the culverts.

To calculate the size of the culvert required to replace the previous culvert destroyed during the fire, analysis first began with the design flow expected to discharge at the bottom of the catchment area. As stated in the previous findings section, the calculated flow was 189 cubic feet per second. The Mile High Flood District (MHFD) Culvert Sizing tool was used to size the culvert based on material, interior angle of the culvert, and the required flow.

The material of the culvert gives Gauckler-Manning's coefficient, commonly known as the Manning's n, which is an empirically derived coefficient used to calculate open channel flow. Manning's n describes the roughness of the material. The most common materials for a culvert are riveted steel, corrugated iron, or concrete. The Manning's n for each are 0.019, 0.016, and 0.014 respectively. A lower Manning's n denotes a smoother surface and consequently more fluid that can pass over the surface. To select the slope for the culvert, three factors were considered which include, preventing too large of a size, attaining a suitable flow rate, and preventing clogging. A lower slope for the culvert would necessitate a larger culvert as the discharge would be moving slower through the culvert. Being part of a forest park, putting a large culvert would take away from the scenery and environment. A larger culvert would also be more expensive to install, requiring larger equipment and more excavation. The natural slope of the park area is around 23%, so dropping the flow to a 1% slope cause a hydraulic jump at the mouth of the culvert and prevent the flow from moving. As well, sediment debris is expected to be suspended in the discharge from the mountain, and a slower flow would drop much of the sediment into the culvert and lead to its being blocked quickly. With these considerations, a 12% invert slope was selected to match the terrain and get a manageable culvert size.

Analysis of the different materials of corrugated iron, riveted steel, and reinforced concrete was performed to get the required sizes to handle the design flow of 189 cubic feet per second. The required diameter for a pipe is based off the full-flow condition. The equation for the diameter is as shown below:

$$d = \left(\frac{N\,Q}{K\,\sqrt{S_0}}\right)^{3/8} \qquad \text{(eq. VII – C1)}$$

Where d = hydraulically required circular diameter in length, K = 0.462 for feet-second units, N = Manning's roughness coefficient, Q = design discharge [cubic feet per second], and S_o = design slope of the culvert.

The required diameters for the different culvert sizes designed for a single pipe are as shown:

	Corrugated Iron	Riveted Steel	Reinforced Concrete Pipe	Reinforced Concrete Box
Diameter (inch)	42	36	36	2 ft x 4 ft

Table 6: Culvert Sizing Based on Material Type

The ultimate recommendation is for a Reinforced Concrete Pipe (RCP) Culvert. This material and type of pipe was chosen due to the size, ease of maintenance, and aesthetic of the location. The reinforced concrete pipe is one of the smaller sizes of culverts that can handle the required flow of 189 cubic feet per second that would reasonably occur during a 10 year event. The concrete surface also is easier for brushing, washing, or shoveling debris to clean compared to the ribs of the riveted steel surface (refer to Exhibit 5 S-2 for culvert detail drawing). Adding a headwall on the inlet side of the culverts is also recommended to help prevent erosion of the banks around the culvert, while also preventing any scouring and undermining of the culvert (refer to Exhibit 5 S-3 for headwall detail drawings). To help prevent erosion and undermining of the headwall apron, a suggestion of adding a small square section of Type L riprap in front of the apron in the drainage channel was made. Finally, concrete for both the pipe and headwall would provide a similar appearance to the nearby parking lot that would give a clean appearance for many years.

D. Debris Deflectors

The first designed preventative measure to protect the roads and creeks are debris deflector fences. Debris deflectors are commonly placed at the entrance to a culvert to push debris to the side of the culvert entrance. The location of these debris deflectors are to be placed on each draw at POI 1 through 3 (refer to Exhibit 3D for locations). The deflectors' purpose for this situation are to protect the road and creek by catching or redirecting debris out of the main draws. Once out of the draws that debris should no longer be carried into the road or into the creek. Deflectors are recommended to be placed with the angled apex of the fence in the center of the draw, with a reasonable distance from the road such that large items caught or pushed out of the draws do not fall directly onto the road. The distance we decided should be between 40 to 70 feet uphill of the road. At POI 1 and 2 the area around the road has been severely burned and dead trees removed, making the space west of the roads clear for a small group of people to be able to clear any rocks or logs that come through the draws without the use of large equipment that would not be able to otherwise access the area.

Figure 10: Example of a Debris Deflector

To design the debris deflectors, procedures from the Federal Highway Administration's (FHWA) publication of "Debris Control Structures Evaluations and Countermeasures, Hydraulic Engineering Circular" were followed and provided the requirements for sizing the debris deflectors. The major design considerations for the deflector are the apex, the area provided by the deflector, and the spacing of the bars. The apex of the deflectors should be between 15 and 25 degrees, so an intermediate angle of 20 degrees was chosen. Areas of deflectors should be 10 times larger than the diameter of the culverts they would be protecting. Bar spacing is also designed off the culvert width, varying between 1/2 the diameter or 2/3 the diameter. Because we recommend placing them a distance away from the culverts and not directly on culverts, one sizing is adequate for all. Height of deflectors should be 2.5 feet tall. Using bar spacing of 1 foot 6 inches, the required length of the sides of the deflector was 18 feet 6 inches long. Horizontal bracing should also be placed along the top of the deflector to prevent bending or breaking at the apex joint (refer to Exhibit 5E for detail drawing).

E. Debris Racks

Another preventative measure that was designed is for a debris rack to be placed over the headwall of the culvert at POI 1 and 3 (refer to Exhibit 3I for rack locations). A debris rack or a trash rack would protect the culvert from becoming clogged with any branches or medium sized debris that can be expected from a significant rain event.

Figure 11: Example of a Debris Rack

To design the debris rack, procedures from the FHWA's publication of "Debris Control Structures Evaluations and Countermeasures, Hydraulic Engineering Circular" were followed again, which provided the requirements for sizing the debris rack. The major design considerations for the rack are the area provided for discharge to pass through and bar spacing. Area of racks should be 10 times larger than the diameter of culverts protecting. Bar spacing is also designed off the culvert width, varying between 1/2 the diameter or 2/3 the diameter.

At POI 1, 36 inch culverts were designed with headwall attachments at a width of 4 feet and 3 inches wide. The bar spacing for the racks her needs to be less than 2/3 of the culvert diameter, or less than 24 inches. Two interior bars are expected to be spaced at even intervals along the 51 inch length of the headwall, spacing of 16.7 inches. This bar spacing provides adequate protection for debris entering the culvert. The 51 inch headwall also provided the basis for the area of the rack. The minimum area required was 71 square feet. The minimum length of the vertical bars would then be 8 feet long to have a net area of 76.6 square feet (refer to Exhibit 5 S-5 for rack detail drawing).

This design of debris racks has suitable dimensions for the existing culvert along Geer Canyon Drive below the lower lots. The culvert is approximately 36 inches in diameter. The culvert does not have a head wall but fabricating an additional debris rack with the same dimensions of 8 feet long, 4 feet 3 inches wide and with two inside bars spaced at

16.7 inches will protect the culvert from debris entering (refer to Exhibit 5 S-5 for rack detail drawing). The rack would have the required area in relation to the culverts area.

Debris racks for POI 3 was designed where a concrete double barrel culvert currently exists. The culvert has a flat headwall 6 to 8 feet wide. The debris rack was designed to be 6 feet wide to fit over the front of the two barrels of the culvert. There should be 5 total vertical bars spaced 17.74 inches apart and 7 feet in length. Following the same design standards as before, the net area of the debris rack should be 5 time the area of the culvert area. With the number of bars and their width and length of the rack, the net area for this rack is 39.83 square feet where 35.34 square feet was required (refer to Exhibit 5 S-5 for detail drawing).

To select material for the deflectors and racks, calculations of the force of the material in the flows needed to be completed. As calculated earlier in the findings, the size of rocks expected in the flow was 4 to 6 inches in diameter. A piece of sandstone of this size would have a volume of 113 cubic inches and with a density of 2.6 grams per cubic centimeter has a weight of 10.62 lbs.

The impact force of a rock when moving at the channel velocity of 22 feet per second is 1.75 lbs. The force was calculated following ASCE 7- Equation C5.4-3:

$$F = \frac{\pi W V_b C_I C_0 C_D C_B R_{max}}{2g\Delta t} \qquad \text{(eq. VII – E1)}$$

Where F = impact force in lbs, W = weight of debris in lbs, V_b = velocity of object, g = acceleration due to gravity, Δt = impact duration, C_I = importance coefficient, C_0 = orientation coefficient, C_D = depth coefficient, C_B = blockage coefficient, and R_{max} = maximum response ratio for an impulsive load.

The material selected for the debris deflectors and debris racks is Pipe ¾ Std. The longest member for the debris deflectors and debris racks is 18.5 feet long. The maximum moment created by the impact force of a rock striking the member is 0.0162 kip-foot. Following the AISC Steel Construction Manual Table 3-15 Pipe ¾ Std has a design flexural of capacity of 0.0164 kip-foot, making it adequate for the structural needs of the racks.

F. Flood Barrier Bags

Figure 12: Example of a Flood Barrier Bags

Flood barriers bags will be used as a mechanism of preventing flows from overtopping one of the existing culverts and headwall (refer to Exhibit 3G for location). The existing culvert is a double barrel culvert with a flat headwall that enables drainage from one of the draws to go under the road. This culvert was not designed with the expected increase of flow rates that results from the burned soils and increased imperviousness. With that said, this culvert structure has the potential for the flows to overtop it in events large than a 10 year storm. Although the mitigation structures were designed with that type of event in mind, during such an event, the existing culvert's combined flow capacity of 42 cubic feet per second is slightly under the 55 cubic feet per second that a 10 year storm will bring. With this being the case, the bowl-shaped embankment in front of the headwall and culvert will flood and create an orifice type flow in the culverts, drainage at a specific discharge.

It is believed that the volume capacity of flow in the bowl shaped that will begin to develop, along with the flow capacity of the culvert, that drainage will still likely occur without overtopping the headwall and drainage into and across the street. In the event that the flow does overtop the culvert and headwall, flood barriers bags were to be placed atop the culvert (refer to Figure 13 for anticipated barrier bag placement).

Figure 13: Anticipated placement of flood barrier bags

In anticipation of an overtopping event, it is recommended to place a total of 6 flood barrier bags directly atop the headwall of the existing culvert. Doing so will allow for the culvert to continue to drain in an orifice type flow while preventing any risk of flow causing erosion to the road due to an overtopping event. The specification of each flood barrier bag includes a dimension of 2 feet x 2feet x 2feet. The bags will be filled with a heavy, coarse grained sand to provide stability and structure against impeding flows. The bags will also be lined with an impermeable plastic shielding on the side where flow will be in contact with them to prevent any water infiltrating and going through the bags (refer to Exhibit 5 S-6 for detail drawings of flood barrier bags). These bags are easy to install and also easy to remove, which is why these are a great and low-cost method to help prevent flows from going over any structures that need this to be prevented.

VIII. <u>Implementation Sequence</u>

Based on the recommendations of adding two RCP culverts and headwalls at both locations where previous culverts were destroyed (POI 1), one armored drainage crossing further up the site (POI 2), flood barrier bags (POI 3), four sets of debris deflectors, three sets of debris racks, and installation of grouted riprap, an implementation sequence is needed. The sequence of installing each of these flood mitigation structures is important to ensure the goal of decreasing debris and water flow and keeping the public safe.

First and most importantly it would be installing the new RCP culverts and headwalls were both previous culverts were destroyed during the fire. This is a necessary first step

as it is needed to restore the location up to original mitigation standards, but also to allow access further up the site for more equipment and personnel. The reinforced culverts are going to be installed at a 12% invert slope with 1-foot fill on the shallow end and 2 feet 10 inches on the deep end add to the 3 foot diameter of the culvert about 11 to 12 cubic yard of soil will need to be removed per culvert. A small dozer with the capacity to dig five to six feet below desired grade, a trailer, or some other flatbed truck in order to haul away excessive soil, all the equipment needed in the proposed building of the headwalls including but not limited to concrete, rebar, and forms as well as equipment to both transport and the handling of the two new RCP culverts without damaging them.
If the goal is to be more cost effective the current riprap at the sites could be separated and reused for part of the construction of the armored drainage crossing, regardless a small portion of the soil obtained from the excavation and installation of the culverts and headwalls will need to be transported down to site 3 to allow for the installation of flood barrier bags.

The necessary quantity of soil needed to fill all six of the estimated 2 feet x 2 feet x 2 feet flood barrier bags are 48 cubic feet of uncompacted soil total or about 56 cubic feet of compacted soil total. This will necessitate acquiring both the flood bags and the materials to install them ahead of time to be at the site while the culvert is being installed. Based on the designs above this will include six flood barrier bags, galvanized wire fence, fence posts, metal ties. None of the equipment needed for installing the flood barrier bags will be at all complicated other than some shovels, mallets, and pliers as well as a vehicle to move materials.

After installing the two RCP culverts installation of the armored trainer crossing can begin. Included in the installation is the excavation of a 30 foot by 25 foot area with a depth of 2.5 feet. From there the new riprap will need to be installed with a compacted berm placed on top at a 10% grade until it reaches the original 5% grade that is seen on the site. This will require getting some equipment that can do the evacuation, soil/riprap hauling and compaction likely the same equipment used for installing the RCP culvert.

During or after the construction of armored drainage crossing welding and installation of the debris racks and debris deflectors can begin. The debris racks will require equipment to cut the pieces and welding equipment to design and put together. They will then need a hammer drill to install at all three locations. For the installation of the debris deflectors once the 3/4 std pipe is brought on to site the same equipment used in the construction of the debris racks and be reused the only addition will be the need of shovels to install into the ground.

Installation of grouted riprap is recommended to be done by a grout pump, for spray length, and a vehicle, such as an excavator, that can carry and place sized riprap along the channel at a minimum length of 13 feet uphill.

IX. Costs

Due to the multiple sites that each have their own individual designs for and use in the overall design of the project it was determined the best way to calculate cost was on a case-by-case basis with all cost broken up per individual piece of the project. Many of these costs also take a somewhat pessimistic view on length of time that equipment will be required to complete the work, as the job site is somewhat isolated. All costs were estimated using the cost estimating software RS Means. RS Means will generalize some of the specified items in the design and the estimates were replaced with a comparable option during the estimating process. (Reference Exhibit 6a for complete breakdown of costs & Reference Exhibit 6b for cost per individual part of project).

During the design process we also looked at different materials to use to lower costs. the two possible material changes we found were making the culvert out of metal and making the debris deflectors out of wood. Replacing the current RCP design with a steel design was found to have a marginal cost savings. This lack of cost savings was due to the similar equipment and labor needed for installation of the steel vs RCP culvert. Also based on preliminary estimates an elliptic metal culvert would be needed which would warrant more excavation further reducing any potential cost saving benefits.

We also debated potentially using wooden debris deflectors with wood on site instead of metal debris deflectors. This was also decided against as the quality of wood would be hard to measure after a fire and any potential debris removal needed to unclog the deflectors could potentially destroy the deflectors and eliminate any cost savings gained in order to rebuild the deflectors. Very few alternatives were found in regard to other parts of the project were found, that would continue to be practical based on our research. Though if a lower cost for the design was needed it is possible to look at our estimates in exhibit 6 to potentially remove some of our designs though this is not recommended.

X. **Future Work and Study**

Figure 14: Vegetation Return After 416 Fire, Expected to Occur in Calwood Fire Area

Understanding how forests respond to the disturbance of a fire is a critical component of managing mitigation structures. Vegetation is expected to return, and with its return, water flows down the draws will decrease. Therefore, not all structures need to be permanent. Structures lasting 5 to 7 years will be sufficient.

XI. Disclaimer

The assumptions, findings, calculations, and conclusions expressed and described in this report and its exhibits were developed by undergraduate civil engineering students who are not licensed, professional engineers. This report was prepared as an academic exercise as partial fulfillment of the Civil Engineering Senior Design course. Pursuant to C.R.S. §12-25, no part of this report should be used for planning, budgeting, construction, or related fiscal decisions without a complete review and written endorsement from an independent, qualified, and licensed engineer who can assume responsible charge of the project and who is willing and able to become the engineer of record for all aspects of the study, calculations, findings, recommendations, and the project in part and in whole.

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XII. Conclusion and Summary

This study encapsulated research and study of various, previous wildfires in the state of Colorado; as well as the subsequent design techniques which should be applied for the mitigation of wildfires eruption and their aftermaths, which could potentially devastate the entire area of land and its overall ecosystem. Every wildfire requires a specific mitigation response depending on the climate, topography, soil burn severity, existing vegetation, and other location-specific factors.

Because wildfires are a natural phenomenon, preservation and prevention are critical for maintaining and balancing the ecosystem, climate, and recreational areas regions. After careful analysis, a total of 6 different structures are recommended to be implemented in order to help guide the flow of the various draws, to mitigate the erosion of the park's infrastructure, and deter large debris and potential clogs of essential drainage structures. These structures include armored drainage crossing, debris deflectors, debris racks, culverts, flood barrier bags, and grouted riprap. These structures have been placed at locations from the perspective of easy access for maintenance and operations as well as achieving the goals of Boulder County to ensure public safety and eliminate or decrease dangerous debris and water flows coming down the sloped terrain

Salutations

The students involved in this project would like to express gratitude to the County of Boulder for allowing us the opportunity to study the effects of wildfire in the Geer Canyon area. The University of Colorado Denver students involved can be contacted should any questions and or comments arise.

