High Drive Road Assessment

Bear Creek Watershed

Pike National Forest, Colorado

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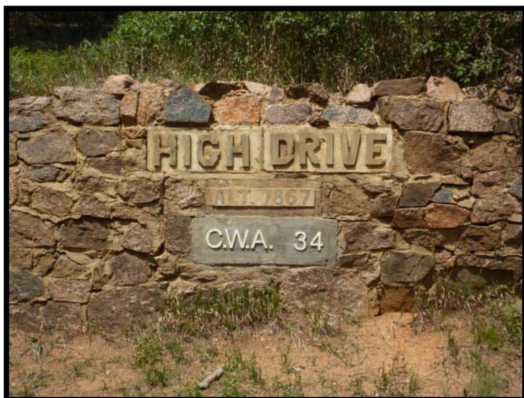

Prepared For:

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*Map Book Prepared by U.S. Forest Service

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Project Overview

Introduction

This High Drive Road Assessment (Assessment) analyzes the road, drainage system, and sediment concerns within the Bear Creek Watershed, located west of Colorado Springs in the Pike National Forest, Colorado. The native Greenback Cutthroat trout in Bear Creek have been determined to be the only remaining fish of their kind on the planet. The goal of the Assessment is to identify road, drainage, and sediment related sustainable solutions in order to protect Bear Creek's habitat and fishery. Runoff from the hill slopes and road contribute high levels of sediment into Bear Creek. The sediment reduces the function of Bear Creek, impairs watershed health, and reduces the amount of effective habitat available for aquatic organisms, fish, and riparian-dependent species, including the federally threatened and protected Greenback Cutthroat trout and Preble's Meadow Jumping Mouse (PMJM). Significant areas of concern are identified, and solutions that align with the partner's available funding, staffing, and equipment are recommended.

This Assessment will be combined with other studies that address other factors within the watershed, such as public access, recreational use, trails, vegetation, the fishery, water quality, and other factors. The multiple assessments are in support of the ongoing U.S. Forest Service (USFS) Bear Creek Watershed Study. The stakeholders on this project realize the critical importance of Bear Creek and hope to partner together to implement sustainable solutions.

Project Area

The project area consists of High Drive Road within the Bear Creek watershed. The assessment of High Drive Road starts at the north intersection with Gold Camp Road and ends at the top of the Bear Creek watershed. The Bear Creek watershed has a lower elevation of approximately 6600 feet and an upper elevation of approximately 7850 feet. High Drive Road at the top of the watershed crosses the hill slopes via five major switchbacks as the road decreases in elevation to the elevation of Bear Creek. High Drive Road then parallels Bear Creek until the road reaches Gold Camp Road. There are locked gates at each end of the road, which are used to close the road during winter.

Bear Creek is a small stream that inhabits the only known strain of native Greenback Cutthroat trout, based on recent and extensive DNA testing. Protection of the fish, stream habitat, and riparian corridor are key elements of this Assessment.

The Bear Creek watershed geology consists of decomposing granite, which is highly erosive. Land owners include the USFS, City of Colorado Springs, and several private parcels. Bear Creek City Park is located within the watershed and is operated by the Colorado Springs Parks Department (City Parks). There are numerous formal and informal trails in the watershed used by pedestrians, mountain bikers, motorcycle riders, and equestrians.

Project Team

The project team consists of several entities that have a vested interest in this project because of the ongoing erosion and critical fishery in Bear Creek. High Drive Road is maintained by City Parks and is heavily used by the public. Ensuring safe and environmentally sustainable roads is a key goal for City Parks, in support of both the local citizens, tourists visiting the area, and associated economic development. City Parks has partnered with the U.S. Forest Service (USFS), Colorado Parks and Wildlife, and CH2M HILL to execute this collaborative project.

The Management Team for this project consists of the following agencies and staff:

- Kurt Schroeder, City of Colorado Springs Parks Department
- Scott Abbott, City of Colorado Springs Parks Department
- Denny Bohon, USFS, South Platte Ranger District
- Doug Krieger, Colorado Parks and Wildlife
- Kyle Hamilton, P.E., CH2M HILL

Data Collection

The following data related to Bear Creek and the surrounding watershed was collected:

- Aerial Photography
- Topography
- GIS layers for roads, PMJM Habitat Limits, and Trails
- U.S. Geological Survey (USGS) National Hydrologic Dataset (NHD) Stream Network

GIS Map Book

This Assessment includes a Geographical Information System (GIS) and aerial photo-based Map Book (Map Book). The Map Book was prepared by the USFS, based on data collected by the project partners. The Map Book summarizes the existing conditions and identifies areas of significant erosion, drainage infrastructure, trails, and other key features identified during the site investigations.

High Drive Road on the Map Book was stationed from the north intersection near Gold Camp Road, starting at Station 0+00, and continues approximately 2.5 miles south to the top of the watershed at Station 132+00. This Assessment uses the term “Lower Reach” for the section of road that is parallel to Bear Creek and “Upper Reach” for the section of road where the road is no longer adjacent to Bear Creek. **Appendix A** contains the Map Book.

Stream Network

The stream network shown on the Map Book is based on the USGS NHD. In some locations, the Map Book notes that the actual location of Bear Creek is different than shown on the NHD GIS layer. The Map Book indicates where the NHD information is incorrect and illustrates the approximate correct location. Bear Creek was the only drainageway near High Drive Road with a base flow at the time of the site assessment.

Map Book Symbology

The following terms and symbols are used in the Map Book:

- Bridges and Culverts: The symbols show the bridges where the creek and road cross and cross culverts that convey flow from one side of the road to the other.
- Runout: These are areas where a man-made or natural ditch conveys concentrated flow away from the roadway.
- Potential Best Management Practices (BMP) Site: These sites are locations where a sediment trap or other feature may be applicable. These BMPs would typically be located at the upstream or downstream ends of the existing roadway culverts.

Site Assessment and Sediment Sources

The Assessment was conducted on November 8, 2012 by Scott Abbott (City Parks), Denny Bohon (USFS), Kyle Hamilton (CH2M HILL), and Candice Hein (CH2M HILL). The site visit focused on the road, the drainage system, and sediment sources and transport. The following sections detail the findings and results of this Assessment.

Natural Hill Slopes and Drainages

The natural hill slopes and drainages in the Bear Creek watershed are a source of sediment. However, it is the human-caused sources of sediment are the focus of this Assessment. It is assumed that Bear Creek, through natural processes of storm runoff and sediment transport, could adequately convey natural levels of sediment in Bear Creek to sustain the natural population of trout. Therefore, although natural processes are introducing sediment into Bear Creek, the human-caused sources are those that are increasing the sediment load on Bear Creek beyond the natural condition.

The natural drainages that cross High Drive Road are relatively stable. For example, the valley upstream of the High Drive Road crossing at Station 79+00 has a vegetated valley bottom with a good duff layer. This indicates that the flow in the valley is not causing significant erosion. It is noted that the nonfunctional drainage system is not contributing flows to some natural drainages that will receive flows after the culverts are cleaned out. The natural drainages should be monitored to confirm the stable conditions remain.

Roadway Assessment

The goal of the road Assessment was to characterize the condition of the roadway and identify potential solutions to identified problems. The analysis and recommendations focus on minimizing the sediment contribution from the road to the creek, but also highlight transportation maintenance and design issues. The Assessment also identifies the locations of culverts along the corridor and provides recommendations for improvements to the culverts to reduce sediment transfer.