Best Regards,

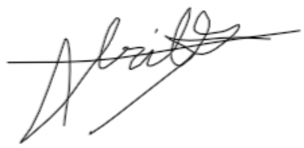
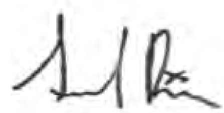
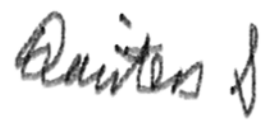
Abril Gonzalez-Torres	Samuel Rivera	Quinten Schaffner
		
Andrew Riley	Shannon Lamb	Batool Shehab
		

Exhibit 1: Maps

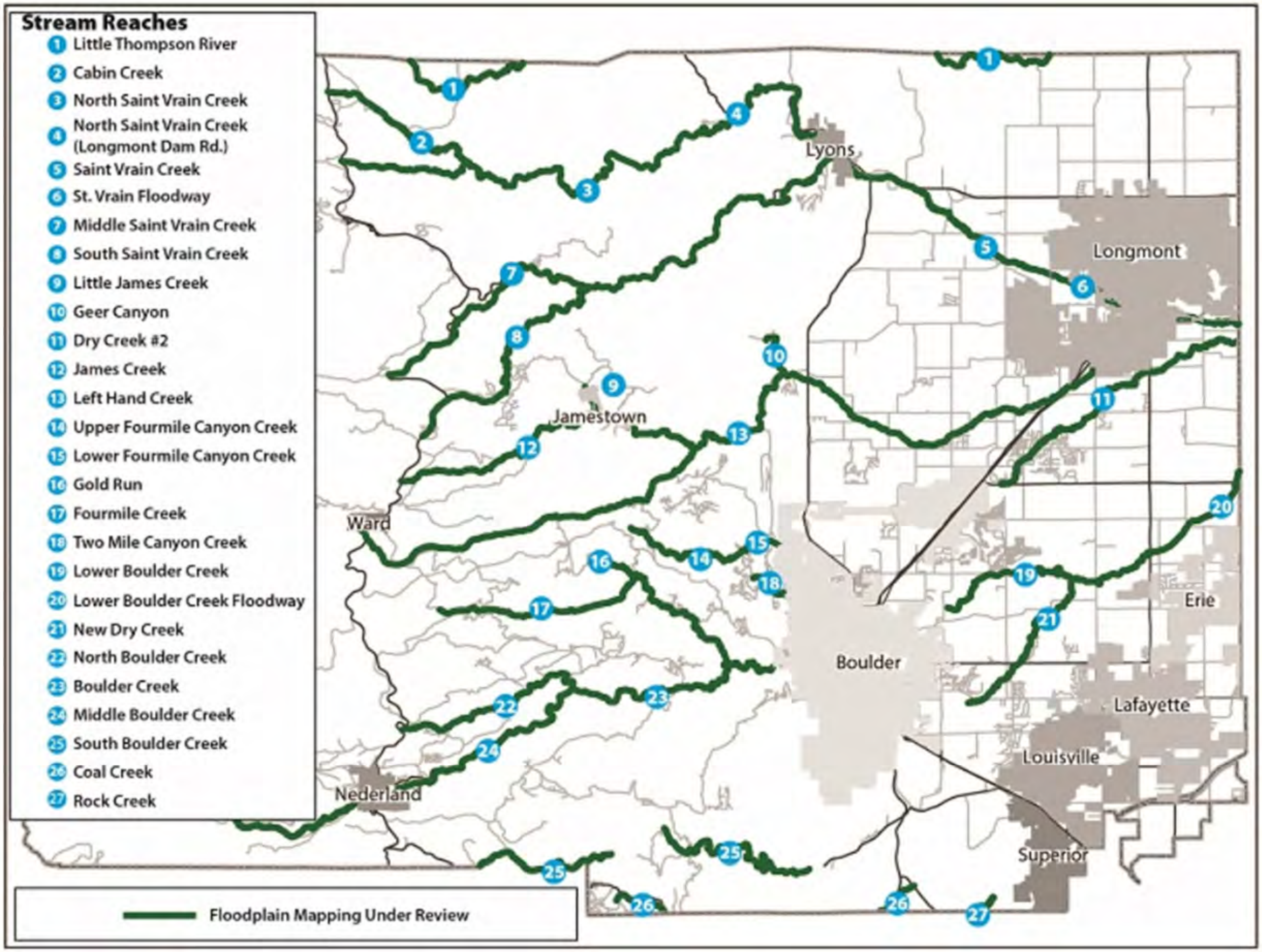


Exhibit 1A:2013 CWCB waterway change map (10 - Geer Canyon)

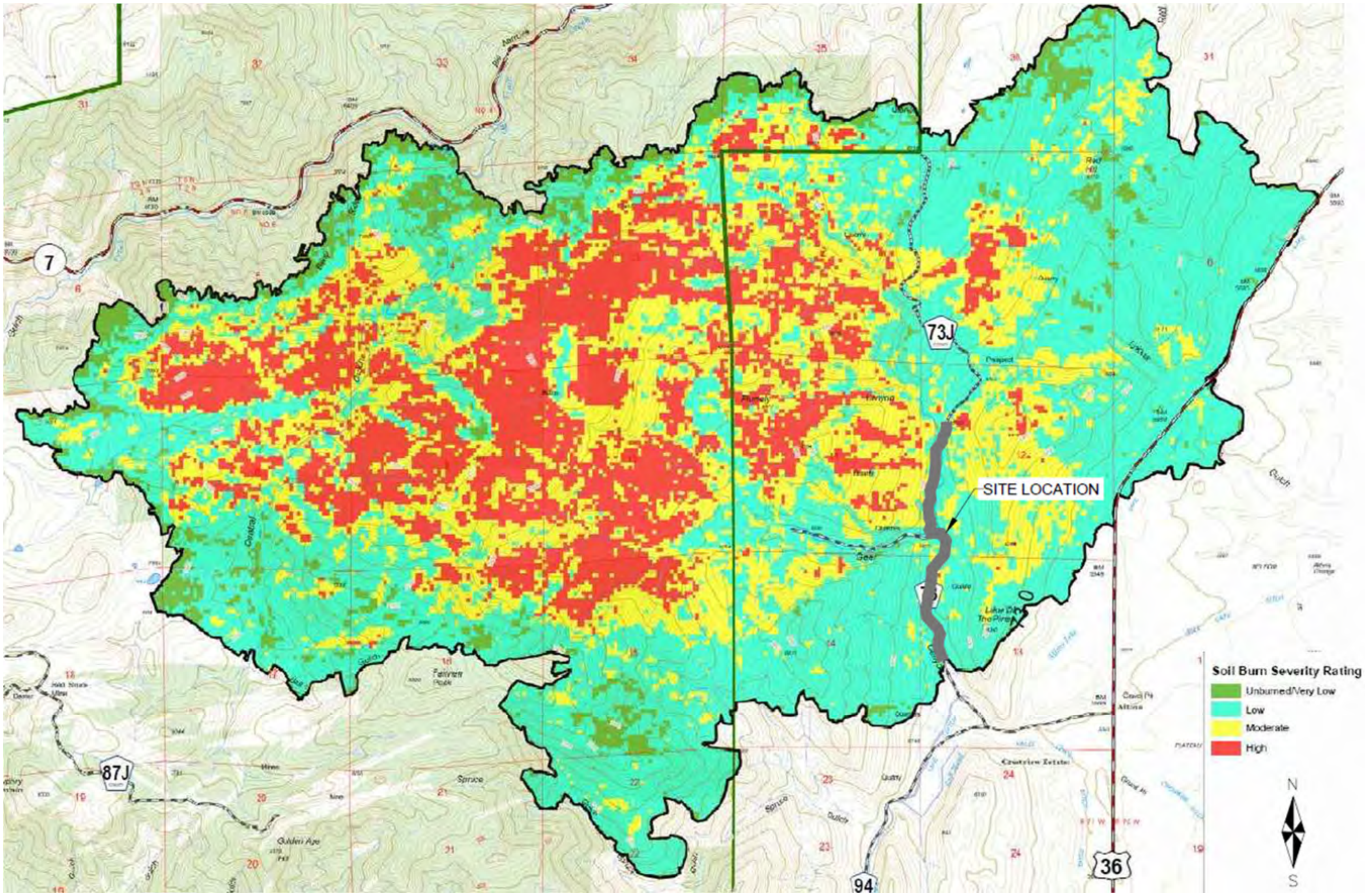


Exhibit 1B: Calwood Wildfire Severity Map

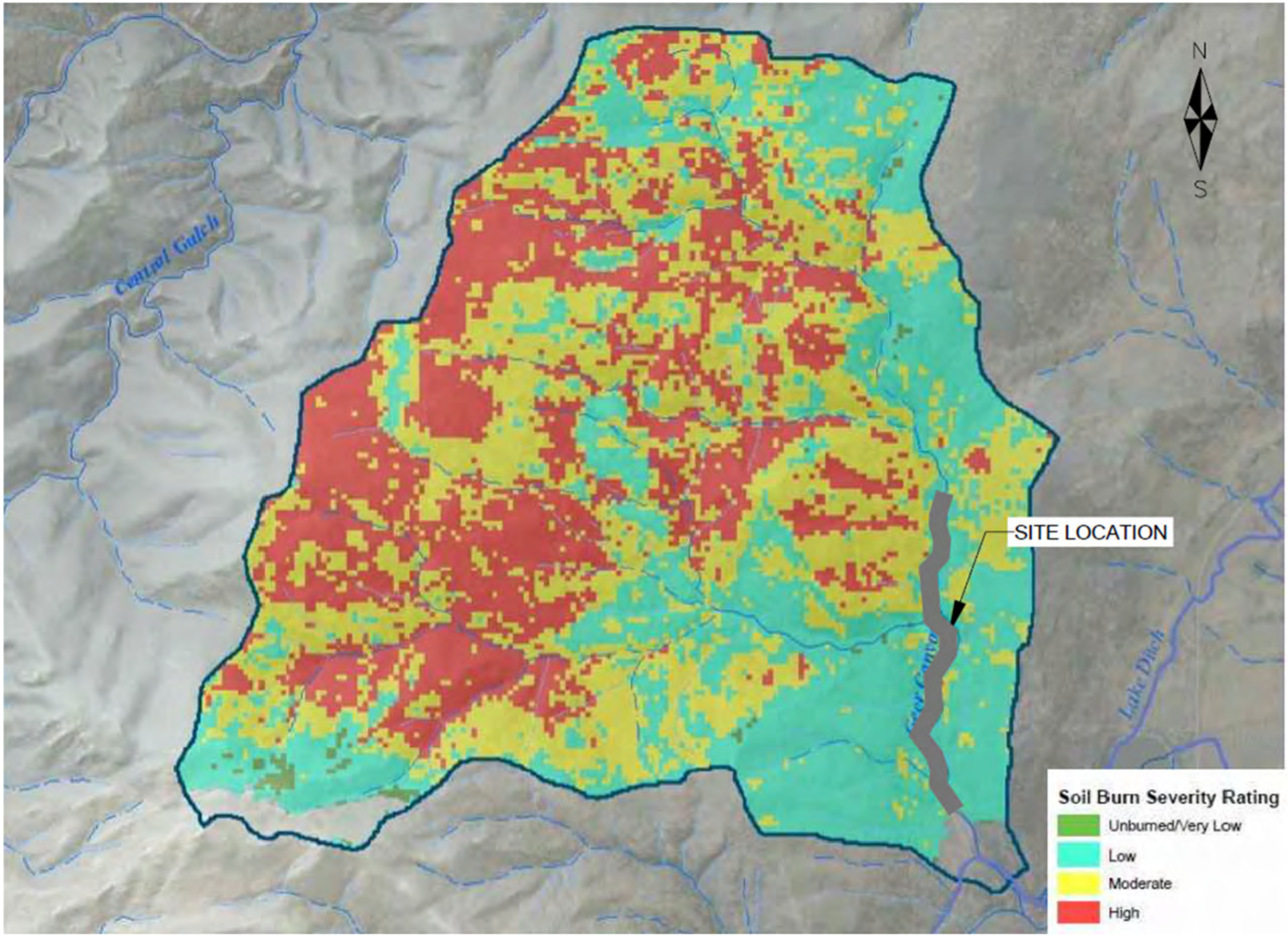
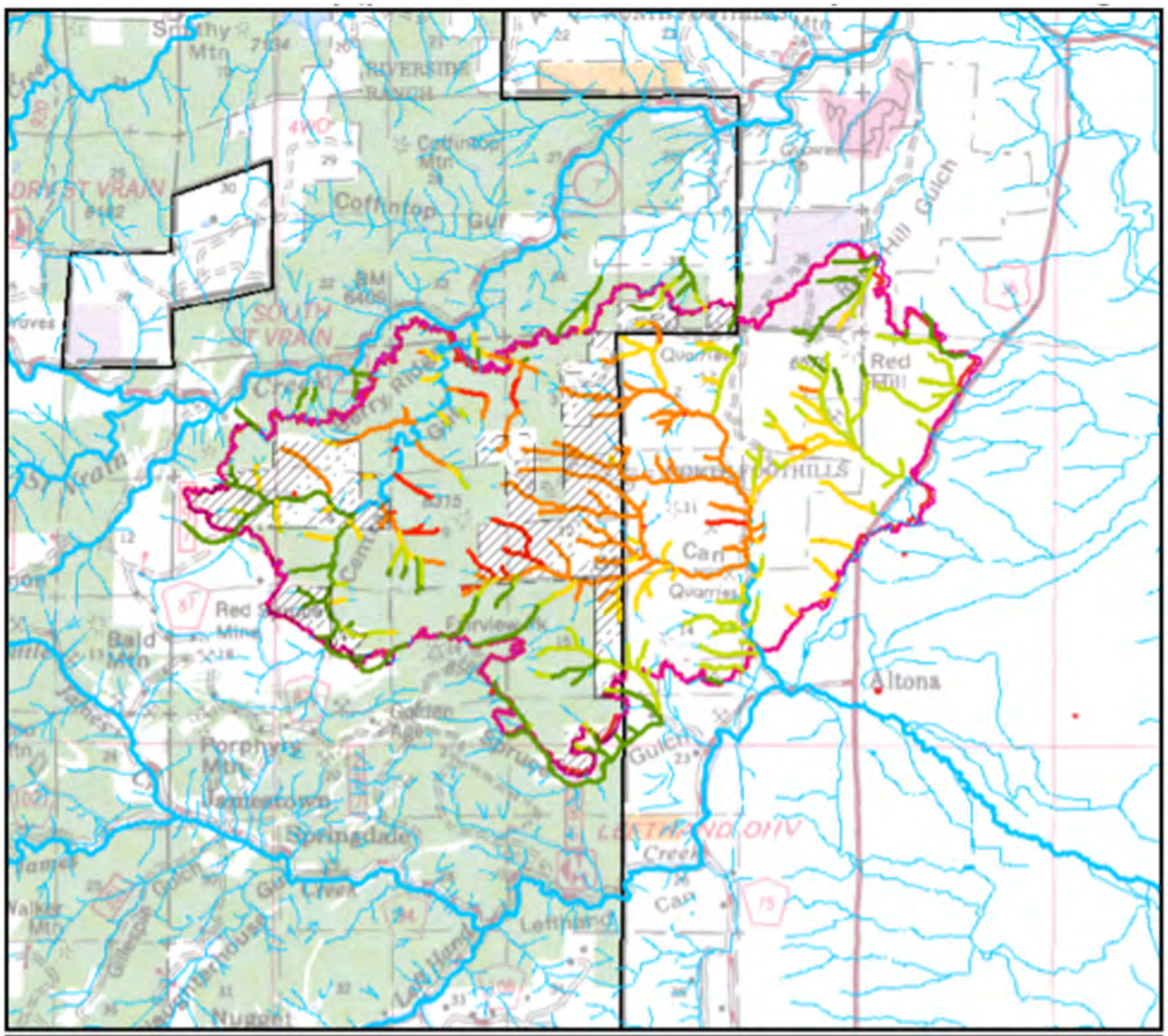


Exhibit 1C: BAER Calwood Wildfire Severity Map (Geer watershed)



Dark Green: 0-20%, Light Green: 20-40%. Yellow: 40-60%, Orange: 60-80%, Red 80-100%

Exhibit 1D: BEAR Debris Flow Probability (peak 15-minute rainfall intensity of 24 mmh-1 design storm)

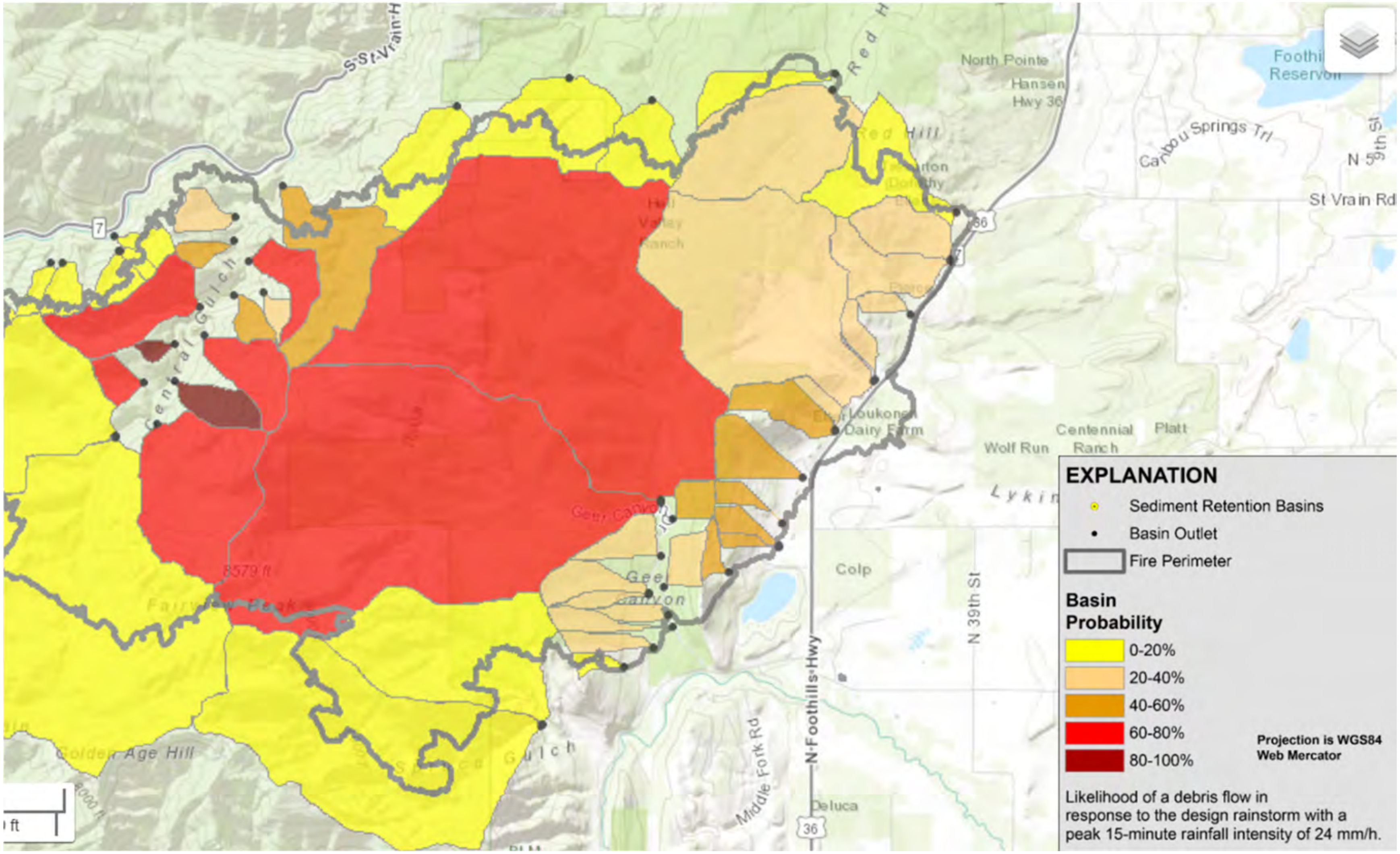


Exhibit 1E: USGS Post-Fire Debris Flow Fire Hazards Map

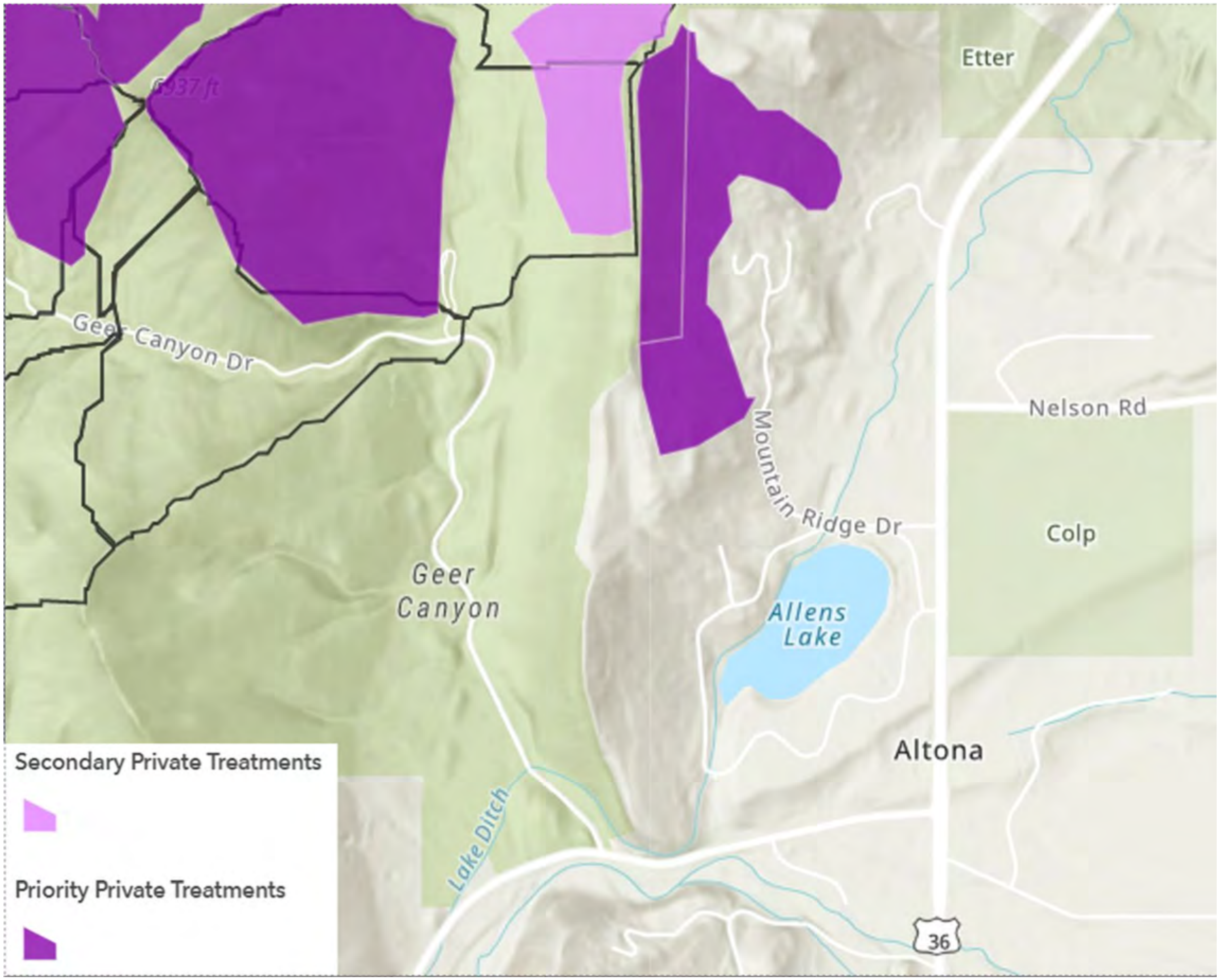


Exhibit 1F: Mulch Boundaries Map

Exhibit 2: Aerial Photograph—Site Location: Geer Canyon

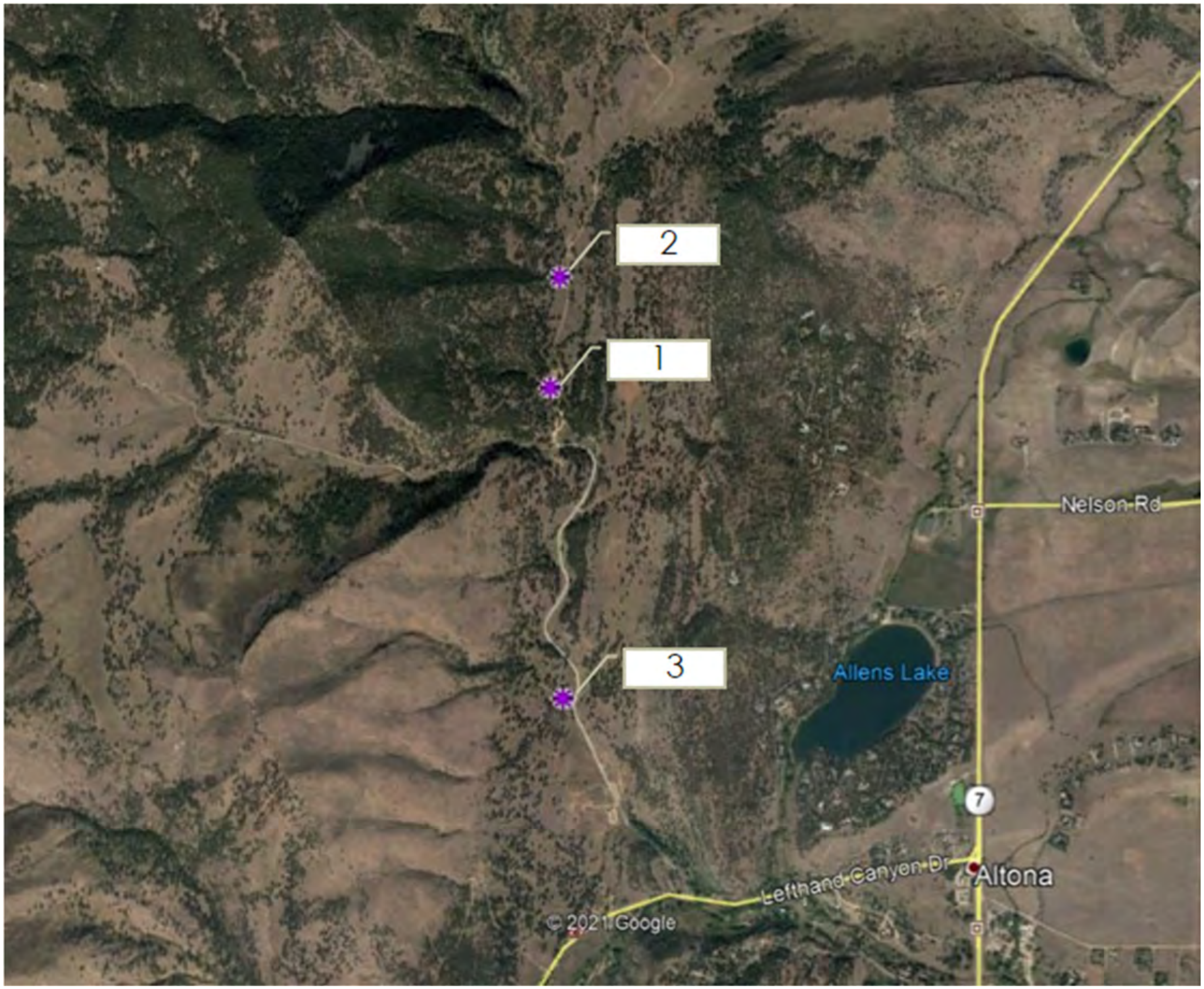


Exhibit 2: Geer Canyon Points of Interest

Exhibit 3: Geer Canyon Points of Interest Photographs and Aerials

a)

b)

c)

Exhibit 3A: Photographs at Point of Interest 1

a) Facing West at Foot of Draw Under the First Collapsed Culvert

b) Facing East Continuation of Draw, Other Side of Collapsed Culvert

c) Facing Southeast, Continuation of Draw onto Geer Creek

a)

b)

c)

Exhibit 3B: Photographs at Point of Interest 2

a) Facing Northwest at Foot of Draw

b) Facing Southeast, Continuation of Geer Creek over Wapiti Trail

c) Facing South, Toward Parking Lot at Beginning of Wapiti Trail

a)

b)

Exhibit 3C: Photographs at Point of Interest 3

a) Facing East at Foot of Draw

b) Facing Northeast at Mouth of Double Barrel Culvert

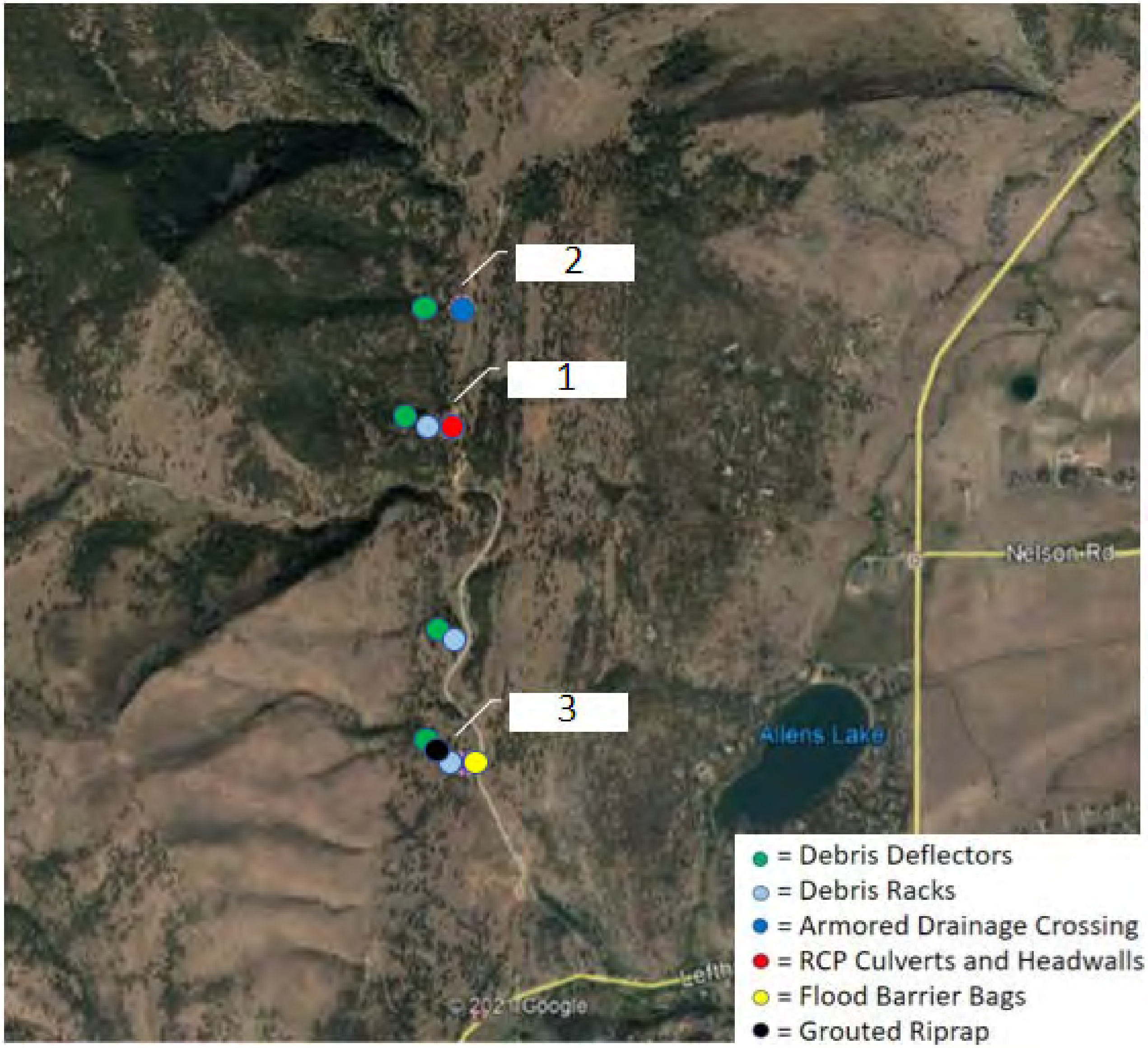


Exhibit 3D: Recommended Mitigation Structures at Points of Interests

Exhibit 3E: Culverts at Point of Interest 1

Exhibit 3F: Armored Drainage Crossing at Point of Interest 2

Exhibit 3G: Flood Barrier Bags at Point of Interest 3

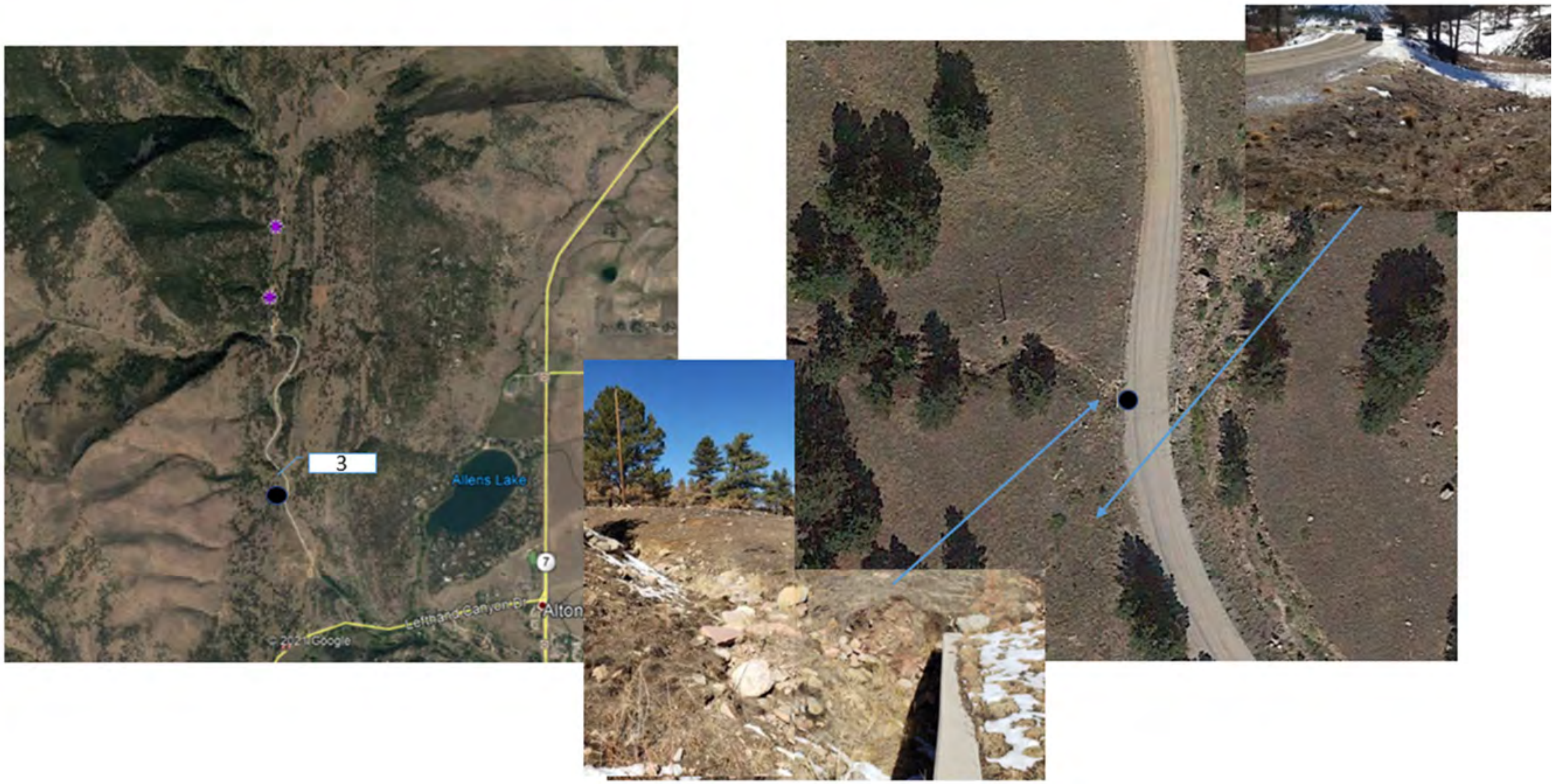


Exhibit 3H: Grouted Riprap Location at Point of Interest 3

Exhibit 31: Debris Rack Locations at Points of Interest 1 and 3

Exhibit 4: Calculations

Calculation of Peak Runoff using Rational Method

Designer: Quinten Schaffner
Company: Initiate Engineering University Consultants
Date: 5/7/2021
Project: Boulder County Post-Fire Mitigation
Location:

Version 2.00 released May 2017

Cells of this color are for required user-input
Cells of this color are for optional override values
Cells of this color are for calculated results based on overrides

$$t_i = \frac{0.395(1.1 - C_5)\sqrt{L_i}}{S_i^{0.33}}$$

$$t_t = \frac{L_t}{60K\sqrt{S_t}} = \frac{L_t}{60V_t}$$

$$\text{Computed } t_c = t_i + t_t$$

$$\text{Regional } t_c = (26 - 17i) + \frac{L_t}{60(14i + 9)\sqrt{S_t}}$$

$t_{minimum}$ = 5 (urban)
$t_{minimum}$ = 10 (non-urban)

$$\text{Selected } t_c = \max\{t_{minimum}, \min(\text{Computed } t_c, \text{Regional } t_c)\}$$

Select UDFCD location for NOAA Atlas 14 Rainfall Depths from the pulldown list OR enter your own depths obtained from the NOAA website (click this link)

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
1-hour rainfall depth, P1 (in) =	0.77	1.04	1.29	1.69	2.04	2.43	3.48

	a	b	c
Rainfall Intensity Equation Coefficients =	28.50	10.00	0.786

$$I(in/hr) = \frac{a * P_1}{(b + t_c)^c}$$

$$Q(cfs) = CIA$$

Subcatchment Name	Area (ac)	NRCS Hydrologic Soil Group	Percent Imperviousness	Runoff Coefficient, C: 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
A1	45.63	D	10.0	0.06	0.12	0.21	0.38	0.44	0.52	0.62
A2	92.14	D	10.0	0.06	0.12	0.21	0.38	0.44	0.52	0.62
E1	75.72	D	35.0	0.26	0.32	0.39	0.52	0.57	0.63	0.70
E2	49.90	D	35.0	0.26	0.32	0.39	0.52	0.57	0.63	0.70
E3	67.58	D	35.0	0.26	0.32	0.39	0.52	0.57	0.63	0.70

Subcatchment Name	Overland (Initial) Flow Time: Overland Flow Length L_i (ft)	U/S Elevation (ft) (Optional)	D/S Elevation (ft) (Optional)	Overland Flow Slope S_i (ft/ft)	Overland Flow Time t_i (min)
A1	500.00			0.275	13.30
A2	500.00			0.261	13.53
E1	500.00			0.231	11.18
E2	500.00			0.250	10.88
E3	500.00			0.250	10.88

Subcatchment Name	Channelized (Travel) Flow Time: Channelized Flow Length L_t (ft)	U/S Elevation (ft) (Optional)	D/S Elevation (ft) (Optional)	Channelized Flow Slope S_t (ft/ft)	NRCS Conveyance Factor K	Channelized Flow Velocity V_t (ft/sec)	Channelized Flow Time t_t (min)
A1	2068.00			0.275	2.5	1.31	26.29
A2	3660.54			0.261	2.5	1.28	47.77
E1	2875.00			0.230	10	4.80	9.99
E2	2855.66			0.250	10	5.00	9.52
E3	2862.00			0.250	10	5.00	9.54

Subcatchment Name	Time of Concentration: Computed t_c (min)	Regional t_c (min)	Selected t_c (min)
A1	39.59	30.62	30.62
A2	61.30	35.78	35.78
E1	21.17	27.24	21.17
E2	20.40	26.90	20.40
E3	20.42	26.91	20.42