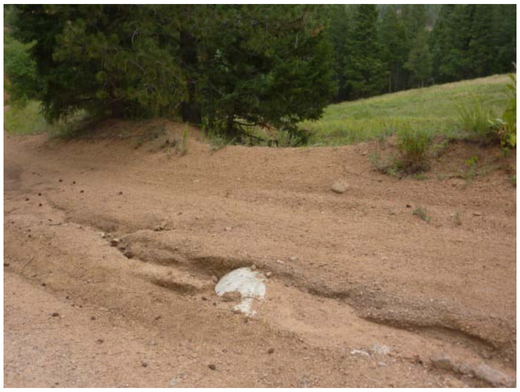
During the field assessment, the use of High Drive Road had been closed to public vehicles. Public vehicular traffic was required to park prior to the gates at each end of the road. The roadway is closed each winter, and maintenance resumes when the road is opened in the spring.

Roadway Criteria

High Drive Road is a low-volume road used primarily to access recreational trails. The roadway width for a rural low-volume road per the American Association of State Highway and Transportation Officials (AASHTO) could be as low as 18 feet. However, maintaining the existing wider road section is preferred, assuming access by public vehicular traffic will continue.

The roadway has existing tight horizontal curves with radii as small as 30 feet. There are no posted speed limit signs, but the tightest curves only allow for speeds up to 15 miles per hour. The maximum grade for the road, per AASHTO criteria assuming a design speed of 15 miles per hour, is 17 percent.

Road Surface Material



High Drive is paved for approximately 420 feet from the intersection with Gold Camp Road south to the entry gate. South of the gate to the top of the watershed, the roadway is an unpaved aggregate surface material. City Parks stated that they do not import road base and that the road surface consists of native material.

The gravel roadway surface can be loosened due to vehicle wear, rain, snow, and freeze/thaw conditions. Thus, the road surface itself is a sediment source. The sediment is then conveyed by gravity and storm flows into the roadside ditch and then to the next downstream culvert.

Roadway Section

The Lower Reach of the roadway has an average width of approximately 20 feet with slopes less than 6 feet high down to the creek. The slopes in this section of road are generally 3(H):1(V) or flatter, except where the creek crosses under the road.

The Upper Reach of the roadway has a width varying from 10 feet to 30 feet. The narrowest widths are where sediment storage has accumulated at the culverts and at the tight curve locations. The cut slope side of the roadway has slopes varying from 1(H):1(V) to 4(H):1(V). In some locations there is exposed bedrock, resulting in even steeper cut slopes. The fill slopes in the Upper Reach of the road are generally 2(H):1(V) or flatter. However, in many locations, the fill slope is at the angle of repose for the natural sediment, which equates to the steepest angle at which the sediment is stable.

In general, the cut slope along the roadway has very low vegetation coverage and a high tendency to erode into the roadside ditch. Over time, the steep roadway cut slopes have become unstable and the loose material has fallen onto the roadway bench. The Upper Reach slopes are very steep and can extend more than 50 feet up the slope. There are some areas where the cut slope consists of bedrock outcroppings, which are relatively erosive as well. In some cases, the sediment from the cut slope completely fills in the ditch, and ditch flow is forced onto the road. Thus, hillside sediment is a major sediment source that can be transported into ditches or onto the road and eventually into Bear Creek.

The roadway fill slope is typically steep with relatively little vegetation. Some areas of the fill slopes are at the angle of repose, have no vegetation, and are very unstable. Where there is no buffer between the road and the creek, eroded sediment can enter directly into the creek. If the road width is to be reduced, the fill slopes could be flattened to support vegetation reestablishment.

Bear Creek runs parallel with High Drive Road along the lower mile near Gold Camp Road. However, the distance between the road and the creek varies between 5 feet and 50 feet. There are reaches where the creek has up to 10 feet of overbank with enough vegetation to create a buffer to naturally filter the sediment before it reaches the creek. However, there are also stretches where the creek meanders much closer to the road, including instances where the creek crosses under the road. The overbank buffer in these locations is non-existent, and the road fill slope enters the creek. In these locations, it is very easy for road material to enter the creek.

Cross Slope and Ditches

In general, the cross slope of the roadway is sloped significantly toward the cut slope. A roadside ditch is located at the interface of the cut slope and the road bench. In many locations, sediment has accumulated in the ditch causing the ditch to become shallow and up to 8 feet wide. The roadside ditches did not show signs of significant lateral erosion or headcutting. However, the accumulated sediment results in a wider and shallower ditch, which has less erosion potential.

The roadway curves have super-elevated cross slopes, resulting in transition sections where the cross slope reverses on either end of a curve. There are also cross slope transition reaches where the roadway crosses over the creek and the cross slope transitions toward the new cut slope side of the road. Significant roadway rutting was observed where these cross slope transitions take place, with the most severe rutting occurring at the switchback locations. Improving the ditches at these locations could help reduce the impacts to the roadway surface.

Horizontal Geometrics

The roadway parallels Bear Creek from Station 0+00 to Station 54+00 (approximately 1 mile), and then departs from the creek corridor. Beyond this departure point, the roadway climbs up the watershed. There are five switchbacks along the route with minimum radii of approximately 30 feet. City Parks has stated that some of the switchback curves are too tight for large equipment. Roadway criteria for a maintenance truck with three axles would require a minimum radius of approximately 52 feet. The curve radii will need to be considered during implementation of solutions that may require large vehicles, such as concrete trucks or rock-hauling trucks. Large trucks could enter the project area from the south access to High Drive Road. There are also no formalized turn-around areas. This situation will need to be considered during implementation of solutions.

Longitudinal Grades

The roadway climbs from an elevation of approximately 6600 feet to approximately 7850 feet. The roadway is relatively flat for the first mile along the creek, and then it climbs up steeper grades for the remaining 1.5 miles. The grades in the upper section average 11 percent.

Roadside Berms

The fill slope side of the roadway in the Upper Reach has a 1-foot-high to 3-foot-high sediment berms created from maintenance operations. City Parks has stated that the berm is somewhat intentional in order to provide a visual safety barrier at the edge of the road. As grading equipment is used to maintain the road, sediment is pushed toward the berm. This results in some sediment being broadcast beyond the berm onto the fill slope. In many locations there is no vegetation adjacent to the road due to the broadcast sediment. These slopes are near the angle of repose and are very unstable. If sediment is no longer broadcast down the slopes, vegetation will have a better chance to establish and stabilize the slopes. Keeping the berms for safety versus removing the berms so that additional sediment is not broadcast down the fill slopes is being considered by City Parks and the USFS, and will likely depend on the future allowed uses of the road.

Safety and Accident History

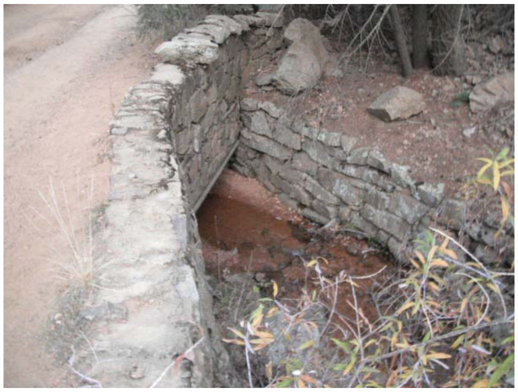
High Drive Road has several challenging roadway geometrics, including steep grades, limited stopping sight distances, and tight horizontal curves, all of which combine to present a very high safety risk. Throughout the corridor, there are horizontal and vertical alignments that do not meet design standards and have significantly limited sight distance. Despite these challenges, according to City Parks, there is no known accident history along this road.

City Parks noted that there are locations where four-wheel drive vehicles attempt to climb the steep hills at the inside bends of the switchbacks. This is an unsafe activity and causes additional erosion.

Major roadway realignment investigations for High Drive Road were beyond the scope of this Assessment. However, it is assumed that the cost for realignment of the road and restoration of the old road location would be beyond the available funding and would cause additional damage to the watershed, including critical habitat area.

Drainage Assessment

This Assessment investigates the existing drainage system, including the bridges, culverts, runouts, and other related features, as described below. The existing drainage system is relatively extensive, and it is apparent that drainage was accounted for during the construction and/or maintenance of High Drive Road over the past decades. However, much of the system is currently not functional due to accumulated sediment. A summary of the information collected during the site visit for the bridges and culverts is included in **Appendix B**. The Map Book illustrates the locations of the significant drainage features.



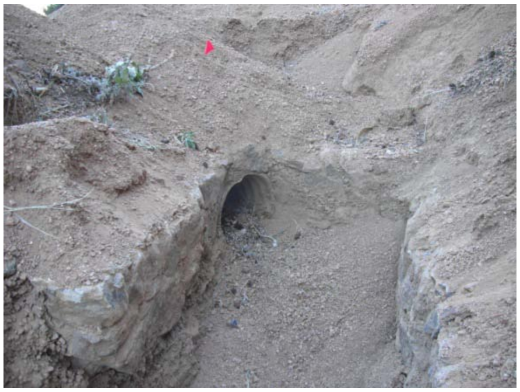
Bridges

High Drive Road crosses Bear Creek via grouted rock bridges in four locations. All the bridge crossings consist of a natural stream bottom and did not have a significant vertical stream bottom drop at the downstream end of the bridge. Thus, it does not appear that the bridge crossings create significant aquatic organism or small mammal passage barriers.

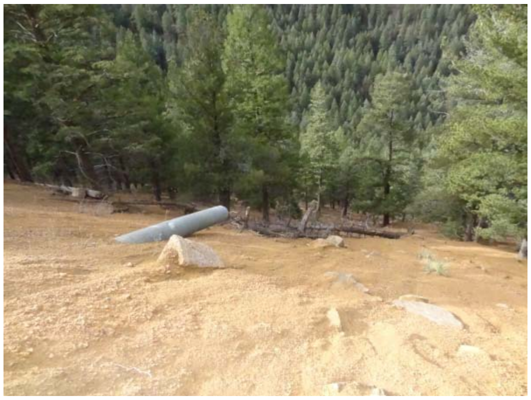
Culverts, Outlets, and Rundowns

High Drive Road has numerous cross culverts that convey ditch flow from one side of the road to the other. The culverts consist of corrugated metal pipe (CMP), concrete pipe, and small grouted rock tunnels. The culverts range in size from 15 inches to 36 inches in diameter and are primarily made of CMP. Most of the culverts have a grouted rock headwall at the upstream end of the pipe. In some locations, the downstream end of the pipe is contained within a rock wall.

Several culverts were found to consist of multiple pipe components due to the upstream and downstream ends of the culvert being different. One culvert (Station 74+20) was exposed in the roadway and there was a gap in a pipe joint, which allowed road sediment to enter the pipe. None of the culverts had formalized sediment traps, but sediment has been removed from the upstream ends of the pipes. The excavated sediment is typically placed around the pipe entrance, resulting in large sediment berms.

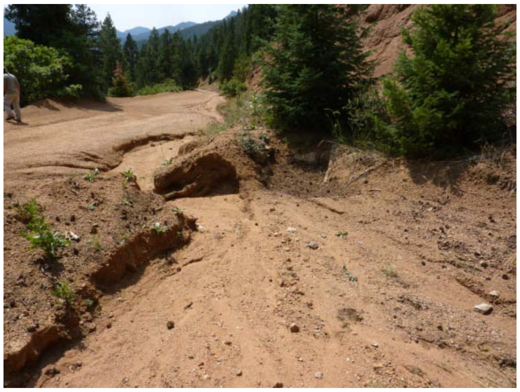


Most of the culverts discharge to a rundown on the roadway fill slope or native ground. The rundowns are typically scoured. The level of erosion in each rundown, from None to High, is noted in **Appendix B**. Some of the rundowns contain riprap, which has had varied success in stopping erosion. Some outfalls discharge to areas with trees whereby the root structure has helped stabilize the soils and resist erosion. In some cases, the erosion has reached bedrock. However, the granite bedrock can still erode and be unstable if the erosive forces of the flows exceed the stability of the bedrock. At Station 11+00, rock lining has been placed in the outfall channel, which has prevented erosion.



Along the Upper Reach of the road, the conditions of the fill slopes are dependent on the function of the existing culverts. The slopes below the non-functioning (plugged) culverts consist of loose sediment, but there are some indications of temporary stability at these locations. The outlets of the functioning culverts show significant erosion, likely because these culverts are conveying much higher flows to compensate for the non-functioning culverts.

The culverts in the Lower Reach discharge onto the Bear Creek overbank, and any sediment conveyed by the culvert enters directly into the creek. Sediment is trapped downstream of a few culverts via vegetated swales. In a few locations, the culverts discharge to small drainages adjacent to Bear Creek, which serve as buffers that prevent the sediment from entering Bear Creek. Additional culvert details are included in **Appendix B**.

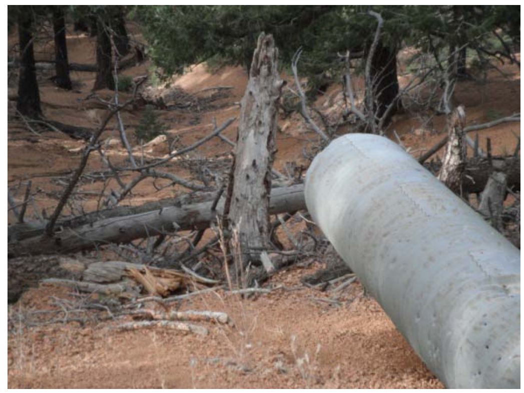


Plugged Culverts and Combined Flows

The vast majority of the culverts are plugged with sediment ranging from 1 inch deep to burying the culverts entirely. In many cases, only a headwall was found and the pipe could not be seen due to the accumulated sediment at the upstream end of the pipe.

The result of the plugged culverts is that flow in the roadside ditch does not get conveyed under the road in regular intervals. Instead, flows bypass the culvert and get combined with flows that drain to the next downstream culvert. The combined flows continue to increase in the roadside ditch and bypass plugged culverts until the flow reaches an open culvert or a roadway runout. These combined flows result in erosive forces that cause additional erosion and sediment buildup in the ditches.

For example, the first three culverts from the top of the watershed are plugged. Thus, ditch flow that is intended to flow through three culverts is combined and enters the fourth culvert at Station 113+70. It is anticipated that the combined flow exceeds the capacity of that culvert, and bypass flow continues downstream. This problem repeats itself along the uppermost reach of High Drive Road, and the combined flows eventually reach the switchback at Station 95+50, where a runout conveys flow away from the road.