Subcatchment Name	Rainfall Intensity, I (in/hr): 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
A1	1.20	1.61	2.00	2.62	3.16	3.77	5.39
A2	1.09	1.47	1.82	2.38	2.88	3.43	4.91
E1	1.48	1.99	2.46	3.23	3.89	4.64	6.64
E2	1.51	2.02	2.51	3.29	3.97	4.73	6.77
E3	1.51	2.02	2.51	3.29	3.97	4.73	6.77

Subcatchment Name	Peak Flow, Q (cfs): 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
A1	3.45	8.57	18.75	44.83	63.84	90.22	152.49
A2	6.34	15.75	34.47	82.39	117.34	165.83	280.29
E1	28.73	48.14	72.58	125.81	166.87	220.28	351.23
E2	19.31	32.35	48.78	84.55	112.14	148.04	236.04
E3	26.14	43.79	66.02	114.44	151.79	200.38	319.50

Exhibit 4A: Pre-Fire Rational Method Discharge Calculations

Calculation of Peak Runoff using Rational Method

Designer: Samuel Rivera
Company: Initiate Engineering University Consultants
Date: 5/7/2021
Project: Boulder County Post-Fire Mitigation
Location:

Version 2.00 released May 2017

Cells of this color are for required user-input
Cells of this color are for optional override values
Cells of this color are for calculated results based on overrides

$$t_i = \frac{0.395(1.1 - C_5)\sqrt{L_i}}{S_i^{0.33}}$$

$$t_t = \frac{L_t}{60K\sqrt{S_t}} = \frac{L_t}{60V_t}$$

$$\text{Computed } t_c = t_i + t_t$$

$$\text{Regional } t_c = (26 - 17i) + \frac{L_t}{60(14i + 9)\sqrt{S_t}}$$

$t_{minimum}$ = 5 (urban)
$t_{minimum}$ = 10 (non-urban)

$$\text{Selected } t_c = \max\{t_{minimum}, \min(\text{Computed } t_c, \text{Regional } t_c)\}$$

Select UDFCD location for NOAA Atlas 14 Rainfall Depths from the pulldown list OR enter your own depths obtained from the NOAA website (click this link)

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
1-hour rainfall depth, P1 (in) =	0.77	1.04	1.29	1.69	2.04	2.43	3.48

	a	b	c
Rainfall Intensity Equation Coefficients =	28.50	10.00	0.786

$$I(in/hr) = \frac{a * P_1}{(b + t_c)^c}$$

$$Q(cfs) = CIA$$

Subcatchment Name	Area (ac)	NRCS Hydrologic Soil Group	Percent Imperviousness	Runoff Coefficient, C 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
A1	45.63	D	50.0	0.38	0.44	0.50	0.60	0.64	0.69	0.75
A2	90.17	D	50.0	0.38	0.44	0.50	0.60	0.64	0.69	0.75
E1	75.72	D	95.0	0.79	0.81	0.83	0.85	0.86	0.87	0.89
E2	49.90	D	95.0	0.79	0.81	0.83	0.85	0.86	0.87	0.89
E3	67.58	D	95.0	0.79	0.81	0.83	0.85	0.86	0.87	0.89

Subcatchment Name	Overland (Initial) Flow Time: Overland Flow Length L_i (ft)	U/S Elevation (ft) (Optional)	D/S Elevation (ft) (Optional)	Overland Flow Slope S_i (ft/ft)	Overland Flow Time t_i (min)	Channelized (Travel) Flow Time: Channelized Flow Length L_t (ft)	U/S Elevation (ft) (Optional)	D/S Elevation (ft) (Optional)	Channelized Flow Slope S_t (ft/ft)	NRCS Conveyance Factor K	Channelized Flow Velocity V_t (ft/sec)	Channelized Flow Time t_t (min)
A1	500.00			0.275	8.89	2068.00			0.275	5	2.62	13.15
A2	500.00			0.260	9.06	3660.54			0.260	5	2.55	23.93
E1	500.00			0.230	4.17	2875.00			0.230	10	4.80	9.99
E2	500.00			0.250	4.06	2855.66			0.250	10	5.00	9.52
E3	500.00			0.250	4.06	2862.00			0.250	10	5.00	9.54

Subcatchment Name	Time of Concentration: Computed t_c (min)	Regional t_c (min)	Selected t_c (min)	Rainfall Intensity, I (in/hr) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
A1	22.04	21.61	21.61	1.46	1.96	2.44	3.19	3.85	4.59	6.57
A2	32.99	24.98	24.98	1.35	1.81	2.25	2.95	3.56	4.24	6.07
E1	14.16	14.33	14.16	1.80	2.43	3.01	3.94	4.76	5.67	8.11
E2	13.58	14.12	13.58	1.84	2.47	3.07	4.02	4.85	5.78	8.27
E3	13.60	14.13	13.60	1.84	2.47	3.06	4.01	4.85	5.77	8.27

Subcatchment Name	Peak Flow, Q (cfs) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
A1	25.55	39.65	55.51	87.21	112.48	144.13	223.50
A2	46.63	72.35	101.30	159.15	205.26	263.02	407.86
E1	107.60	148.60	189.11	253.94	310.60	374.37	545.17
E2	72.29	99.84	127.05	170.60	208.67	251.52	366.27
E3	97.84	135.11	171.94	230.89	282.41	340.40	495.69

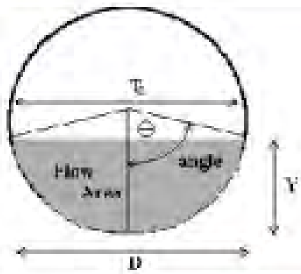
Exhibit 4B: Post-Fire Rational Method Discharge Calculations

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

MHFD-Culvert, Version 4.00 (May 2020)

Project: Access Road Culverts 10-Yr 14 min duration (E1)

Pipe ID: Riveted Steel Pipe (Single)



Design Information (Input)			
Pipe Invert Slope	So =	0.1200	ft/ft
Pipe Manning's n-value	n =	0.0155	
Pipe Diameter	D =	36.00	inches
Design discharge	Q =	189.10	cfs
Full-Flow Capacity (Calculated)			
Full-flow area	Af =	7.07	sq ft
Full-flow wetted perimeter	Pf =	9.42	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	194.31	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0<Theta<3.14)	Theta =	2.21	radians
Flow area	An =	6.04	sq ft
Top width	Tn =	2.42	ft
Wetted perimeter	Pn =	6.62	ft
Flow depth	Yn =	2.39	ft
Flow velocity	Vn =	31.33	fps
Discharge	Qn =	189.11	cfs
Percent of Full Flow	Flow =	97.3%	of full flow
Normal Depth Froude Number	Fr_n =	3.49	supercritical
Calculation of Critical Flow Condition			
Half Central Angle (0<Theta-c<3.14)	Theta-c =	3.04	radians
Critical flow area	Ac =	7.07	sq ft
Critical top width	Tc =	0.32	ft
Critical flow depth	Yc =	2.99	ft
Critical flow velocity	Vc =	26.76	fps
Critical Depth Froude Number	Fr_c =	1.00	

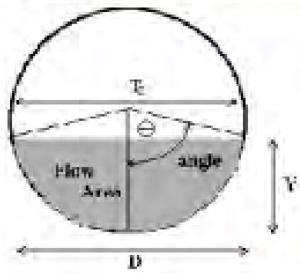
Exhibit 4C: Riveted Steel Culvert Size Calculations from MHFD Sheets

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

MHFD-Culvert, Version 4.00 (May 2020)

Project: Access Road Culvert 10-yr 14-min duration (E1)

Pipe ID: Reinforced Concrete Pipe (single)



Design Information (Input)			
Pipe Invert Slope	So =	0.1200	ft/ft
Pipe Manning's n-value	n =	0.0140	
Pipe Diameter	D =	36.00	inches
Design discharge	Q =	189.10	cfs
Full-Flow Capacity (Calculated)			
Full-flow area	Af =	7.07	sq ft
Full-flow wetted perimeter	Pf =	9.42	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	215.12	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0<Theta<3.14)	Theta =	2.04	radians
Flow area	An =	5.51	sq ft
Top width	Tn =	2.67	ft
Wetted perimeter	Pn =	6.13	ft
Flow depth	Yn =	2.18	ft
Flow velocity	Vn =	34.33	fps
Discharge	Qn =	189.10	cfs
Percent of Full Flow	Flow =	87.9%	of full flow
Normal Depth Froude Number	Fr_n =	4.21	supercritical
Calculation of Critical Flow Condition			
Half Central Angle (0<Theta-c<3.14)	Theta-c =	3.04	radians
Critical flow area	Ac =	7.07	sq ft
Critical top width	Tc =	0.32	ft
Critical flow depth	Yc =	2.99	ft
Critical flow velocity	Vc =	26.76	fps
Critical Depth Froude Number	Fr_c =	1.00	

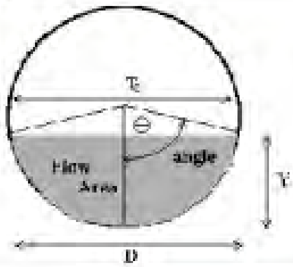
Exhibit 4D: Reinforced Concrete Culvert Size Calculations from MHFD Sheets

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

MHFD-Culvert, Version 4.00 (May 2020)

Project: Access Road Culvert 10-Yr 14 min (E1)

Pipe ID: Corrugated Iron Pipe (Single)



Design Information (Input)			
Pipe Invert Slope	So =	0.1200	ft/ft
Pipe Manning's n-value	n =	0.0240	*
Pipe Diameter	D =	42.00	inches
Design discharge	Q =	189.10	cfs
Full-Flow Capacity (Calculated)			
Full-flow area	Af =	9.62	sq ft
Full-flow wetted perimeter	Pf =	11.00	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	189.29	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0<Theta<3.14)	Theta =	2.26	radians
Flow area	An =	8.43	sq ft
Top width	Tn =	2.70	ft
Wetted perimeter	Pn =	7.92	ft
Flow depth	Yn =	2.87	ft
Flow velocity	Vn =	22.43	fps
Discharge	Qn =	189.10	cfs
Percent of Full Flow	Flow =	99.9%	of full flow
Normal Depth Froude Number	Fr_n =	2.24	supercritical
Calculation of Critical Flow Condition			
Half Central Angle (0<Theta-c<3.14)	Theta-c =	2.91	radians
Critical flow area	Ac =	9.60	sq ft
Critical top width	Tc =	0.80	ft
Critical flow depth	Yc =	3.45	ft
Critical flow velocity	Vc =	19.70	fps
Critical Depth Froude Number	Fr_c =	1.00	

*** Unexpected value for Manning's n**

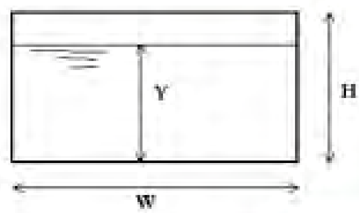
Exhibit 4E: Corrugated Iron Culvert Size Calculations from MHFD sheets

BOX CONDUIT FLOW (Normal & Critical Depth Computation)

MHFD-Culvert, Version 4.00 (May 2020)

Project: **Access Road Culvert 10 yr 14 min Duration**

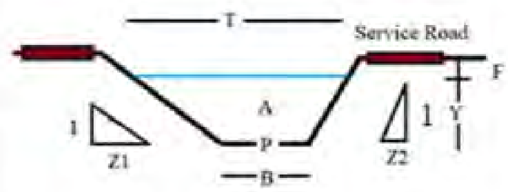
Box ID: **Catchment E1 Box Concrete Culvert**



Design Information (Input)			
Box conduit invert slope	So =	0.1200	ft/ft
Box Manning's n-value	n =	0.0140	
Box Width	W =	4.00	ft
Box Height	H =	2.00	ft
Design discharge	Q =	189.11	cfs
Full-flow capacity (Calculated)			
Full-flow area	Af =	8.00	sq ft
Full-flow wetted perimeter	Pf =	12.00	ft
Full-flow capacity	Qf =	225.08	cfs
Calculations of Normal Flow Condition			
Normal flow depth (<H)	Yn =	1.44	ft
Flow area	An =	5.77	sq ft
Wetted perimeter	Pn =	6.89	ft
Flow velocity	Vn =	32.77	fps
Discharge	Qn =	189.13	cfs
Percent of Full Flow	Flow =	84.0%	of full flow
Normal Depth Froude Number	Fr_n =	4.81	supercritical
Calculation of Critical Flow Condition			
Critical flow depth	Yc =	2.00	ft
Critical flow area	Ac =	8.00	sq ft
Critical flow velocity	Vc =	23.64	fps
Critical Depth Froude Number	Fr_c =	2.95	

Exhibit 4F: Reinforced Concrete Box Culvert Size Calculations from MHFD sheets

DESIGN CONDITIONS:			
Bottom Width	B =	1	ft
Left Side Slope	Z1 =	3	ft/ft
Right Side Slope	Z2 =	3	ft/ft
Mannings n	n =	0.03	
Longitudinal Slope	S =	25%	ft/ft
Flow rate	Q =	189	cfs



	Draw 1	Draw 2	Draw 3
Q anticipated (cfs)	189	127	171
V (fps)	21.5	19.5	21.1
Fr	4.12	4.01	4.09
Y (ft)	1.55	1.3	1.5

Flow Depth Y ft	Flow Area A sq ft	Top Width Top ft	Wetted P-meter P-meter ft	Hy-Radius R ft	Hy-Depth D ft	Flow Velocity U fps	Flow rate Q cfs	Froude Number Fr
1.300	6.37	8.80	9.22	0.691	0.724	19.35	123.28	4.01
1.325	6.59	8.95	9.38	0.703	0.737	19.58	129.05	4.02
1.350	6.82	9.10	9.54	0.715	0.749	19.80	134.98	4.03
1.375	7.05	9.25	9.70	0.727	0.762	20.02	141.08	4.04
1.400	7.28	9.40	9.85	0.739	0.774	20.24	147.34	4.05
1.425	7.52	9.55	10.01	0.751	0.787	20.46	153.78	4.06
1.450	7.76	9.70	10.17	0.763	0.800	20.68	160.39	4.07
1.475	8.00	9.85	10.33	0.775	0.812	20.89	167.17	4.08
1.500	8.25	10.00	10.49	0.787	0.825	21.11	174.13	4.09
1.525	8.50	10.15	10.64	0.799	0.838	21.32	181.26	4.11
1.550	8.76	10.30	10.80	0.811	0.850	21.53	188.57	4.12
1.575	9.02	10.45	10.96	0.823	0.863	21.74	196.06	4.13

$$A = 0.5 * (T + B) * Y$$

$$T = B + ((Z_1 * Y) + (Z_2 * Y))$$

$$P = B + (Y(1 + Z_1)^{0.5} + Y(1 + Z_2)^{0.5})$$

$$R = \frac{P}{A}$$

$$D = \frac{A}{T}$$

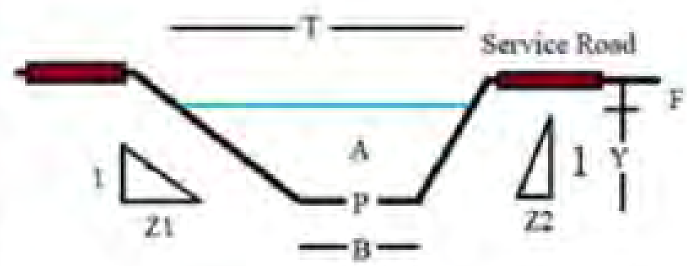
$$U = \frac{1.486}{n} R^{\frac{2}{3}} \sqrt{S_e}$$

$$Q = U * A$$

$$Fr = \frac{U}{\sqrt{g * D}}$$

Exhibit 4G: Draw Channel Flow Calculations

DESIGN CONDITIONS:			
Bottom Width	B =	10	ft
Left Side Slope	Z1 =	10	ft/ft
Right Side Slope	Z2 =	10	ft/ft
Mannings n	n =	0.025	
Longitudinal Slope	S =	10%	ft/ft
Flow rate	Q =	173	cfs



Flow Depth Y ft	Flow Area A sq ft	Top Width Top ft	Wetted P-meter P-meter ft	Hy-Radius R ft	Hy-Depth D ft	Flow Velocity U fps	Flow rate Q cfs	Froude Number Fr
0.7	11.9	24	24.070	0.494	0.495833	11.75	139.85	2.94
0.75	13.125	25	25.075	0.523	0.525	12.21	160.23	2.97
0.8	14.4	26	26.080	0.552	0.553846	12.65	182.17	3.00
0.85	15.725	27	27.085	0.581	0.582407	13.08	205.71	3.02
0.9	17.1	28	28.090	0.609	0.610714	13.50	230.87	3.04
0.95	18.525	29	29.095	0.637	0.638793	13.91	257.71	3.07
1	20	30	30.100	0.664	0.666667	14.31	286.26	3.09

Exhibit 4H: Drainage Crossing Dimension Calculations and Capacity

Sediment Diamtwer Transport = Qd * S		
Qd = Flow depth in feet		
S = slope in feet/feet		
Estimated flow depth =		2 ft
Calculated slope =		0.25 ft/ft
Diameter = (Q * S) =		0.5 ft
		6 imches
Volume = $4\pi/3 * (D/2)^3$		113.0973 in.3
		1853.337 cm2
Sandstone density =		2.6 g/cm3
		2600 kg/m3
Mass = density * volume		4818.677 g
		4.818677 kg
Weight =		10.62335 lbs
F = π*W*V*Ct*Co*Cd*Cb*Rmax / 2*g*t		
π =	3.141593	
W =	10.62335 lbs	1000 lbs
V =	22 ft/s	
Ct =	0.6	
Co =	0.8	
Cd =	0.12	
Cb =	0.2	
Rmax	0.4	
g =	32.2 ft/s2	
t =	0.03 s	
F =	1.751215 lbs	164.8458 lbs

Exhibit 4I: Force and Size of Debris carried in a channel from ASCE 7-12

Debris Deflector

Height = 1.1 * Diameter				
	29.7	inches	2.475	ft
			2.5	ft
Width = 1.1*D = 1.1*2D+thickness = 1.1 * (2*27 + 4) =				
	63.8	inches	5.316667	ft
			5.33	ft
Apex angle = (15/25) =			20	
	25	degrees		
Bar spacing = 2/3 D =				
	18	inches	1.5	ft
thickness =				
	1	in	0.083333	
Minimum Side area = 5* Areaq of Culvert				
	5725.553	in.2	39.76078	sq ft
assum L =	192.7795	inches	16.06496	ft
	192		16	ft
	222		18.5	ft
Vertical Bars = (l+s)/(s+t)				
	11.09366	bars	12	
	12.63158		13	
Horizontal bars =(H+s)/(S+t)				
	2.526316	bars	3	
Gross area = L*H =				
			40	sq ft
			46.25	

Area of bars = (number of H bars)*(t)*(L) + (number of v bars)*(t)*(H)				
			6.5	sq ft
			7.333333	
Net area = Gross - A bars =				
			33.5	
			38.91667	
Distance to Apex = Lcos(0.5 a) =			18.21894	ft
Width = 2 * L * sin(0.5 a) =			6.424983	
Horizontal top supports				
2.166667 ft				
3.208333 ft				
4.25 ft				
5.291667 ft				
6.333333 ft				

Exhibit 4J: Debris Deflector Dimensions Calculations

Debris Rack 36 inch culvert

width		4.25	ft	
bar thickness		1	in. Pipe 3/4 std	
Minimum area = 4(Area Culvert =				
	35.34292	sq ft		
	36	sq ft		
Minimum Spacingt = 1/2 D				
		18	in.	
Maximum Spacingt = 2/3 D				
		24	in.	
Number of Vertical Bars = (w-smin)/(smin+t)				
per min spacing		1.736842	2	
per max spacing		1.08	2	+2
Spacing = (W-t(Number bars) / (number of bars +1)				
	16.33333	in.		
Horizontal bars				
		2		
Height = Arack /(n+1)(s) + t(number of hoizontal) =				
	6.658223	ft		
	8	ft		
Gross area = w*H =				
	34	sq ft		
Area of bars =				
	3.375	sq ft		
Net area =				
	30.625	sq ft		

Exhibit 4K: Debris Rack Dimensions Calculations for draw E1

A2 Debris Rack existing double culvert

width		6	ft	
bar thickness		1	in. Pipe 3/4 std	
Minimum area = 10(Area Culvert =				
	35.34292	sq ft		
	36	sq ft		
Minimum Spacingt = 1/2 D				
		18	in.	
Maximum Spacingt = 2/3 D				
		24	in.	
Number of Vertical Bars = (w-smin)/(smin+t)				
	min	2.842105	3	
	max	1.92	2	+2
Spacing = (W-t(Number bars) / (number of bars +1)				
	23.33333	in.		
Horizontal bars				
		2		
Height = Arack /(n+1)(s) + t(number of hoizontal) =				
	6.171429	ft		
	7	ft		
Gross area = w*H =				
	42	sq ft		
Area of bars =				
	2.166667	sq ft		
Net area =				
	39.83333	sq ft		

Exhibit 4L: Debris Rack Dimensions Calculations for draw A2

Rock Size

	PI3	PI1
Q anticipated (cfs)	45	178
D (ft)	2	3
Q/D^1.5	15.90990258	34.25611597
Y (ft)	1.55	1.3
Y/D	0.775	0.433333333
d50	0.496859174	2.149212903
Type	L	VH

Exhibit 4M: Grouted Riprap Sizing

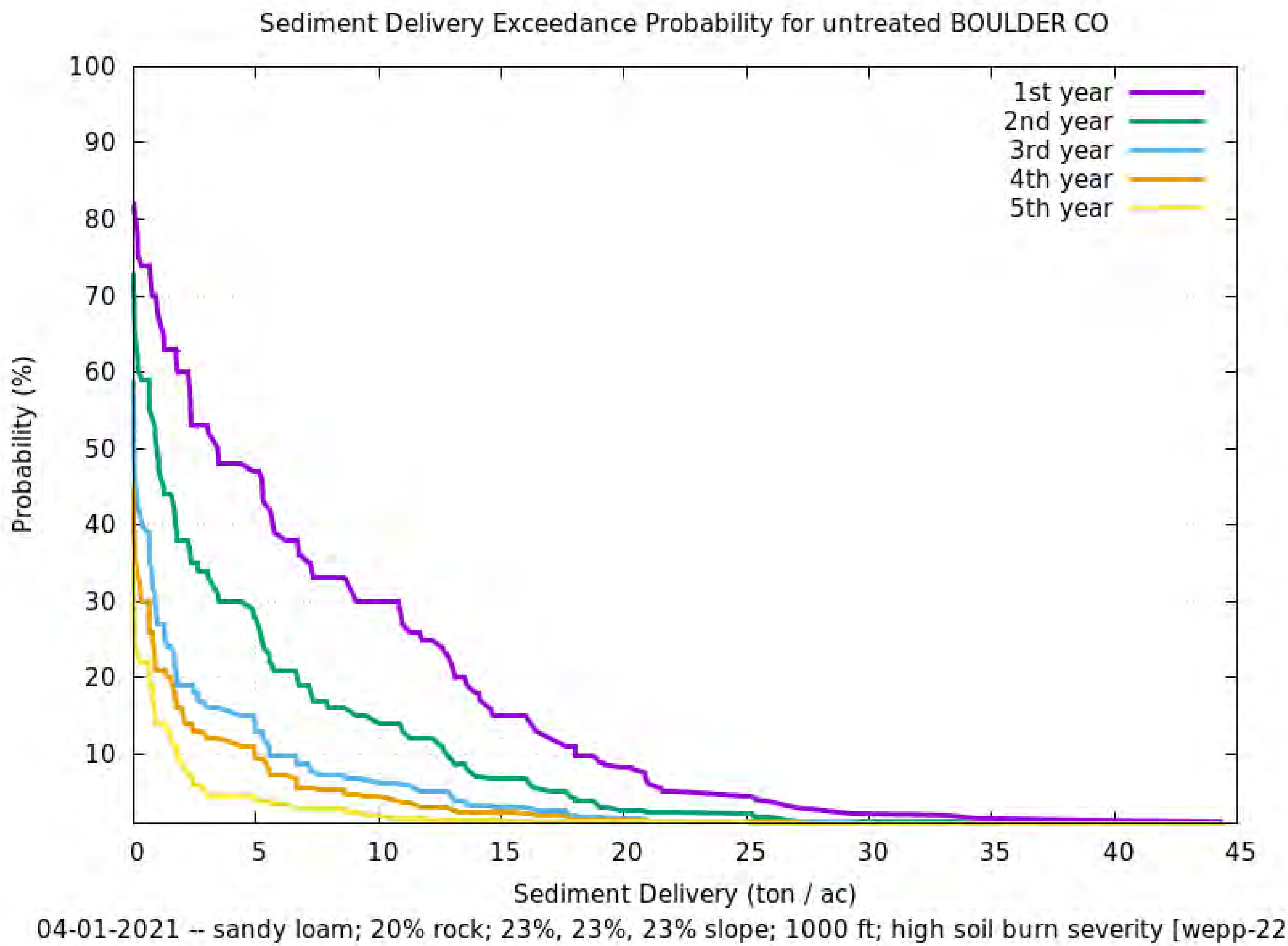


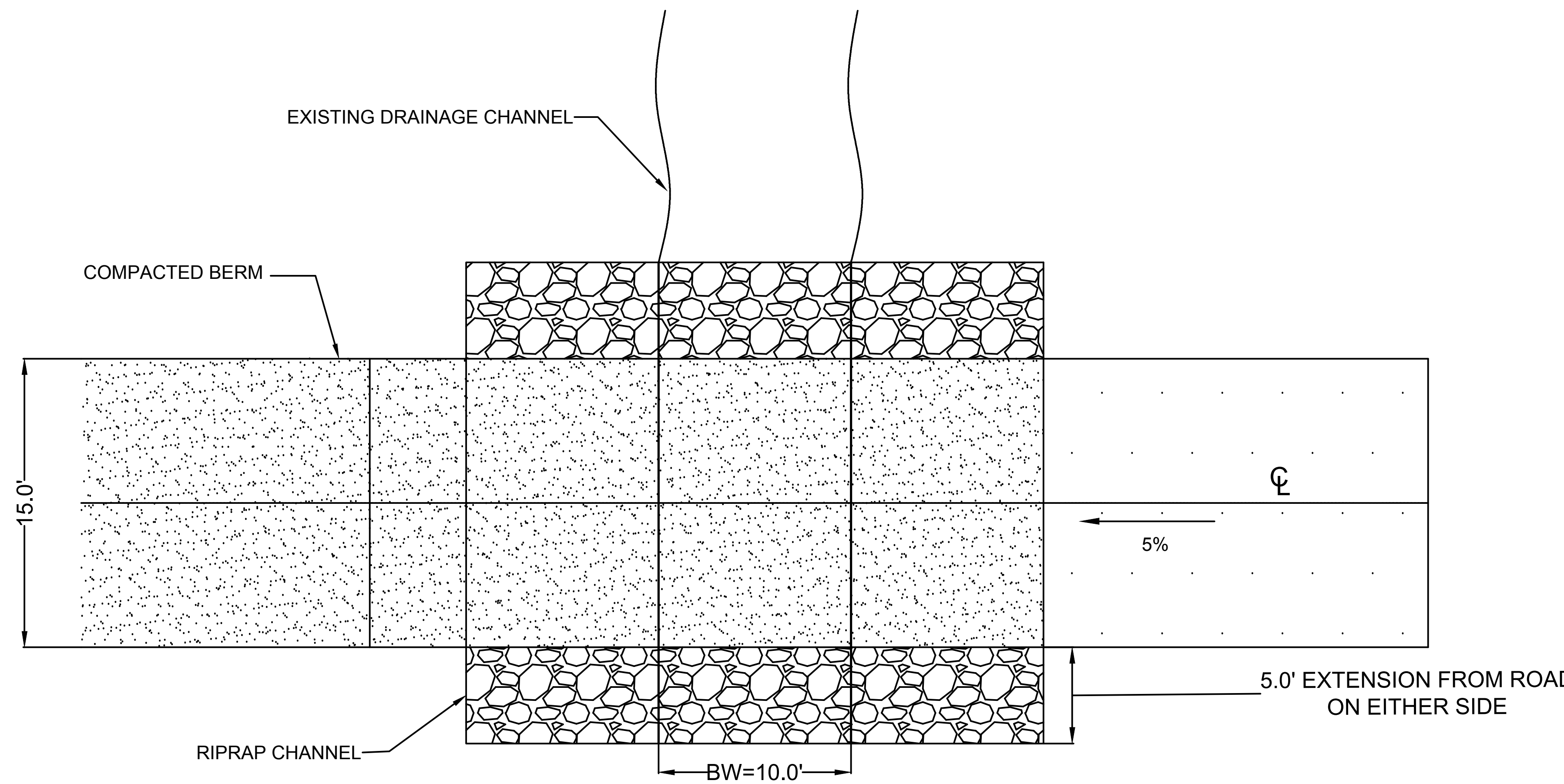
Exhibit 4N: Sediment Delivery Exceedance Probability

Sediment Delivery					
Probability that sediment yield will be exceeded 20 % go	Event sediment delivery (ton ac^{-1})				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	13.39	6.82	1.77	1.49	0.64
Seeding	13.39	4.87	1.58	0.89	0.64
Mulch (0.5 ton ac^{-1})	4.89	3.33	1.77	1.49	0.64
Mulch (1 ton ac^{-1})	2.83	2.39	1.77	1.49	0.64
Mulch (1.5 ton ac^{-1})	2.63	2.28	1.77	1.49	0.64
Mulch (2 ton ac^{-1})	2.26	2.27	1.77	1.49	0.64
Erosion Barriers: Diameter 0.15 ft Spacing 5 ft go ?					
Logs & Wattles	13.39	6.82	1.77	1.49	0.64

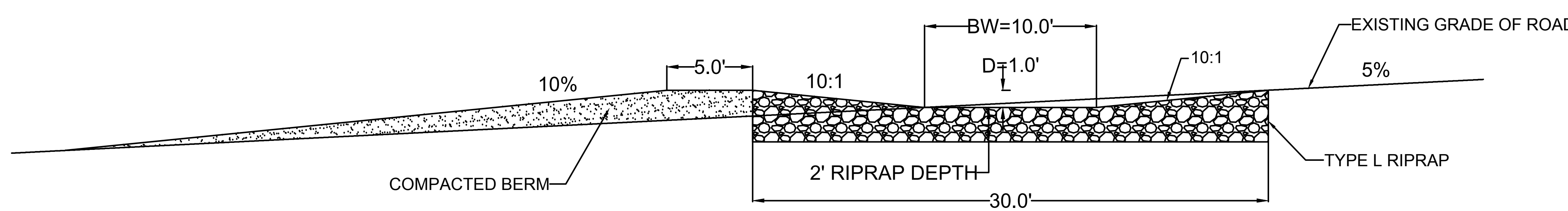
Exhibit 4O: Erosion Risk Management Tool Results for location and events

Exhibit 5: Standard Drawings

PLAN VIEW



PROFILE VIEW



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COLORADO LAW (SENATE BILL 93-155) REQUIRES PERSONS TO NOTIFY THE UTILITY NOTIFICATION CENTER OF COLORADO 2 BUSINESS DAYS PRIOR TO MAKING OR BEGINNING AN EXCAVATION. NOTIFICATION MAY BE MADE BY CALLING:
811

DESIGNED SR
DRAWN SR AGT

Boulder County

INITIATE ENGINEERING

1200 LARIMER ST #3034, DENVER, CO 80204

STANDARD DETAIL

ARMORED DRAINAGE CROSSING

IE PROJECT NO. 0001

DATE ISSUED 05/06/2021

SHEET NO. S-1

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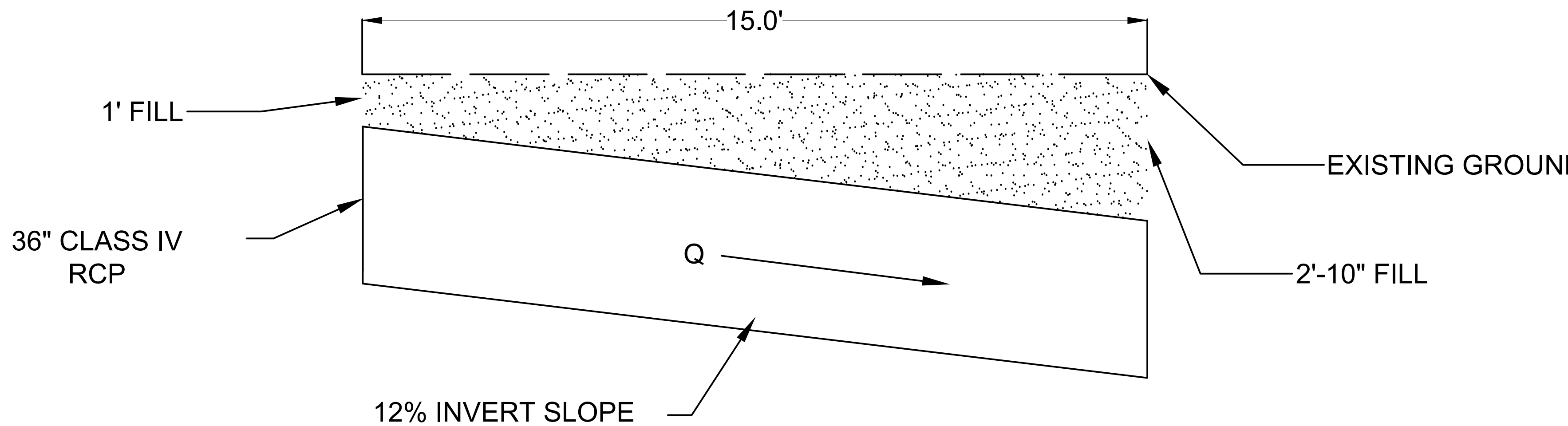
PROFILE VIEW



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SR

DRAWN
SR AGT

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DENVER, CO 80204

STANDARD DETAIL

CULVERT

IE PROJECT NO. 0001

DATE ISSUED 05/06/2021

SHEET NO. S-2

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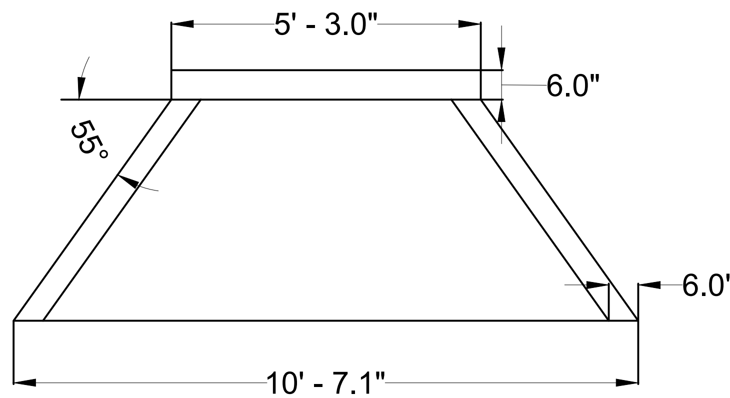
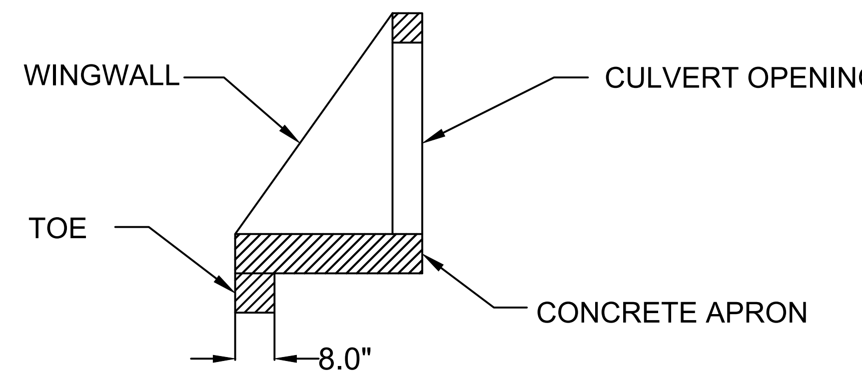
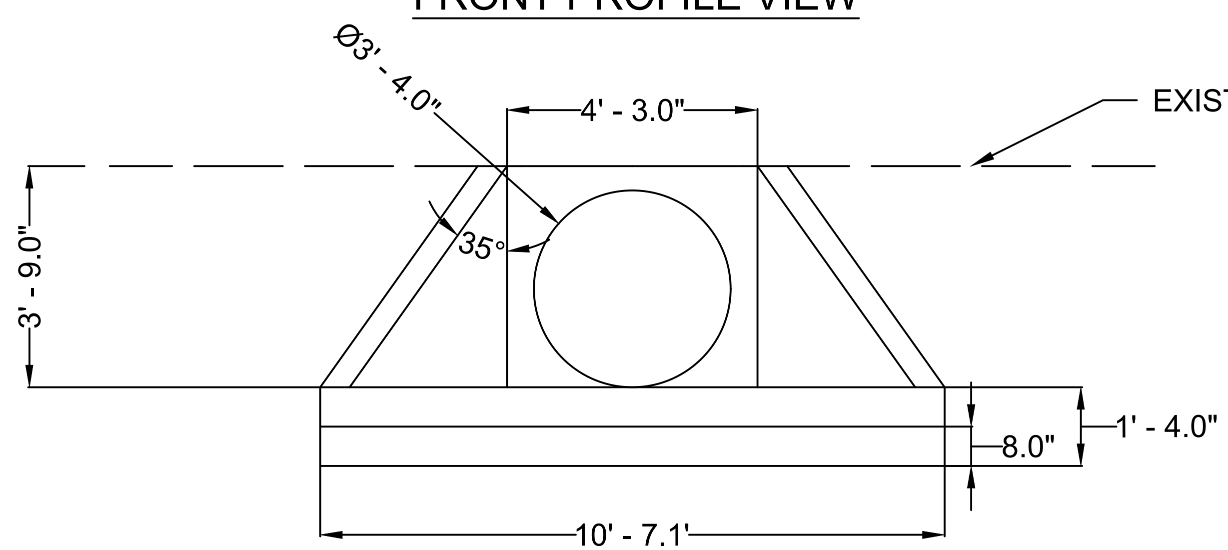
PLAN VIEW