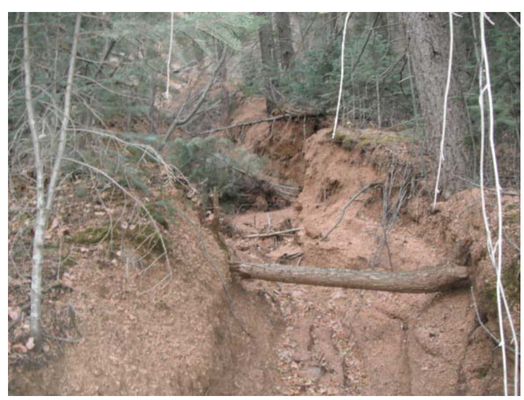
Due to the combined flows at the culvert at Station 113+70, the rundown downstream of the culvert is significantly scoured. The scoured sediment is conveyed down the gully to High Drive Road at Station 79+00. A very large sediment fan has accumulated, and there is no culvert under the road at this location. (See the section on buried culverts below.) This sediment fan causes flow at this point to be diverted along the south side of the road, instead of following the natural drainage valley under the road. The diverted flow results in significant scour and erosion at Station 76+00.

Many of the combined flow, erosion, and diverted flow problems are a result of the existing drainage system being plugged with sediment and not functioning correctly. Reestablishment of a functional existing drainage system is a critical first step in reducing erosion in the watershed.

Switchback Runouts

The most significant runouts occur at Station 54+00, Station 65+50, and Station 95+50, as described below:

- Station 54+00: This runout is unintentional and is a result of the diverted flows near Station 79+00. Once the drainage conveyance is reestablished at Station 79+00, only minor flows will reach this runout. A culvert could be installed upstream of this runout to convey flows to a swale on the north side of the road.



- Station 65+50: Flows that exit the road via the runout at Station 65+50 are conveyed into a flatter valley, such that the flow spreads out and the sediment settles in the upland vegetation before reaching Bear Creek.
- Station 95+50: The runout at Station 95+50 is one of the most significant problems in the watershed. The combined flows conveyed by the runout have scoured a very large gully down the natural hill slope. Sediment from the scoured gully enters directly into Bear Creek.

Buried Culverts

It is anticipated that there are several buried culverts that were not able to be identified during the site assessment. The following locations have been identified as possible culvert locations due to the surrounding features.

- Station 5+00: Could not find a pipe or headwall.
- Station 13+20: Only a headwall was found.
- Station 38+30: Only a headwall was found.
- Station 43+40: Only a headwall was found.
- Station 79+00: This is where High Drive Road crosses a natural valley. The same valley crosses the road at Station 74+00, where a 36-inch concrete culvert is located. Thus, it is assumed that a similar culvert is located at Station 79+00, but it is entirely buried by sediment.
- Station 81+50: Could not find a pipe or headwall.

Roadway Maintenance

City Parks maintains High Drive Road. Road maintenance typically consists of grading with a motor grader to remove ruts, regrading roadside ditches, and removing sediment from culvert inlets with a backhoe. The sediment removed from culvert inlets is stacked near the entrance of the culvert. This sediment has the potential to erode back to the culvert entrance. City Parks does not have the needed equipment to remove sediment from the insides of the culverts. Based on discussions with City Parks, roadway maintenance typically takes place only after large storm events.

Roadway grading operations can loosen the existing material, which can then erode into the creek. This is especially true when the road material is pushed to the creek side of the road by grading operations. In these instances, the material could reach the creek by either sloughing down the creek side fill slope, or via ditches and cross culverts. Grading of the roadway over time has widened the roadway in some locations. Grading operations should limit the impact area to only the needed roadway width to allow vegetation on the fill slopes to establish for slope stability and erosion protection. It was also seen that in some cases the motor grader working alongside the cut slope of the road has cut into the slope too far, resulting in a small vertical edge at the bottom of the slope. This edge is unstable and can cause erosion to progress up the unstable hill slopes.

The grading activities have created the roadside sediment berms on the fill side of the roadway. If the berms are needed as a visual edge of road reference for safety, additional sediment should not be placed on the berms or broadcast down the fill slope. This will allow vegetation to attempt to establish either by natural means or reseeding. If the berms are not needed, then it is recommended that they be removed so that maintenance personnel don't assume the berm is needed or should be rebuilt.

In some cases, heavy equipment has damaged the culverts, likely because they were buried. It is recommended that each end of all culverts be identified with a roadside post and reflective marker to support maintenance activities.

Sediment Production Research Data

Sediment production data has been collected for areas in the Upper South Platte River Watershed, which has similar geologic conditions. One study reviewed both forest roads and off-highway vehicle (OHV) trails (Welsh, 2008). The study indicates that the amount of sediment reaching a stream is a function of precipitation, summer erosivity, segment slope, segment length, proximity to the stream, and other factors. In 2006, roads were found to produce on average 3.1 kg m-2 yr-1, and OHV trails could produce up to 53.3 kg m-2 yr-1. The average sediment production from roads between 2001 and 2006 was 3.5 kg m-2 yr-1. Although OHV trails were found to have higher production rates than forest roads, forest roads are adjacent to creeks for much greater lengths. Where roads and OHV trails are connected to streams, the average sediment production from the watershed is 1.1 Mg km-2 yr-1 for roads and 0.8 Mg km-2 yr-1 for OHV trails.

Another study by Colorado State University provides the following summary (Welsh, 2006):

> *Unpaved roads are often the dominant source of sediment in forested areas, and they are of particular concern in the Upper South Platte River (USPR) watershed because this is the primary source of drinking water for Denver, has a high-value fishery, and has a high density of roads and off-highway vehicle (OHV) trails. The goal of this project is to quantify sediment production and delivery from unpaved roads and OHV trails, as there are no data on these sources in the USPR watershed. Since summer 2001 we have been measuring rainfall, sediment production, and segment characteristics from up to 20 road segments, and in August 2005 we began making similar measurements on OHV segments. Sediment delivery is being assessed by detailed surveys of selected roads and OHV trails. Summer rainstorms larger than 10 mm typically produce sediment from each road and OHV segment while undisturbed areas generally produce no surface runoff. The mean annual sediment production from unpaved roads has ranged from 0.4 to 6.7 kg m-2 yr-1, and this variation is largely due to differences in the amount and intensity of summer precipitation. In summer 2006 the mean sediment production from OHV trails was 18.4 kg m-2, or more than 5 times the mean value from unpaved roads. A survey of 17.3 km of unpaved roads showed that 14% of the total road length was connected to the stream network; initial surveys on 3 km of OHV trails indicate a similar degree of connectivity. The overall road density in the study area is about 1.1 km km-2, so unpaved roads are contributing about 1.3 Mg km-2 yr-1 of sediment to the stream network. The results suggest that unpaved roads and OHV trails may be the largest chronic sediment source in the Upper South Platte River watershed.*

Field Assessment Summary

The field assessment identified the existing conditions, key problem areas, and potential locations for improvements, as shown in the Map Book (**Appendix A**). The following items were determined to be the most significant findings in this study:

1. **Bridges:** The bridges appear intact and do not create fish, aquatic organism, or small mammal passage barriers.
2. **Roadway Cut and Fill Slopes:** The High Drive Road cut and fill slopes consist of very loose decomposed granite that is highly erosive. There is very little vegetation on the steep slopes. The loose material is being transported off of the slopes and into the drainage system, where it eventually reaches Bear Creek. Minimizing the disturbance of the sediment will help reduce erosion.
3. **Roadway Rutting:** The roadway is experiencing rutting in the middle of the road where the drainage crosses from one side of the road to the other, particularly at the switchbacks. Improving the drainage capacity of the roadside ditches and culverts prior to these transitions will help reduce erosion in the roadway.
4. **Plugged Culverts and Ditch Capacity:** The erosion from the slopes and roadway has plugged culverts and filled in the roadside ditches. This creates combined flows that exceed the capacity of the drainage infrastructure. Thus, the existing roadway drainage system has been compromised and new flow paths and erosive gullies have formed. Reestablishment of a functional ditch and culvert systems is a near term priority to separate flows and reduce the erosion potential.
5. **Combined Flow Eroded Gullies:** The combined flows resulting from the plugged culverts have caused significant erosion. The most evident locations are at the runouts at Station 76+00 and Station 95+50 and from the discharge from the culvert at Station 113+70. The gullies formed by these discharges are severely eroded. Cleaning the existing culverts will decrease the flows to these areas, and additional culverts could be installed to decrease the flows even more. Stabilization of these gullies could be implemented, but heavy equipment access will be difficult at two of the gullies. Hand-based treatments may be required in these areas.
6. **Upper Reach Culvert Rundowns:** In the Upper Reach, culverts are discharging onto erosive fill slopes. These culvert outlets pose significant challenges because implementing stable erosion protection methods on the steep and long slopes will be difficult and costly. Addressing this erosion via a regional sediment trap at an accessible location near Station 79+00 is recommended. With a functional drainage system, the rundowns will receive smaller flow rates with less erosion potential.
7. **Regional Sediment Trap:** Regional sediment traps could be located at Station 79+00 and Station 95+50, and potentially other locations where there is sufficient area. A regional sediment trap at Station 79+00 could potentially treat all flows from Station 79+00 to the top of the watershed. This concept would include the addition of a couple culverts and the closure of the culverts between Station 80+00 and 95+00, such that those flows are conveyed down a stabilized roadside ditch to the regional sediment trap. Design would be needed to analyze the culvert capacities, determine the needed capacity of the ditch, and determine if there is adequate width for the ditch adjacent to the road.

8. **Lower Reach Culverts:** The culverts in the Lower Reach discharge onto the Bear Creek overbank, and any sediment conveyed by the culvert enters directly into the creek. Collection of sediment at the upstream end of these culverts will have an immediate benefit to Bear Creek.
9. **Roadside Berms:** These berms lead to erosive fill slopes and should be removed if not needed for safety.
10. **Sediment Traps:** There are no formalized sediment traps within the study area. Sediment traps could be implemented at many of the culverts and at the runouts.
11. **Maintenance Operations:** Limiting the impact of maintenance operations will reduce erosion in the watershed. Preventing the creation of roadside berms, preventing grading at the base of cut slopes, and removal of accumulated sediment at culvert inlets will all provide benefit to Bear Creek.
12. **Other Sediment Sources:** Sediment sources associated with public access, recreational uses, formal and information trails, etc., are being addressed in separate studies and are not included herein.

Conceptual Solutions

Based on the field investigations described above, Conceptual Solutions have been identified and are summarized in the Conceptual Solutions Matrix in **Appendix C**. The conceptual solutions shown are intended to be a menu of options for consideration, but some of the solutions may not be applicable to Bear Creek. Stakeholder input, funding availability, maintenance needs, and other factors will determine the desired and recommended improvements.

The unit costs shown in the Conceptual Solutions Matrix are based on 2011 construction cost information obtained from the Colorado Department of Transportation, Urban Drainage and Flood Control District, CH2M HILL's project libraries, and engineering judgment. The unit costs do not include contingencies nor do they account for costs associated with administration, engineering, permitting, and other standard project components.

The qualitative benefit-to-cost ranges in the Conceptual Solutions Matrix are based on a basic, qualitative review of each feature for the Bear Creek conditions, and account for the feature's cost, ability to control sediment, longevity, stability in the Bear Creek environment, and anticipated success rate.

Conceptual Solution Guidelines

The following guidelines will be used as much as practical during development of the preferred solutions:

- Use eco-friendly solutions that protect the environment.
- Maintain the channel geometry (no major excavation, channel realignment, etc. should be considered).
- Maintain the roadway alignment to prevent disturbance of other areas.
- Maintain the cross slopes toward the cut slope so that sediment from the road can be captured.
- Use natural products.
- Focus on the most cost-efficient solutions.
- Minimize long-term maintenance needs.
- Limit disturbance areas because revegetation can be difficult.
- Set realistic expectations.
- Preserve prime habitat.
- Focus on the "bad" and don't try to convert "good" to "better."
- Use filter strips and sediment traps.
- Disperse flow in regular intervals to decrease the erosion potential.
- In erosive areas, armor outlets.
- Stabilize the loose material where feasible.

- Per USFS recommendations, don't spend money on natural hill slope erosion protection (via hydroseed, erosion control blankets, mats, additional vegetation, etc.).

Sediment Removal and Disposal

Most of the conceptual solutions relate to control, capture, or removal of sediment. The following sections describe options for the removal of sediment that has been mobilized.

Natural Processes

Natural processes and storm flows in Bear Creek will continue to transport sediment downstream. Decreasing the sediment input, primarily from man-made impacts, should be the first area of focus.

Sediment Removal with a Vacuum Truck

Many agencies use vacuum trucks when cleaning culverts and sediment traps. A vacuum truck could also be used to remove sediment from inlet catch basins, small sediment ponds, and from other BMPs that trap sediment.

Excavation with Heavy Equipment

Excavation with heavy equipment can be feasible if large amounts of sediment accumulate and adequate access is provided. City Parks has indicated that they prefer that all sediment traps be cleaned with a bobcat or backhoe. If a vacuum truck is needed, they may need to hire an outside contractor.

Sediment Disposal Options

The Bear Creek corridor is narrow, and disposal of large quantities of sediment within the corridor are unlikely. Thus, it is anticipated that the majority of sediment collected and removed from the Bear Creek corridor will need to be hauled off site. At this time, there are no known commercial uses for the sediment. Other agencies removing sediment from the upper South Platte watershed may use the sediment for pipe trench material or for other suitable uses.

Haul trucks or vacuum trucks are anticipated to be the primary means for removing sediment from the Bear Creek watershed. The impact of these trucks on High Drive Road is not expected to be more significant than the affects of existing traffic and maintenance equipment.

Preferred Alternatives

City Parks and the USFS have determined their conceptual priority areas and preferred solutions, as described below. The recommendations are based on the information provided in this Assessment, field investigations, and anticipated available funding.

It is assumed that due to funding limitations, the following types of improvements are currently not feasible:

- Paving the roadway.
- Changing the roadway alignment, curve radii, or cross slopes.
- Construction of retaining walls to change the roadway section.
- Per previous discussions with USFS, attempting to stabilize large hill slope areas or roadway cut slopes has proven difficult, if not impossible given funding constraints.
- Constructed rundowns on long slopes that don't have access for heavy equipment.

It is also assumed that aggregate road stabilizers, such as magnesium chloride, should not be used in the Bear Creek watershed due to the critical fishery.

Near-Term Plan

The Near-Term Plan elements are those that will require little or no permitting, and could be implemented in early 2013, as follows:

- Identify missing culverts (use metal detector and/or backhoe) and update the Map Book.
- Place roadside markers on each side of the road to identify culvert locations and alignments.
- Remove sediment from all culverts.
- Redefine roadside ditches and increase the ditch capacity at roadway transition areas to minimize flow across the road.
- Repair erosive gullies, if permitting allows (north of Station 95+50).
- Install culverts in strategic locations if needed based on the results of the missing culvert research. The first priority area is at Station 79+00.
- Remove sediment berms along the road shoulders, if not needed for safety.
- Begin a maintenance program that keeps the drainage infrastructure functioning and removes accumulated sediment from the watershed.
- Discuss sediment control goals with maintenance staff and equipment operators.
- Consider maintenance barriers to guide / control maintenance operations.
- Maintain a minimum road width for the desired road uses and maximize roadside vegetation.
- Monitor erosion downstream of plugged culverts. Some erosion may occur until equilibrium is re-established with the functioning culverts.

- Install temporary sediment collection features to better estimate the amount of sediment that accumulates at a typical culvert over the course of a summer storm season. This information would be used when sizing the permanent sediment traps.
- Develop the 2-Year Plan Schedule. Upper watershed sediment control improvements should be coordinated with any downstream improvements, including work in Bear Creek.
- Develop an Operations and Maintenance Plan, including establishment of the maintenance interval that is needed to keep the drainage system functional.

2-Year Plan

The following 2-Year Plan elements are those that will require data collection, permitting, or design:

- Install sediment traps at the culverts where the road parallels the creek.
- Install sediment traps at switchbacks, before the runouts.
- Install “regional” sediment traps at strategic locations to capture sediment from multiple culverts or areas where flows combine. The primary location is at Station 79+00.
- Install sediment traps or other BMPs to address ditch flows that enter Bear Creek at the bridge crossing locations.
- Upsize culverts, if needed, to minimize bypass flows at strategic locations (such as at switchbacks).
- Install additional culverts or steepen existing culverts, if culvert plugging continues to occur.
- Install stabilized ditches and stabilized rundowns where needed, such as to convey combined flows to a regional sediment trap. Concrete, riprap, and other features could be considered, but would need to withstand impacts from ditch grading equipment.
- Stabilize erosive upland areas via seeding, plantings, or erosion control features.
- Stabilize erosive gullies, where needed, based on the improved drainage system and corresponding flows.
- Consider decreasing the road width where feasible by moving the fill slope toward the road to allow a flatter fill slope to support vegetation reestablishment. The road width may also be reduced due to grading a wider cut ditch where additional capacity is needed.
- Consider the future road uses, including use as fire and emergency vehicle access. Determine if any legal ownership or easement documents exist that would define the use of the road. City Parks stated that maintenance vehicle access will need to be maintained.
- Monitor the drainage system, since some new erosion may occur until equilibrium is re-established with the functioning drainage system and constructed improvements.
- Measure and document sediment contributions and removals.

Next Steps

The following sections provide the anticipated next steps.

Coordination of Priority Areas

City Parks and the USFS have identified their recommended priority areas. The project partners will continue to coordinate as funding becomes available so that the most beneficial and cost-effective projects can be constructed first. A decision model could be developed to ensure that each project is consistent with the project partner's desires.

Anticipated Permitting Requirements

Work within Potentially Sensitive Areas, as listed below, may require special permitting:

- Jurisdictional Waters of the U.S.
- Wetlands
- Greenback Cutthroat Trout Reaches of Bear Creek
- PMJM Habitat Areas
- Other Threatened Species
- Cultural or Historical Features

Additional permits may be required, as follows:

- Colorado Department of Public Health and Environment (CDPHE) Stormwater Permit and Stormwater Management Plan.
- CDPHE Groundwater Dewatering Permit.
- Grading, Erosion, and Sediment Control Permit.
- Land Use and/or Right-of-Way Permit.
- If the disturbance area is large, a CDPHE Air and Dust Control Permit may be required.
- Other permits as determined to be required during design.

Design and Construction of Preferred Solutions

Design is needed for permitting, construction cost estimating, and to construct the improvements. The level of detail for each design can be tailored to the construction approach used, which may vary from using City Parks staff to an open public bid and contractor selection process. Depending on the level of design, various types of data will need to be collected, as described below in the Future Data Needs section.

The design process will include detailed cost estimates for each project. Operations and maintenance costs can also be estimated once the project details are known. The cost estimates performed during design can build upon the unit costs in the Conceptual Solutions Matrix and will also include costs for mobilization, surveying, water control, and other construction components.

Future Data Needs

The following items may be needed for design and/or permitting:

- 1-foot Design Topography
- Infrastructure Information
- Utility Locates
- Wetlands Surveys for the Impact Areas
- Threatened and Endangered Species, Cultural, and Historic Surveys
- Survey of the Ordinary High Water Mark for U.S. Army Corps of Engineers 404 Permitting

References

American Association of State Highway and Transportation Officials. 2001. *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT less than or equal to 400)*.

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Welsh, M. J.; MacDonald, L. H.; Brown, E.; Libohova, Z. 2006. *Erosion and Sediment Delivery From Unpaved Roads and Off-Highway Vehicle (OHV) Trails in the Upper South Platte River Watershed, Colorado*. American Geophysical Union, Fall Meeting 2006, Abstract #B23B-1086.

Welsh, M. J. 2008. *Sediment Production and Delivery from Forest Roads and Off-Highway Vehicle Trails in the Upper South Platte River Watershed, Colorado*. Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University.

Appendix A: Map Book

Appendix B: Road and Culvert Field Logs

High Drive
Road Assessment Field Log

Reach		**Road - General**					**Drainage**			**Hill Slope**		
Start Sta, or Sta Point	End Sta	Road Traveled Way Width	Additional Width of Sediment Berm (piles near culverts created during maintenance procedures)	Horizontal Curve (Sharp, Flat)	Grade (Steep Flat)	Washboard or Rutting	Ditch on Left, Right, Both	Creek Side Road Embankment - Fill or Natural	Edge Scour due to Runoff	Vegetation Coverage: Left & Rt	Sediment Source to Creek	Notes
(ft)	(ft)	(ft)	(ft)	(Sh, F)	(St, F)	(NLMH)	(L, R, B)	(F or N)	(NLMH)	L / R	(NLMH)	
130+00		19	-	-	St	rut near ditch	R	N/A	N/A	5/5	H	<1:1 slope up to the mountain bike/ dirt bike trail which is 2' width with varying rills down to the road
125+00		15	-	-	F	deep aggregate	R	N/A	N/A	60/5	H	culvert ditch with rock wall
122+00								N/A	N/A			Re-establish cross slope to keep ditch on cut slope
121+00		9	8	Sh	ST	rut in middle	R	N/A	N/A	20/5	H	<1:1 riprap on fill, need to grade cross slope
117+50		11	6	-	St	N	R	N/A	N/A	5/0	H	
114+00		9	7	-	F	washboard under aggregate	R	N/A	N/A	30/10	H	1st functioning culvert, gulley at outlet
110+00		18	-	F	St	N	R	N/A	N/A	80/20	L	long runout into trees
109+00		12	8	Sh	St	rut in middle x 2	R	N/A	N/A	50/10	M	riprap gulley, no inlet found
105+00		12	8	F	St	washboard	Rx2 (before and after)	N/A	N/A	80/0	M	gulley
101+00		20	6	Sh	St	ruts in middle	Rx2 (before and after)	N/A	N/A	90/50	M/H	gulley with riprap
98+00		35	-	Sh	St	N	R?	N/A	N/A	90/0	L	
95+50	95+00	37	-	Sh	St	-	L	N/A	N/A	90/0	M/H	switchback w/ ruts in the road, cut better ditch outside
90+00		22	-	2 Sh	St	2 ruts	L	N/A	N/A	5/20	H	adverse super issues
85+00		10	12	-	St	-	? Along buildup	N/A	N/A	0/15	H	gulley
79+00		20	30' (sediment fan)	Sh	St	sediment build up	L rundown	N/A	N/A	90/90	H	collection from 13, could change cross slope toward fill, possible sediment trap location, add rock check dams
76+00		30	-	Very Sh	St	-	-	N/A	N/A	75/100	L	could adjust toward the fill
74+00		22	12	-	F	rutting	R	N/A	N/A	80/80	N	equipment storage
69+00		15	-	-	F	-	-	N/A	N/A	5/20	N	culvert riprap berm outlet
66+00		15-20'	-	Sh	St	rut inside switchback	-	N/A	N/A	-	L	standing water in spring
62+50		15'-20'	-	Sh	St	rutting	L	N/A	N/A	75/100	L	fix cross slope around curve, keep ditch outside, mouse habitat in the meadow
62+00		16	-	-	F	-		N/A	N/A	100/100	L	culvert 48" into meadow
54+00		15-50'	-	Sh	St	rut inside switchback	B-cut on left more	N	L	80/100	L	cut better ditch around switchback
51+00		15'	6	-	F	-	R	N	L			
47+50		20	-	-	F	minor rutting	R- eroded	N	L	75/80	L	Palmer trail off of the road
43+00		20	-	-	F	minor rutting	L	N	L	20/50	N	buried culvert
41+00		20	-	-	F	-	-	N	L	20/50	L	social trails on both sides of the road
19+00		20	-	-	F	-	-	N	L	50/50	L	Retaining wall after creek crosses
14+00		20	-	-	F	rutting in center	-	N	L	5/50	L	need to cut ditch and adjust center road rutting
12+50		20	-	-	F	deep rut in center	-	N	L	40/20	L	deep rut in center, need to grade ditch right, large rock on R then retaining wall, rut continues down to gate
5+00		20	-	-	F	potholes	-	N	L	50/50	L	cross slopes down to center valley gutter, asphalt paving past gate, pothole at shack and near stop sign in valley gutter, social trails on the north side and south side, drainage meets creek at 7+00