SIDE PROFILE VIEW



FRONT PROFILE VIEW



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STANDARD DETAIL

HEADWALL

IE PROJECT NO. 0001

DATE ISSUED 05/06/2021

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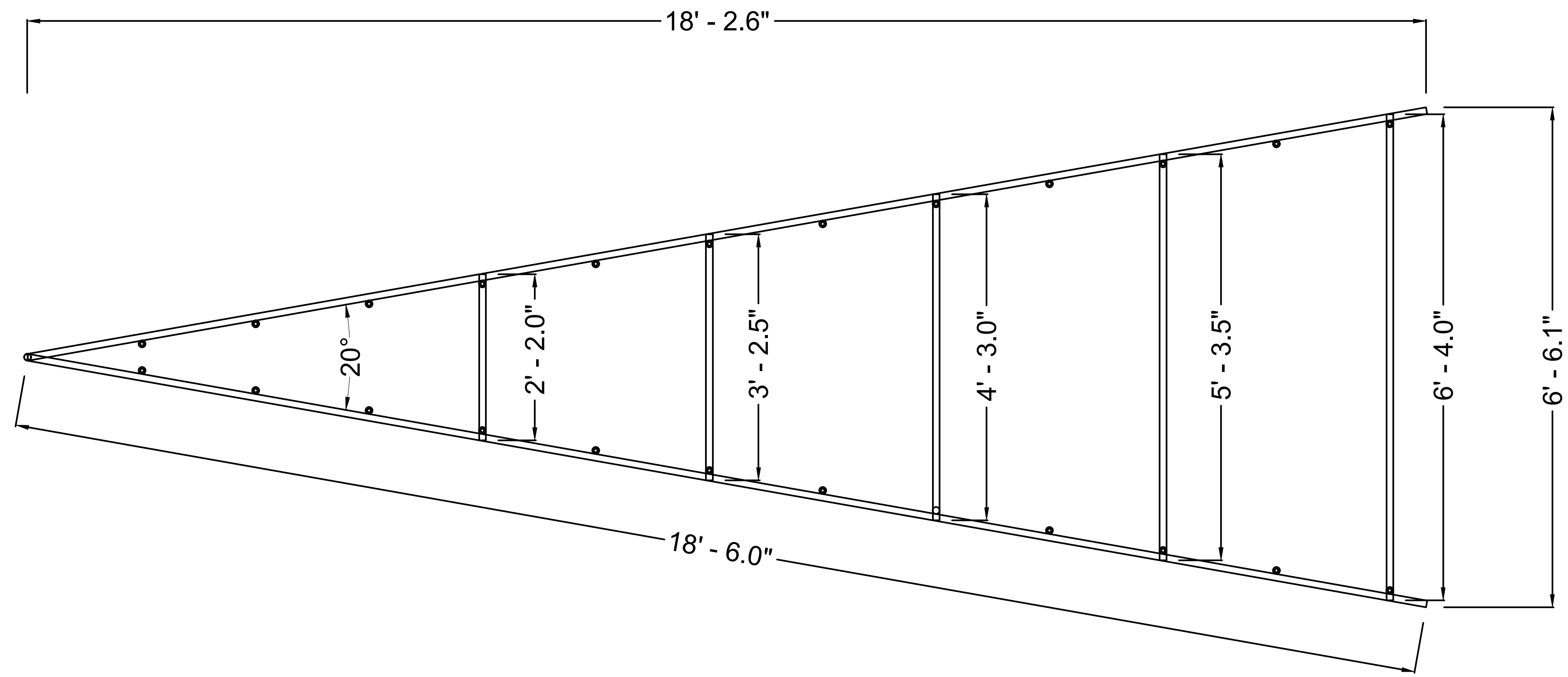
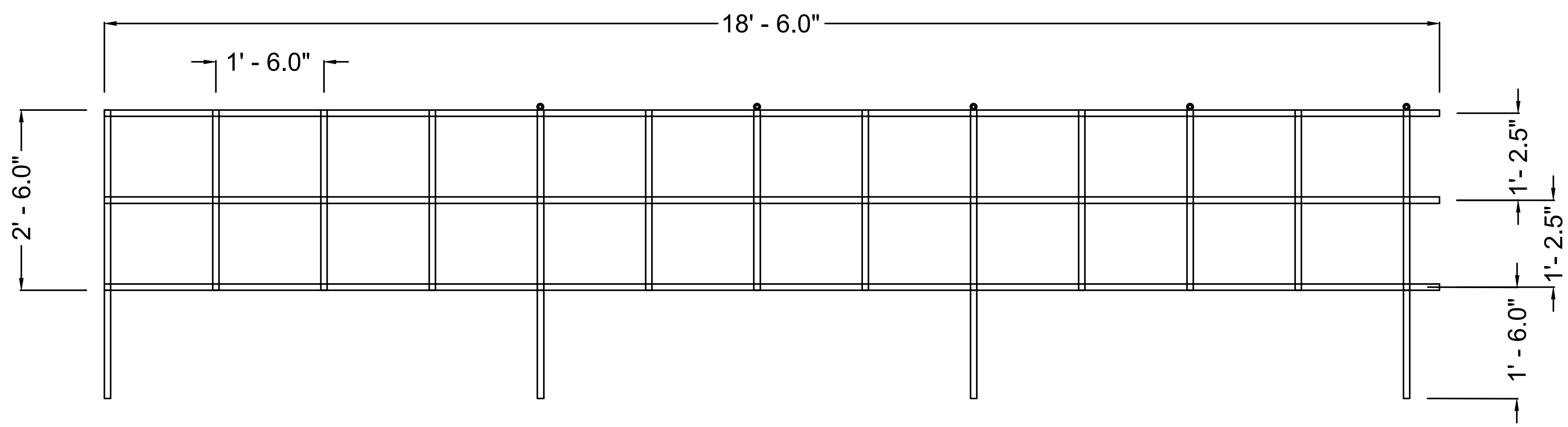
PLAN VIEW



PROFILE VIEW



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Boulder County

INITIATE ENGINEERING

1200 LARIMER ST #3034, DENVER, CO 80204

STANDARD DETAIL

DEBRIS DEFLECTOR

IE PROJECT NO. 0001

DATE ISSUED 05/06/2021

SHEET NO. S-4

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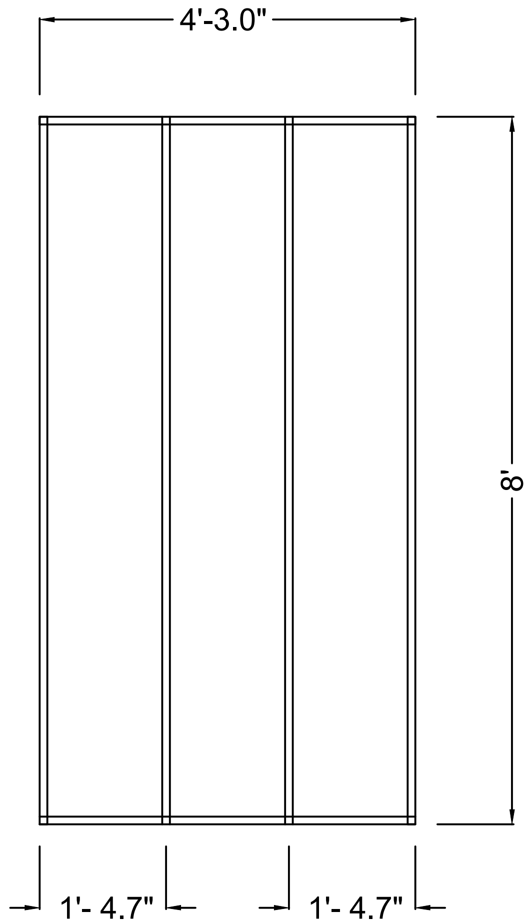
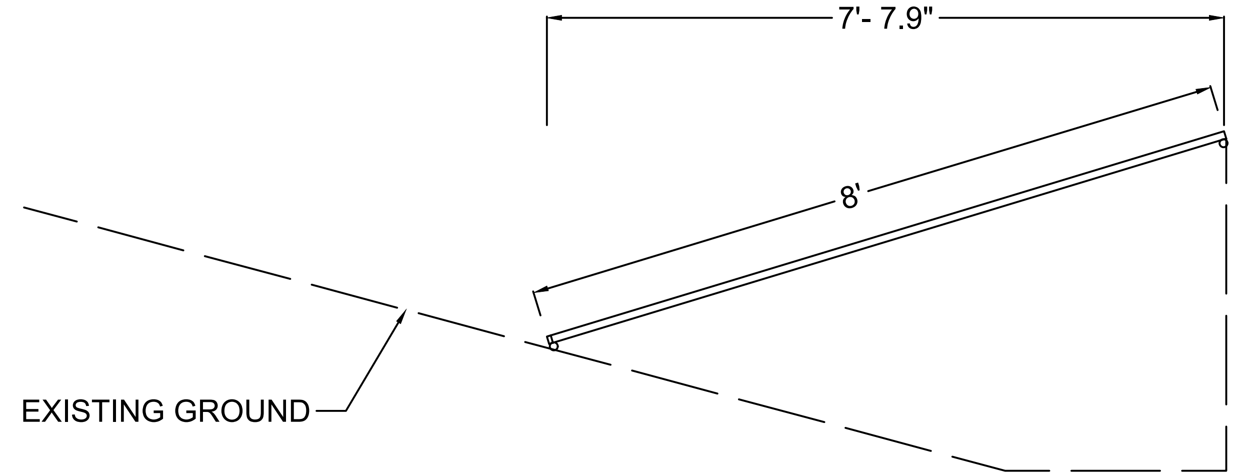
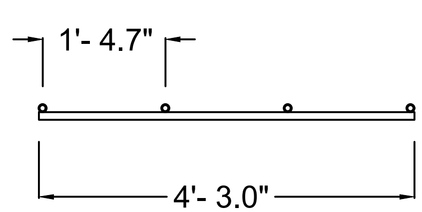
PLAN VIEW



SIDE PROFILE VIEW



LOWER PROFILE VIEW



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INITIATE ENGINEERING

1200 LARIMER ST #3034,
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STANDARD DETAIL

DEBRIS RACK

IE PROJECT NO. 0001

DATE ISSUED 05/06/2021

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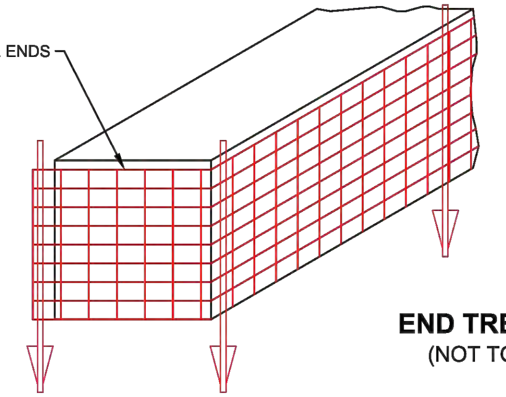
EWP TYPICAL DETAILS

FLOOD BARRIER BAG WITH WIRE FENCE

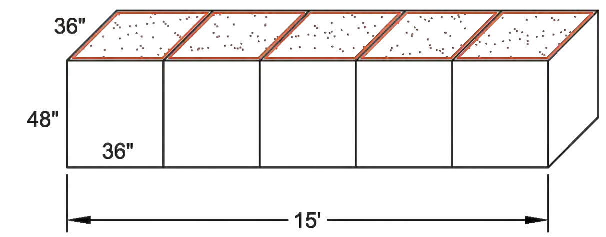
(NOT TO SCALE)

[FOR LOCATIONS THAT REQUIRE ADDITIONAL DEBRIS PROTECTION]



END TREATMENT
(NOT TO SCALE)

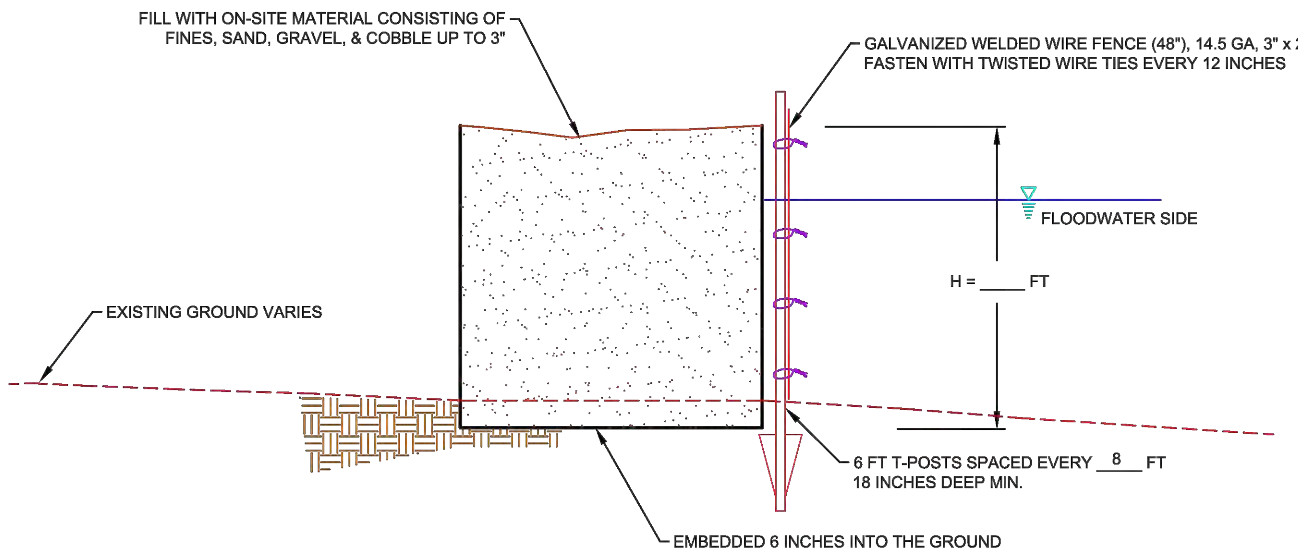
BARRIER MATERIAL SPECIFICATIONS:
MATERIAL: WOVEN POLYPROPYLENE COATED FABRIC
MASS/UNIT AREA: >8 OZ./SQ. YD.
CHAIN STITCH
STITCH MATERIAL: POLYPROPLYLENE
TENSILE STRENGTH: 312 x 312 LBS/FT
UV RESISTANCE: >70% AT 1,200 HRS
PUNCTURE STRENGTH: > 100 LBS



"EXAMPLE" FLOOD BARRIER BAG SYSTEM

FILL REQUIRED = (LENGTH x H x W)/27 = CY

FILL VOLUME =(_____ x ____ x ____)/27 = _______ CY



SECTION THROUGH BARRIER
(NOT TO SCALE)

DESIGN QUANTITIES			
NO.	DESCRIPTION	QTY	UNITS
1	FLOOD BARRIER BAGS		LF
2	STEEL T-POSTS		EA
3	WELDED WIRE FENCE, 48"		SF
4	EARTHFILL FOR BAGS		CY

LF: LINEAR FEET CY: CUBIC YARDS EA: EACH SF: SQUARE FEET

CONSTRUCTION NOTES:

1. PLACE THE FLOOD BARRIERS AT THE LOCATION AND CONFIGURATION SHOWN ON THE SITE PLAN OR AS DIRECTED BY AN NRCS REPRESENTATIVE.
2. OBTAIN NRCS APPROVAL OF THE BARRIER PRODUCTS BEFORE PURCHASING THEM. INSTALL MANUFACTURED PRODUCTS TO THE MANUFACTURER'S GUIDELINES UNLESS OTHERWISE DIRECTED BY NRCS.
3. CLEAR AND GRUB THE FOUNDATION AREA FOR THE BARRIERS TO A MINIMUM DEPTH OF 6 INCHES BEFORE PLACING THE BARRIER. REMOVE ALL ORGANIC MATERIALS WITHIN THE FOOTPRINT OF THE BARRIER.
4. FILL MATERIAL FOR BARRIER BAGS AND BACKFILL SHALL BE FREE OF ROOTS, SOD, AND OTHER ORGANIC MATERIALS; SHARP OBJECTS INCLUDING LARGE ROCKS; FROZEN SOILS; OR OTHER OBJECTIONABLE MATERIAL. IF A BORROW SITE IS NOT SHOWN ON THE DRAWINGS, THE CONTRACTOR SHALL USE OTHER ON-SITE FILL MATERIAL AS APPROVED BY THE NRCS.
5. SEED AND MULCH ALL DISTURBED AREAS AND BARE GROUND WITHIN 200 FEET OF THE WORK SITE.
6. THE FLOOD BARRIER PRODUCT SHALL BE RATED FOR A LIFESPAN OF AT LEAST _5_YEARS.

	Date
Designed by: TJ BURR	8/23/2019
Drawn by: TJ BURR	6/1/2020
Checked by: ----	__/__/2019
Approved by: ____	__/__/2019

WATERSHED:
TYPICAL DWGS & SPECS SITE
EROSION PROTECTION
FBB WITH WIRE FENCE

USDA United States Department of Agriculture
Natural Resources Conservation Service

JOB CLASS: ?
SHEET REVISED: 10/1/2019
SHEET 23 OF 24

0_Standard_Drawings_EWP_TJB.dwg PRINT DATE-TIME: Oct 27, 2020 - 6:31 PM

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COLORADO LAW (SENATE BILL 93–155) REQUIRES PERSONS TO NOTIFY THE UTILITY NOTIFICATION CENTER OF COLORADO 2 BUSINESS DAYS PRIOR TO MAKING OR BEGINNING AN EXCAVATION. NOTIFICATION MAY BE MADE BY CALLING: 811

DESIGNED SR
DRAWN SR AGT

Boulder County
INITIATE ENGINEERING
1200 LARIMER ST #3034, DENVER, CO 80204

STANDARD DETAIL

FLOOD BARRIER BAG
IE PROJECT NO. 0001
DATE ISSUED 05/06/2021
SHEET NO. S-6

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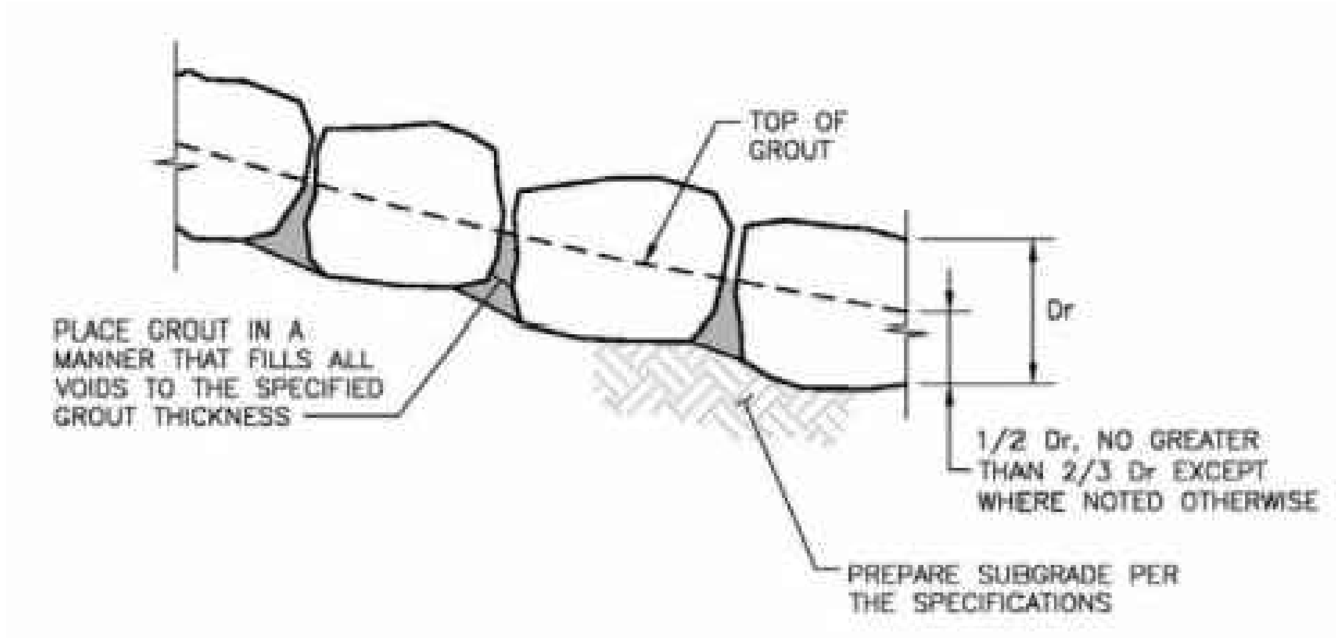

BOULDER PLACEMENT NOTES:

1. PLACE BOULDERS WITH THE REQUIRED BOULDER HEIGHT VERTICAL. PLACE BOULDERS AS TIGHTLY TOGETHER AS POSSIBLE (WITHOUT TOUCHING) WHILE PROVIDING ENOUGH ROOM BETWEEN THEM TO THOROUGHLY VIBRATE THE GROUT AND TO ENSURE NO GAPS IN THE GROUT. THE SMALL DIMENSION OF A 2X4 CAN BE USED AS A GUIDE TO CHECK MINIMUM SPACING.
2. BEFORE GROUTING, CLEAN ALL DIRT AND MATERIAL FROM ROCK THAT COULD PREVENT THE GROUT FROM BINDING TO THE ROCK. KEEP BOULDERS FROM TOUCHING. AVOID SLIDING BOULDERS AGAINST SUBGRADE TO PROPERLY POSITION.

MATERIAL SPECIFICATIONS:

1. ALL GROUT SHALL HAVE A MINIMUM 28-DAY COMPRESSIVE STRENGTH EQUAL TO 3200 PSI.
2. ONE CUBIC YARD OF GROUT SHALL HAVE A MINIMUM OF SIX (6) SACKS OF TYPE II PORTLAND CEMENT.
3. A MAXIMUM OF 25% TYPE F FLY ASH MAY BE SUBSTITUTED FOR THE PORTLAND CEMENT.
4. THE AGGREGATE SHALL BE COMPRISED OF 70% NATURAL SAND (FINES) AND 30% ⅜-INCH ROCK (COARSE).
5. THE GROUT SLUMP SHALL BE BETWEEN 4-INCHES TO 6-INCHES.
6. AIR ENTRAINMENT SHALL BE BETWEEN 5.5% AND 7.5%.
7. TO CONTROL SHRINKAGE AND CRACKING, 1.5 POUNDS OF FIBERMESH, OR EQUIVALENT, SHALL BE USED PER CUBIC YARD OF GROUT.
8. COLOR ADDITIVE IN REQUIRED AMOUNTS SHALL BE USED WHEN SO SPECIFIED BY CONTRACT.

GROUT PLACEMENT SPECIFICATIONS:

1. SPECIAL PROCEDURES SHALL BE REQUIRED FOR GROUT PLACEMENT WHEN THE AIR TEMPERATURES ARE LESS THAN 40°F OR GREATER THAN 90°F. CONTRACTOR SHALL OBTAIN PRIOR APPROVAL FROM THE DESIGN ENGINEER OF THE PROCEDURES TO BE USED FOR PROTECTING THE GROUT.
2. GROUT SHALL BE DELIVERED BY MEANS OF A LOW PRESSURE (LESS THAN 10 PSI) GROUT PUMP USING A 2-INCH DIAMETER (MAXIMUM) NOZZLE.
3. FULL DEPTH PENETRATION OF THE GROUT INTO THE BOULDER VOIDS SHALL BE ACHIEVED BY INJECTING GROUT STARTING WITH THE NOZZLE NEAR THE BOTTOM AND RAISING IT AS THE GROUT FILLS, WHILE VIBRATING GROUT INTO PLACE USING A PENCIL VIBRATOR.
4. ALL GROUT BETWEEN BOULDERS SHALL BE TREATED WITH A BROOM FINISH.
5. AFTER GROUT PLACEMENT, EXPOSED BOULDER FACES SHALL BE CLEANED AND FREE OF GROUT.
6. ALL FINISHED GROUT SURFACES SHALL BE SPRAYED WITH A CLEAR LIQUID MEMBRANE CURING COMPOUND AS SPECIFIED IN ASTM C309.

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Boulder County

INITIATE ENGINEERING

1200 LARIMER ST #3034, DENVER, CO 80204

STANDARD DETAIL

GROUT RIPRAP

IE PROJECT NO. 0001

DATE ISSUED 05/06/2021

SHEET NO. S-7

Exhibit 6: RSMeans Cost Analysis

Boulder

Data Release : Year 2021 Quarter 1 **Unit Cost Estimate**

Quantity	LineNumber		Description	Daily Output	Labor Hours	Unit	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P	Notes
69.44	312316130060		Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	200	0.08	B.C.Y.	$ -	$ 376.36	$ 79.86	$ 456.22	Armored Drainage Crossing
2	015433200100		Rent excavator diesel hydraulic crawler mounted 1/2 CY capacity, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 1,267.80	$ 1,267.80	Armored Drainage Crossing
2	015433407200		Rent truck pickup 3/4 ton 4 wheel drive, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 478.92	$ 478.92	Armored Drainage
96.44	313713100350		Rip-rap and rock lining, random, broken stone, 100 lb, average, dumped	700	0.02	Ton	$ 2,704.18	$ 149.48	$ 205.42	$ 3,059.08	Armored Drainage
2	015433406500		Rent trailer, platform, flush deck 2 axle, 25 ton, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 383.96	$ 383.96	Armored Drainage
1	015433201200		Rent compactor, manually guided 2-drum vibratory smooth roller, 7.5 H.P., Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 234.99	$ 234.99	Armored Drainage
10.38	312323130400		Backfill and compact, by hand, 6" layers, compaction in layers, roller compaction with operator walking, add to above	100	0.12	E.C.Y.	$ -	$ 88.85	$ 16.92	$ 105.77	Armored Drainage
1	015433200100		Rent excavator diesel hydraulic crawler mounted 1/2 CY capacity, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 633.90	$ 633.90	RCP
2	015433407200		Rent truck pickup 3/4 ton 4 wheel drive, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 478.92	$ 478.92	RCP
22.52	312316130090		Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	200	0.08	B.C.Y.	$ -	$ 122.06	$ 25.90	$ 147.96	RCP
1	015433406500		Rent trailer, platform, flush deck 2 axle, 25 ton, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 191.98	$ 191.98	RCP
30.22	334211602060		Public storm utility drainage piping, reinforced concrete pipe (RCP), 36" diameter, 8' lengths, class 3, excludes excavation or backfill, gaskets	72	0.78	L.F.	$ 2,616.75	$ 1,164.38	$ 241.46	$ 4,022.58	RCP

12.66	312323130400		Backfill and compact, by hand, 6" layers, compaction in layers, roller compaction with operator walking, add to above	100	0.12	E.C.Y.	$ -	$ 108.37	$ 20.64	$ 129.01	RCP
60	031113300050		C.I.P. concrete forms, culvert, square or rectangular, 5' to 8', 2 use, includes erecting, bracing, stripping and cleaning	180	0.18	SFCA	$ 233.40	$ 574.20	$ -	$ 807.60	RCP
2	015433100200		Rent bucket concrete lightweight 1/2 CY, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 87.60	$ 87.60	RCP
108	033113250130		Concrete, hand mix, for small quantities or remote areas, 3000 psi, using gas powered cement mixer, includes local bulk aggregate & sand, bagged Portland cement (Type I) and water, excludes, forms, reinforcing, placing & finishing	135	0.06	C.F.	$ 637.20	$ 303.48	$ 115.56	$ 1,056.24	RCP
100	032105100100		Beam bolsters, for reinforcing steel, lower (BB), plain steel, 1-1/2" high, includes material only	0	0	C.L.F.	$ 2,455.00	$ -	$ -	$ 2,455.00	RCP
143	033113250130		Concrete, hand mix, for small quantities or remote areas, 3000 psi, using gas powered cement mixer, includes local bulk aggregate & sand, bagged Portland cement (Type I) and water, excludes, forms, reinforcing, placing & finishing	135	0.06	C.F.	$ 843.70	$ 401.83	$ 153.01	$ 1,398.54	Debris Deflectors
5.3	312316131400		Excavating, trench or continuous footing, common earth, by hand with pick and shovel, 2' to 6' deep, light soil, excludes sheeting or dewatering	8	1	B.C.Y.	$ -	$ 310.85	$ -	$ 310.85	Debris Deflector
75	050523900020		Weld rod, steel, 1/8" diameter, less than 500#, type 6011	0	0	Lb.	$ 210.75	$ -	$ -	$ 210.75	Debris Deflector and Debris Rack
810	221113440580		Pipe, steel, black, threaded, 1" diameter, schedule 40, Spec. A-53, includes coupling and clevis hanger assembly sized for covering, 10' OC	53	0.15	L.F.	$ 3,134.70	$ 8,780.40	$ -	$ 11,915.10	Debris Deflectors
141	221113440580		Pipe, steel, black, threaded, 1" diameter, schedule 40, Spec. A-53, includes coupling and clevis hanger assembly sized for covering, 10' OC	53	0.15	L.F.	$ 545.67	$ 1,528.44	$ -	$ 2,074.11	Debris Racks
3	015433407700		Rent arc welder electric 200 amp, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 189.82	$ 189.82	Debris Deflectors and Debris Racks
1	015433401850		Rent drill, rotary hammer, electric, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 79.62	$ 79.62	Debris Racks
3	015433406100		Rent saw circular electric 7-1/4" diameter, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 46.37	$ 46.37	Debris Deflectors and Debris Racks

26	031519100060		Anchor bolts, hooked type, single, 5/8" diameter x 12" long, installed in fresh concrete, includes nut and washer, excludes template	127	0,06	Ea,	$ 127,14	$ 92,56	$ -	$ 219,70	Debris Racks
6	1		Flood Barrier Bags	0	0	Ea.	$ 2,700.00	$ 300.00	$ 120.00	$ 3,120.00	Flood Barrier Bags
3	313713100110		Rip-rap and rock lining, random, broken stone, 3/8 to 1/4 C.Y. pieces, machine placed for slope protection, grouted	80	0,7	S.Y.	$ 198,93	$ 133,62	$ 21,57	$ 354,12	Grouted Riprap
3	312316130090		Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	200	0,08	B,C,Y.	$ -	$ 16,26	$ 3,45	$ 19,71	Grouted Riprap
4	015433200100		Rent excavator diesel hydraulic crawler mounted 1/2 CY capacity, Incl. Hourly Oper. Cost.	0	0	Day	$ -	$ -	$ 2,535,59	$ 2,535,59	Grouted Riprap
							$ 16,407,42	**$ 14,451,14**	**$ 7,613,26**	**$ 38,471,81**	

	Materials	Labor	Equipment	Total
Armored Drainage Crossing	$ 2,704.18	$ 614.69	$ 2,667.87	$ 5,986.74
RCP Culverts	$ 5,942.35	$ 2,272.49	$ 1,795.96	$ 10,010.79
Debris Deflectors	$ 3,345.45	$ 9,091.25	$ 189.82	$ 12,626.52
Debris Racks	$ 672.81	$ 1,621.00	$ 125.99	$ 2,419.80
Flood Barrier Bags	$ 2,700.00	$ 300.00	$ 120.00	$ 3,120.00
Grouted Riprap	$ 198.93	$ 149.88	$ 2,560.61	$ 2,909.42
Total	**$ 16,407.42**	**$ 14,451.14**	**$ 7,613.26**	**$ 38,471.81**

Exhibit 7: References

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Exhibit 8: Time Sheet

PROJECT SUMMARY OF HOURS - JANUARY

Date	1/17 - 1/23	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		6.5	2.5	3	2	2.5	9		Discription
Administration		3						AGT	Created douments for future work, contacted client & faculty support, passed on client sent info to team
								AR	
								BS	
								QS	
								SR	
								SL	
Training		1	2	2.5	1.5	2	6	AGT	Research
								AR	Research
								BS	research
								QS	Research
								SR	research
								SL	research and finding references
Teams		0.5	0.5	0.5	0.5	0.5	0.5	AGT	Meeting w/ Client
								AR	Meeting w/ Client
								BS	Meeting w/ Client
								QS	Meeting w/ Client
								SR	Meeting w/ Client
								SL	Meeting w/ Client
Design								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Report		2					2.5	AGT	Layout
								AR	
								BS	
								QS	
								SR	
								SL	began filling in skeleton report

Date	1/24 - 1/30	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		4	1	2.5	1.5	3	5		Discription
Administration		3						AGT	Availability sheet setup, Excel Time Sheet setup
								AR	
								BS	
								QS	
								SR	
								SL	
Training		1	1	2.5	1.5	1	1.5	AGT	Research
								AR	Research
								BS	research
								QS	Reviewed detail and spec drawings, some research
								SR	

			SL	research over previous fire mitigtion designs
Teams		3.5	AGT	
			AR	
			BS	
			QS	
			SR	
			SL	pro/con chart of individual mitigation designs
Design	2		AGT	
			AR	
			BS	
			QS	
			SR	
			SL	
Report			AGT	
			AR	
			BS	
			QS	
			SR	
			SL	

PROJECT SUMMARY OF HOURS - FEBRUARY

Date	1/31 - 2/6	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		6.5	3.5	5.5	5	2.5	5.5		Discription
Administration					1.5			AGT	
								AR	
								BS	
								QS	Scanned project pdf
								SR	
								SL	
Training		1	1	3			3	AGT	Watched soil presentation sent by Mike
								AR	Research into the 416 fire
								BS	research
								QS	
								SR	
								SL	research and watching presentation sent by Mike
Teams		2.5	2.5	2.5	2.5	2.5	2.5	AGT	Project Check-In
								AR	Project Check-In
								BS	Project Check-In
								QS	Project Check-In
								SR	Project Check-In
								SL	Project Check-In
Design		3			1			AGT	CAD Maping
								AR	
								BS	
								QS	Came up with and typed preliminary dersign plan
								SR	
								SL	
Report								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	

Date	2/7 - 2/13	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		1	5	5.5	3.5	5	7.5		Discription
Administration							2.5	AGT	
								AR	
								BS	
								QS	

								SR	
								SL	contacting other municipalities for advise and recommendations
								AGT	
								AR	Research into the 416 fire
								BS	research
Training			4	4.5	2.5	2	4	QS	Researched various concepts about post-fire response and debris flow mitigation
								SR	reading and research
								SL	research over soil erosion control and vegetative recovery
								AGT	met with Professor Li
								AR	met with Professor Li
								BS	met with Professor Li
Teams		1	1	1	1	1	1	QS	met with Professor Li
								SR	met with Professor Li
								SL	met with Professor Li
								AGT	
								AR	
								BS	
Design						2		QS	
								SR	mapping model
								SL	
								AGT	
								AR	
								BS	
Report								QS	
								SR	
								SL	

Date	2/14 - 2/20	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		0	2.5	8.5	3.5	9	2		Discription
								AGT	
								AR	
								BS	
Administration								QS	
								SR	
								SL	
								AGT	
								AR	
								BS	research
Training				3.5	3.5	2	2	QS	Looked over maps, continued some research, looking into GIS maps
								SR	research and map data for model
								SL	contacted other municipalities and researched project background

	Abril	Andrew	Batool	Quinten	Samuel	Shannon		Discription
Teams							AGT	
							AR	
							BS	
							QS	
							SR	
							SL	
Design					7		AGT	
							AR	
							BS	
							QS	
							SR	Modeling design
							SL	
Report		2.5	5				AGT	
							AR	Adding information on the 416 fire
							BS	background info on risk of infrastructure
							QS	
							SR	
							SL	

Date	2/21 - 2/27	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		0	2	9.5	4	9	8		Discription
Administration								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Training				5.5	4	2	3	AGT	
								AR	
								BS	research
								QS	Research into mitigation structures relevant to project
								SR	research and site area research
								SL	research over previous mitigation projects and their approaches
Teams								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
								AGT	
								AR	

Design				7		BS QS SR SL	3-D model design and begin calculations'
Report	2	4			5	AGT AR BS QS SR SL	Reading and adding more information on finds adding to report background, other fires, and applicable codes added to report

PROJECT SUMMARY OF HOURS - MARCH

Date	2/28 - 3/6	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		18	14	11	12	18	11.5		Discription
Administration		2					3.5	AGT	Talk with Marx and SEH
								AR	Meeting Sammy to confirm scope of work completed
								BS	
								QS	
								SR	
								SL	edited information previously added
Training				3	6		2	AGT	
								AR	
								BS	researching
								QS	Research into mitigation structures and calculations
								SR	
								SL	research over previous mitigation projects and their approaches
Teams		8	10	6	6	10	3	AGT	Site Visit (3), Meetings (5)
								AR	Site Visit (3), Meetings (5) Meeting Sammy to confirm scope of work completed(2)
								BS	Site Visit (3), Meetings (3)
								QS	Site Visit (3), Meetings (3)
								SR	Site Visit (3), Meetings (5)
								SL	Meetings (3)
Design						8		AGT	
								AR	
								BS	
								QS	
								SR	Flow calculations
								SL	
Report		8	4	2			3	AGT	Letter of Transmittal, Background, Purpose, presentation to SEH
								AR	Reading and adding more information on finds
								BS	writing
								QS	
								SR	
								SL	added relevant info from helpful mitigation links-CO, USFS, CSU FS

Date	3/7 - 3/13	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		3.5	0.5	6.5	13	12	8.5		Discription
Administration								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Training				2	4		3	AGT	
								AR	
								BS	researching and reading
								QS	More research into design structures and calculations
								SR	
								SL	editing and adding to skeleton report
Teams		2.5	0.5	2.5	2	2	2.5	AGT	Team Meeting(2), Meeting w/ Andrew(0.5)
								AR	Meeting w/ Andrew(0.5)
								BS	Team Meeting(2), Meeting w/ Andrew(0.5)
								QS	Team Meeting
								SR	Team Meeting
								SL	Team Meeting(2), Meeting w/ Andrew(0.5)
Design					7	10	3	AGT	
								AR	
								BS	
								QS	Began design calculations for flows and structures
								SR	calculations for flow and structures
								SL	erosion control structures analysis for 3 points of interest
Report		1		2				AGT	
								AR	
								BS	writing
								QS	
								SR	
								SL	

Date	3/14 - 3/20	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		6	7	5	8	14	5.5		Discription
Administration								AGT	
								AR	
								BS	
								QS	
								SR	