NOTES: All measurements taken looking downstream (left, right, etc.)
NLMH = None, Low, Medium, High

BEAR CREEK AND HIGH DRIVE
CULVERT AND BRIDGE SUMMARY TABLE

Culvert Identification			Creek Crossing - Bridges and Culverts										Entrance Data		Exit Data				
No.	GPS ID	ROAD STATION	Type (bridge, culvert)	Size (Dia, WxH)	Sediment Depth in Pipe	Top of Pipe to Road Elev	Headwall?	Blowout or Bypass?	Inlet or other components to note?	U/S End of Pipe - Area for BMP?	Approx. Length	D/S End of Pipe - Area for BMP?	Channel Bottom Width	Avg. Channel Side Slope	Discharges to	D/S End Height Above Bank	Erosion due to Culvert Flow	Sediment Directly Into Creek	Notes
					(in)	(ft)	Y / N	Y / N		Y / N	(ft)		(ft)	(_H:1V)		(ft)	(NLMH)	Y / N	
	TOPOFH2O	132+00	TOP OF ROAD																TOP OF WATERSHED, PARKING, TRAIL 667 CROSSING
1	CD10	127+00	CMP	18"	18"	2'	Y	N	BERM	ROCK WALL	45	TOO STEEP	3' RSD	1:1 HILL	ROAD SLOPE	3	M	N	HOLE IN TOP OF PIPE, BLOWOUT TO ROAD, FLOW GOES DOWN RT SIDE RD, D/S LARGE SCOUR VALLEY (TRIANGULAR 25' WIDE AT TOP, 10' DEEP)
2	CD11	120+40	CMP	BURIED	BURIED	BURIED	BURIED	N		NARROW ROAD	40	TOO STEEP	6' RSD	1:1 HILL	ROAD SLOPE	5	L	N	INLET BROKEN, FLOW INTO RD AND SCOUR ALONG CAR RUTS, VERTICAL STAND PIPE, D/S 2 CMP PIPES, 2-3' DIA ROCKS PLACED IN SWALE AND WORKING WELL, D/S SLOPE NOT AS STEEP
3	CD12	117+50	CMP	BURIED	BURIED	BURIED	Y	N		NARROW ROAD	40	TOO STEEP	6' RSD		ROAD SLOPE	3	L	N	D/S FLOW TO LOGS, POSSIBLY NO FLOW OUT OF PIPE
4	CD13	113+70	CONC	15"	0"	2'	Y	N		NARROW ROAD	30	RIPRAP, STEEP	3' RSD	1:1 HILL	ROAD SLOPE	3	H	N	FIRST OPEN PIPE FROM TOP OF ROAD, D/S ROCK WALL, 1.5' - 2' RIPRAP IN GULLY
5	CD14	109+30	CMP	15"	BURIED	BURIED	Y	N		Y	50	RIPRAP	3'		ROAD SLOPE	5	L/M	N	D/S ROCK WALL, D/S OUTLET IS 25' FROM RD, POSSIBLY NO FLOW OUT OF PIPE, 2' RIPRAP IN SWALE, PIPE BAND SEEN, LOST SECTION OF PIPE. TRIBUTARY FROM EAST SLOPE.
6	CD15	105+00	CMP	18"	0"	0'	Y	N	Y	Y	45	SCOURED	6'	1:1	ROAD SLOPE	12'	VERY H	N	PIPE HAS BEND UNDER ROAD, D/S ROOTS CREATE AGGRADATION AND FLAT CHANNEL SLOPE, BOULDERS IN SWALE, RELAT EROSIVE.
7	CD16	101+00	VARIES	U/S: 15" CONC D/S: 22" CMP	10"	0'	Y	N		Y	45	RIPRAP	10	1:1	ROAD SLOPE	1'	M	N	BROKEN PIPE, CHANGES TYPE UNDER ROAD, LOTS OF VEG, GOOD EXAMPLE. TRIBUTARY FROM EAST SLOPE.
	SWITCHBAC1	95+50	SWITCHBACK																SEVERE EROSION DOWN THE HILLSLOPE DUE TO RUNOFF FROM THIS SWITCHBACK. FLOW AND SEDIMENT DIRECTLY ENTER BEAR CREEK.
8	CD16B	89+00	CMP	24"	BURIED	BURIED	BURIED	Y		SMALL	30	SOME RIPRAP	3	1:1	ROAD SLOPE	1	M/H	N	RIPRAP AND TREES IN D/S GULLY
	CD16OUTLET	90+20	FLOW FROM CULVERT ABOVE																D/S OF CULVERT 16, ROCK WALL, NO FAN, RELAT STABLE
9	CD17	85+00	VARIES	U/S: 15" CONC D/S: 18" CMP	3"	2.5'	N	N	NATURAL ROCK WALL	VERY NARROW	30	LOGS, SCOUR	5	WALL ON LEFT	ROAD SLOPE	5	H	N	U/S CONC PIPE IS BROKEN, D/S MAJOR EROSION, PIPE FALLING OFF, TREES SCOURING OUT, POSSIBLE ROAD SAFETY CONCERN IF MORE SCOUR, SWALE GOES TO ROAD BELOW
	SMCHANLFAN	85+00	SEDIMENT FAN																SEDIMENT FAN FROM UPPER SLOPE.
	SWITCHBAC2	76+00	SWITCHBACK, VALLEY BOTTOM, LIKELY MISSING CULVERT, SEE NOTES																MAJOR SEDIMENT FAN, POSSIBLE BURIED LARGE CULVERT, NATURAL SWALE COMBINES WITH FLOW FROM CULVERT ABOVE, FLOW GETS REDIRECTED TO THE WEST ALONG LT SIDE OF RD INTO LARGE SCOUR SLOT. NEED TO INVESTIGATE MISSING CULVERT AND REESTABLISH ORIGINAL DRAINAGE PATTERNS.
10	CD18	74+20	CONC	36"	2'	0'	Y	N	VALLEY BOTTOM	Y, LARGE	40	N, GOOD VEG	VALLEY	1:01	FLATTER SLOPE	BURIED	N	N	LARGE RCP PIPE INDICATES A SIMILAR LARGE PIPE IS LIKELY BURIED UP-VALLEY, PIPE JOINT HAS GAP AND IS EXPOSED IN THE ROAD.