Teams		2			2		AR	Meeting with Sammy
							BS	
							QS	
							SR	Meeting with Andrew
							SL	
Design				5	6		AGT	
							AR	
							BS	
							QS	Calculations for design structures
							SR	design structure calculations and debris flow
							SL	
Report	2	4	4	3	1	2	AGT	Create visuals for exhibits
							AR	Analyzing Costs
							BS	ppt,, adding to report
							QS	Began adding to powerpoint
							SR	drafting flow report sections
							SL	Exhibits

PROJECT SUMMARY OF HOURS - APRIL

Date	3/28 - 4/3	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		3	1	8	11	6	1		Discription
Administration								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Training					2			AGT	
								AR	
								BS	
								QS	Researched CAD applications for drawings and plots
								SR	
								SL	
Teams		1	1	1	1	1	1	AGT	Team meeting-practicing presentation
								AR	Team meeting-practicing presentation
								BS	Team meeting-practicing presentation
								QS	Team meeting-practicing presentation
								SR	Team meeting-practicing presentation
								SL	Team meeting-practicing presentation
Design					5			AGT	
								AR	
								BS	
								QS	CAD drawings for design structure details
								SR	
								SL	
Report		2		7	3	5		AGT	Presentation
								AR	
								BS	ppt , presentation, report
								QS	Added to powerpoint
								SR	power point and report
								SL	

Date	4/4 - 4/10	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		0	3	4.5	10.5	5	0		Discription
Administration								AGT	
								AR	
								BS	
								QS	

								SR	
								SL	
Training					3.5			AGT	
								AR	
								BS	
								QS	Continued research as needed for help with design structure details
								SR	
								SL	
Teams								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Design					5.5	5		AGT	
								AR	
								BS	
								QS	CAD work for design structure details
								SR	Cad drawings
								SL	
Report			3	4.5	1.5			AGT	
								AR	Edits to powerpoint
								BS	edit report
								QS	Made edits to powerpoint
								SR	
								SL	

Date	4/11 - 4/17	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		0	5	3	8	4	4		Discription
Administration								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Training								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	

Teams							AGT	
							AR	
							BS	
							QS	
							SR	
							SL	
Design				6	4		AGT	
							AR	
							BS	
							QS	Finished CAD drawings and plots
							SR	
							SL	
Report		5	3	2		4	AGT	
							AR	Edit Report
							BS	Edit Report
							QS	Added to final report
							SR	
							SL	worked on proposal, edited writing

Date 4/18 - 4/24	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
	AGT	AR	BS	QS	SR	SL		
Total Hours	8.5	7.5	5.5	6.5	5.5	6		Discription
Administration							AGT	
							AR	
							BS	
							QS	
							SR	
							SL	
Training							AGT	
							AR	
							BS	
							QS	
							SR	
							SL	
Teams	2.5	2.5	2.5	2.5	2.5	2.5	AGT	Practice Powerpoint and Present
							AR	Practice Powerpoint and Present
							BS	Practice Powerpoint and Present
							QS	Practice Powerpoint and Present
							SR	Practice Powerpoint and Present
							SL	Practice Powerpoint and Present
							AGT	CAD titleblocks and edits
							AR	

Design	3				3		BS QS SR SL	 finalize cad drawings
Report	3	5	3	4		3.5	AGT AR BS QS SR SL	Report Edit and Writing Adding to report add to report Made edits to and added to report adjusted report based on presentation and exhibits

Date 4/25 - 5/1	Abril AGT	Andrew AR	Batool BS	Quinten QS	Samuel SR	Shannon SL		
Total Hours	24	18	4.5	5.5	0	4		Discription
Administration							AGT AR BS QS SR SL	
Training	3						AGT AR BS QS SR SL	Riprap standards
Teams							AGT AR BS QS SR SL	
Design	4	4		1.5			AGT AR BS QS SR SL	Riprap Calculations Research into differetnt flood barrier bags Researched compacted gravel for armored drainage
Report	17	14	4.5	4		4	AGT AR BS QS	Powerpoint work, Report edits and rewrites Powerpoint work, reasearching different costs ppt, prepare presentation Powerpoint work and edited report

PROJECT SUMMARY OF HOURS - MAY

Date	5/2 - 5/8	Abril AGT	Andrew AR	Batool BS	Quinten QS	Samuel SR	Shannon SL		Discription
Total Hours		18.5	17.5	9.5	7.5	8	6.5		
Administration								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Training								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Teams		3.5	2.5	2.5	2.5	2.5	2.5	AGT	5-7 Minute Presentation, Video edit and turn in
								AR	5-7 Minute Presentation
								BS	5-7 Minute Presentation
								QS	5-7 Minute Presentation
								SR	5-7 Minute Presentation
								SL	5-7 Minute Presentation
Design								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Report		15	15	7	5	5.5	4	AGT	Report Edits and rewrites, Presentation
								AR	Finalizing Report, and Cost Estimates
								BS	conclusion, edit, ppt
								QS	Edited powerpoint and finalizing report
								SR	edit, references, exhibits to report, powerpoint
								SL	met with writing center and made formatting edits

Date	5/9 - 5/12	Abril	Andrew	Batool	Quinten	Samuel	Shannon		
		AGT	AR	BS	QS	SR	SL		
Total Hours		6	13	3	6	5	6		Discription
Administration								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Training								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Teams		3	3	3	3	3	3	AGT	Final Presentation with client
								AR	Final Presentation with client
								BS	Final Presentation with client
								QS	Final Presentation with client
								SR	Final Presentation with client
								SL	Final Presentation with client
Design								AGT	
								AR	
								BS	
								QS	
								SR	
								SL	
Report		3	10		3	2	3	AGT	Finalizing Report, Formating and submital
								AR	Finalizing Report
								BS	
								QS	Finalizing report
								SR	finalizing references and exhibits
								SL	finalizing report
	Total Hrs	107.5	109	99	118.5	117.5	92		

Exhibit 9: Team Initiate Engineering Resumes

Samuel Rivera
7900 E. Iowa Ave Denver, Colorado 80231
303-551-5137
Samuel.Rivera@ucdenver.edu

Objective: Apply and expand engineering design principles in order to become a certified P.E.

Education:

University of Colorado Denver — Denver, Colorado
Major: Civil Engineering — (2017-Present)
Deans List: S19, F19
Expected Graduation Date: Spring 2021

University of Colorado Boulder — Boulder, Colorado
Applied Math Major — (2014-2016)

Relevant Courses:

- Construction Engineering Systems
- Highway Engineering
- Civil Engineering Graphics and Design
- Storm Water System Design
- Intermediate Foundations
- Structural Steel Design
- Geotechnical Eng. I
- Hydrosystems Engineering

Skills: MS Excel, MS Word, AutoCAD, Revit, Civil3D, Sap2000, EPANet, Spanish Language Communication

Work Experience:

Safeway Inc, Starbucks Kiosk: Starbucks Barista (2016-2019)

- Certified Barista, Certified AST Barista Trainer
- Team and individual work. Hand craft drinks, high-quality customer service.
- Track and order inventory. Quarterly new standards training
- Maintain Food and Safety service standards

Underground Infrastructure Technologies: Laborer (Summer 2015)

- Assist microbore tunneling machine operator
- Set up and maintain tunneling construction site

Leadership Experience:

ASCE Student Member (2019 - Present)
Liga Universal Men's Soccer Club – Defensive Captain (2011-Present)
Social Justice Council, First Universalist Church -Youth Representative (2013-2014)
Young Rotary Youth Leadership Awards – Program Scholarship (Summer 2011)

Quinten Schaffner, E.I.

720-346-2442 | qschaffner1@gmail.com | 11466 Kenton St. Henderson, CO 80640

Professional Summary

Civil Engineering soon-to-be graduate seeking an entry-level position as a stormwater engineer. Offer hands-on experience in construction inspection along with education in Civil Engineering principles and tools. In addition to being driven with a dedicated work ethic, I also encompass the ability to:

- Work independently and efficiently on projects and tasks.
- Manage several priorities with excellent time management and organizational skills shown through being a full-time student and working 24 hrs./week.
- Provide high quality work and sound solutions with minimal supervision.
- Effectively collaborate and work in a team environment.

Technical Skills

- AutoCAD/AutoCAD Civil 3D
- EPANET
- Analytical Problem Solving
- Onsite Construction Observation & Management
- OnBase Document Management Software
- Excellent Verbal & Written Communication
- Microsoft Suite Products

Education

Bachelor of Science, Civil Engineering **January 2017 - May 2021**
University of Colorado Denver

Metropolitan State University **August 2015 - December 2016**
Completed 28 credits towards a BS in Civil Engineering Technology

Relevant Coursework

- Graphics and CAD/CAD Civil 3D
- Fluid Mechanics
- Stormwater System Design
- Hydrosystems
- Vadose Zone Hydrology
- Water Supply and Distribution
- Engineering Surveying
- Highway Engineering

Work Experience

Stream Services Student Intern, Mile High Flood District, Denver, CO **May 2019 - Present**

- Inspect ongoing stream management work and other small construction activities.
- Review change orders and billing for maintenance work across Arapahoe County.
- Create mock drawings to send to the Corps of Engineers to attain permits for projects.
- Analyze construction plans to verify project is built according to design.
- Maintain various databases and spreadsheet files pertaining to projects.

Deli/Bakery Clerk, Sprouts Farmer's Market, Thornton, CO **July 2016 - May 2019**

- Managed Deli Counter, trained new employees, interim supervisor of 2-3 employees.
- Assisted in taking customer orders, answered customer questions, oven cooks, and production.
- Placed orders for supplies and product in place of manager, when needed.

Optician Assistant, Northglenn Optometric Center, Northglenn, CO **June 2015 - Oct. 2015**

- Organized 30-60 patient files per week.
- Conducted 30-60 patient pre-exam testing per week.
- Assisted in patient services, including product sales.

Projects

Senior Design Project, Boulder County Post-Fire Mitigation Response **January 2021 – May 2021**

- Analyze and calculate stormwater flows of impacted watersheds and catchments.
- Design drainage and debris control structures to mitigate erosion of local infrastructure and waterways.
- Write technical report to explain project information, calculations/analysis, and design choices.
- Present findings and design recommendations to the client using a detailed visual presentation.

Honors and Certifications

- Engineering Intern (E.I.) (Application Pending) January 2021
- Tau Beta Pi Honor Society December 2018
- National Society of Collegiate Scholars June 2017

Abril Gonzalez-Torres

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Education

Anticipated Graduation Date: 2021

University of Colorado Denver — Denver, CO

Bachelor of Science: Civil Engineering

Timber Design, Steel Design, Reinforced Concrete Design, StormWater Design,Water Supply and Distribution Systems, Transportation Engineering, Highway Engineering, Geotechnical Engineering, Engineering Economy, Engineering Contracts, Construction Engineering Systems

Skills

- CAD / Civil3D/Revit
- Primavera
- Fluent in English and Spanish
- EPANET
- Microsoft Office/Adobe Cloud/Bluebeam
- Intermediate in French

Experience

Short Elliot & Hendrickson — Denver, CO - 2019, 2020

- Assist Civil team to draft drawings for a variety of projects and create layout drawings and designs in accordance with standard specifications
- Prepare project cost estimates
- Identify potential operation design improvements

Advanced Circuits — Aurora, CO - 2017

- Provided software engineering support for circuit design
- Ensured CAM's optimal interoperability with manufacturing
- Performed cost estimations

Volunteering: Between the Notes (BTN) — Aurora, CO - 2015, 2016

- Created non-profit organization, located at the Aurora Public Libraries, Tallyn's Reach library, with the purpose to give instruction in music
- Collaborated with students, parents, teachers, and library administrators, to determine student needs and develop teaching plans
- Organized and participated in public performances.

Projects

Senior Design Project — Boulder, CO - 2021

- Presented findings and design recommendations through a detailed visual presentation and a technical report
- Managed a team and aided in design

Timber Project — Denver, CO - 2021

- Load Tracked and designed a residential structure and a commercial structure in accordance to NDS and IBC guidelines and standards

Developed hypothetical project management system for Residential Construction — Denver, CO - 2020

- Utilized construction planning and scheduling techniques such as WBS charts and resource leveling
- Presented final product with a 5D model walkthrough of the project

Developed working hypothetical potable water system for Aurora Water | Denver, CO - 2019

- Programed proposed system and handled cost estimating for services
- Proposal writing
- Operated with associates to conclude best outcome by comparing designs, costs, feasibility, and compliance to regulations

Affiliations

ASCE, American Society of Civil Engineers	President, Member	Denver, CO
SHPE, Society of Hispanic Professional Engineers	Member	Boulder, CO/Denver, CO

Developed working hypothetical potable water system for Aurora Water | Denver, CO - 2019

- Programed proposed system and handled cost estimating for services
- Proposal writing
- Operated with associates to conclude best outcome by comparing designs, costs, feasibility, and compliance to regulations

ANDREW J. RILEY

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ajriley45@gmail.com

Resourceful, diligent, and professional with the ability to effectively balance a multitude of responsibilities. Hardworking, a can-do attitude, and a quick learner with a willingness to put in the necessary time to complete any task. Hands-on experience in ordering and stocking product, customer service and overseeing project operations. Currently seeking a position that will allow me to bring my experience, knowledge, skills and abilities to your company.

EDUCATION

AUGUST 2015 - CURRENT
CIVIL ENGINEER, UNIVERSITY OF COLORADO, DENVER

- Top fifteen percent of my class
- On Dean's List almost every year
- 3.6 GPA

AUGUST 2009 - MAY 2013
MOUNTAIN VISTA HIGH SCHOOL

- Experience in Debate Club
- 3.5 GPA

WORK EXPERIENCE

OCTOBER 2018 – CURRENT 35 HOURS/WEEK DURING SCHOOL 45 HOURS/WEEK OUT OF SCHOOL
ASSISTANT GROCERY MANAGER, SPROUTS FARMER'S MARKET

- Handling product from ordering to stocking to tracking sales.
- Helping customers and vendors
- Working as an acting manager, loading dock receiver, and backup bulk and frozen manager

AUGUST 2018 – CURRENT
AIRBNB HOST, AIRBNB

- Two years in a row of Super Host rating
- Cleaning and maintaining property to a five-star rating.
- Communicating with clients and handing any possible questions or complaints

JUNE 2016 – JULY 2018 25 HOURS/WEEK DURING SCHOOL 55 HOURS/WEEK OUT OF SCHOOL PAID PERCENT OF INVESTMENT
HOME RENOVATION, RRI

- Handling contractors
- Demolition
- Tiling, Painting, Basic Electrical, etc.
- Budget Analysis between different contractor bids

MARCH 2015 – JUNE 2016 AVERAGE 53 HOURS/WEEK
GROCERY NIGHT-CREW CLERK, KING SOOPERS MARKETPLACE

- Ordering all frozen product five days a week
- Unpacked and stocked hundreds of boxes of product
- Unloading cargo from trucks

TECHNICAL SKILLS

PROGRAMS: AutoCad, EPANet, MatLab, RISA2D and RISA3D, Excel, Word, and Powerpoint, RS Means

RELEVANT COURSEWORK

- **AutoCAD / AutoCAD Civil 3D**
- **Engineering Surveying**

• **Steel Design**	• **Foundations**
• **TIMBER Design**	• **Geotech 1 & 2**
• **Fluid Mechanics**	• **Cost Estimating**

Shannon Lamb

Denver, CO 80203 ♦ 720-347-1500 ♦ shannonl2016@gmail.com

Professional Summary

Goal-driven student studying civil engineering with minors in Spanish and construction management. Skilled at problem-solving and team-oriented projects through forming relationships with team members and clients. Detail-oriented and organized in time management for school, work, and other responsibilities.

Education

Bachelor of Science: Civil Engineering, 05/2021
University Of Colorado At Denver - Denver, CO

- Minor in Construction Management
- Minor in Spanish
- Graduating with cumulative 3.5 GPA

Civil Engineering
Colorado State University - Fort Collins, CO

Spanish
Universidad De Sevilla - Seville, Spain

Skills

- Organization
- Customer service-comfortable conversing with anyone
- Time management
- Point of Sale Knowledge
- Proficient in AutoCAD, AutoCAD Civil 3D, Python, Microsoft Word, Excel, and Powerpoint
- Comfortable Spanish speaker

Work History

Server, 09/2020 to Current
Adelitas Cocina Y Cantina – Denver, CO

- Upsold high-profit items such as appetizers and mixed drinks to enhance sales numbers.
- Kept updated knowledge of menu and promotions, recommending specific items according to preferences and food allergies.
- Created orders, documented special requests and followed up with kitchen personnel to foster top-quality service and minimize complaints.
- Helped customers place orders, explained menu items and suggested appropriate options for food allergy concerns.

- Worked during COVID pandemic, learning new regulations and safety sanitation requirements to uphold for customers and coworkers to stay healthy

Server/Bartender, 06/2019 to 07/2020
On The Border – Highlands Ranch, CO

- Learned to bartend while serving multiple tables on patio and in the bar area
- Regularly had 6-7 tables at a time
- Trained in Aloha POS system
- Adjusted to various work environments and the to-go process during COVID pandemic
- Monitored guests for intoxication and immediately reported concerns to management, contributing to safe and welcoming environments for all patrons
- Greeted and maintained relationships with regular customers.

Server, 02/2018 to 01/2019
Rainbow Café and Restaurant – Fort Collins, CO

- Worked in a fast-paced breakfast environment; learning to multitask and work efficiently.
- Pooled tips are used, so being team-oriented is vital.
- Assisted guests with their requests in a timely-manner.
- Assisted approximately 60 guests per hour.
- Relayed allergies, sensitivities, and diet restrictions to kitchen staff and adjust food order accordingly.
- Worked with POS system to place orders, manage bills and handle complimentary items for dissatisfied customers.
- Kept register accurate through correct billing, payment processing and cash management practices.

Server and Hostess, 06/2014 to 08/2017
Olive Garden – Highlands Ranch, CO

- Provided guests with friendly and efficient customer service.
- Took care of any and all of guests needs with food specifications and requests.
- Trained in DASH point of sales system.
- Handled cash and credit card transactions.
- Learned how to multitask well and efficiently.

BATOOL SHEHAB

801 Englewood PKWY, Englewood, Colorado 80110

Email: Batoolmsh98@gmail.com Cell Phone: +1 (720) 209-1443

➢ CAREER OBJECTIVE

Responsible and ambitious student with a high GPA and has the ability to multitask and work well with others. Seeking to apply my studies and knowledge of civil engineering to your engineering firm.

➢ EDUCATION

- Bachelor of Science, Civil Engineering

University of Colorado Denver

Aug 2017 - Expected graduation May 2021

- Certificate of Completion of English Program

English as a Second Language Academy of the University of Colorado Denver Oct 2016 – July 2017

➢ SKILLS

- Bilingual – Fluent Arabic and English
- Microsoft Office: Microsoft Word, Excel, PowerPoint, Project, and Access
- Expert in social media platforms (Twitter, Instagram and Snapchat)
- Time management
- APA and MLA style understanding
- Working collaboratively
- Work well under pressure to meet deadlines

➢ EXPERIENCE

- Public Relations Intern at The Scientific Center of Kuwait Responded to visitors' of TSCK questions and concerns at the information desk and phone.

Resolved visitors' complaints and issues.

- Volunteered at Denver Rescue Mission multiple times to serve the homeless. Also, volunteered at several nonprofit organizations in Kuwait.
- Student advisor to help students in Kuwait register in different U.S. universities and academies.