BEAR CREEK AND HIGH DRIVE
CULVERT AND BRIDGE SUMMARY TABLE

Culvert Identification			Creek Crossing - Bridges and Culverts										Entrance Data		Exit Data				
No.	GPS ID	ROAD STATION	Type (bridge, culvert)	Size (Dia, WxH)	Sediment Depth in Pipe	Top of Pipe to Road Elev	Headwall?	Blowout or Bypass?	Inlet or other components to note?	U/S End of Pipe - Area for BMP?	Approx. Length	D/S End of Pipe - Area for BMP?	Channel Bottom Width	Avg. Channel Side Slope	Discharges to	D/S End Height Above Bank	Erosion due to Culvert Flow	Sediment Directly Into Creek	Notes
					(in)	(ft)	Y / N	Y / N		Y / N	(ft)		(ft)	(_H:1V)		(ft)	(NLMH)	Y / N	
	OUTLET17	70+60	FLOW FROM CULVERT ABOVE																OUTLET FROM CULVERT ABOVE, LOT OF BEDROCK IN SWALE, SEDIMENT FAN IS NOT LARGE.
11	CD19	68+90	CMP	15"	BURIED	BURIED	BURIED	N	STEEP EAST SLOPE	NARROW	50	N	10	1:1	VALLEY	8'	M	N	RIPRAP IN GULLY
	SWITCHBAC3	66+10	SWITCHBACK																FAN FROM EAST FORCED FLOW IN ROADSIDE DITCH TO LEFT INTO RD, CAUSED 4' DEEP SCOUR SLOT IN RD, OLD ROCK WALL BUILT TO CAPTURE HILLSLOPE FLOW AND DIRECT IT TO THE NE CORNER OF THE SWITCHBACK.
12	CD20	61+90	CONC	32"	0	1'	Y	N		Y, LARGE	40	Y, LARGE	3'	1:1	VALLEY	0'	M	N	EROSION IN U/S VALLEY AND ROAD SWALE, DISCHARGES TO FLAT VALLEY, SEDIMENT CAPTURED IN VALLEY.
13	CD21	50+40	CMP	24"	20"	2'	N	N	SIDE TRIBUTARY	Y, LARGE	35	Y	10'	4:01	DRY SIDE CHANNEL	1'	L	N, SIDE CHANNEL	OUTFLOW ENTERS SWALE ACROSS OVERBANK.
B1	CRKXING1	47+80	BRIDGE	9'W X 4'H	NATURAL BOTTOM				GROUTED ROCK CULVERT										
14	CD21B	43+40	BURIED	BURIED	BURIED	BURIED	Y	N		N	40	N, VEG	2.5'	1:1	DRY SIDE CHANNEL	BURIED	N	N, SIDE CHANNEL	LIKELY CULVERT, LEFT SIDE RD FLOWS INTO SWALE THAT ENDS AT HEADWALL, COULDN'T FIND U/S OR D/S END OF PIPE, SIDE CHANNEL EAST OF RD INTERCEPTS FLOW BEFORE IT GETS TO CRK.
15	CD21C	39+90	CMP	24"	10"	0'	Y	N	ROCK SIDE CHAN	Y	40	VEG	2'	2:1	CREEK OVERBANK	0"	L	Y	TRIBUTARY FROM WEST ENTERS GROUTED ROCK CHANNEL THAT COMBINES WITH THE RSD GROUTED ROCK CHANNEL.
16	CD21D	38+80	BURIED	BURIED	BURIED	BURIED	Y	BURIED	BURIED	BURIED	BURIED	BURIED	BURIED	BURIED	BURIED	BURIED	BURIED	BURIED	ONLY A HEADWALL WAS FOUND.
17	CD21E	36+90	VARIES	U/S: 21"W X 16"H ROCK D/S: 18" CMP	0"	1'	Y	N		N	30	N	2'	WALL	CREEK	2'	L	3' FROM CREEK	THIS CULVERT IS UNIQUE AND MAY BE HISTORIC.
B2	CRKXING2	32+20	BRIDGE	8'W X 3'H	NATURAL BOTTOM				GROUTED ROCK CULVERT										FLOW FROM LT SIDE OF ROAD GOES INTO CRK AT BRIDGE
B3	CRKXING3	28+80	BRIDGE	9'W X 2.5'H	NATURAL BOTTOM				GROUTED ROCK CULVERT										FLOW FROM RT SIDE OF ROAD GOES INTO CRK AT BRIDGE
18	CD22	27+60	CMP	30"	6"	1'	Y	N		POSSIBLY, ROCK INLET CHANNEL	40	Y	3'	GROUTED ROCK WALLS	CREEK OVERBANK	0'	L	Y	TRIBUTARY FROM WEST
19	CD23	23+50	CMP	21"	BURIED	2'	N	N		Y	40	N, AT CREEK	4'	1:1	CREEK	0'	N	Y, AT CREEK	ONLY D/S END OF PIPE FOUND
B4	CRKXING4	17+70	BRIDGE	7'W X 1.5'H	NATURAL BOTTOM				GROUTED ROCK CULVERT										LT SIDE DITCH ENTERS CREEK
	BARRIERPIPE	15+20	LANDMARK																
20	CD24	14+80	CMP	20"	4"	1'	Y	N		N	40'	NO, STEEP	2'	NATURAL WALL	STEEP SLOPE	SLOPE	L	Y, DOWN SLOPE TO CREEK	FLOW DISCHARGES TO BEAR CREEK OVERBANK
21	CD25	13+20	BURIED	BURIED	BURIED	BURIED	Y	N		N	40	NO, STEEP	2'	1:1	OVERBANK	2'	L	Y, NO VEG ON SLOPE	FLOW DISCHARGES TO BEAR CREEK OVERBANK
22	CD25X	11+00	VARIES	U/S: 20"W X 18"H D/S: 20" CMP	3"	0'	Y	N		N	40	NO, STEEP	4'	1:1	OVERBANK	SLOPE	L	N, LONG OVERBANK	ROCK / BOULDER CHANNEL LINING D/S OF OUTLET, STABLE, EXAMPLE OF STABILIZED RUNDOWN. FLOW DISCHARGES TO BEAR CREEK OVERBANK.

BEAR CREEK AND HIGH DRIVE
CULVERT AND BRIDGE SUMMARY TABLE

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					(in)	(ft)	Y / N	Y / N		Y / N	(ft)		(ft)	(_H:1V)		(ft)	(NLMH)	Y / N	
23	CD26	7+00	CMP	24"	BURIED	0'	Y	Y		N	30	SLOPE	2'	1:1	OVERBANK	10'	L	N, 50' TO CREEK	FLOW DISCHARGES TO BEAR CREEK OVERBANK
	GATE	3+80	GATE																
24	CD27	5+00	IT APPEARS A CULVERT IS LIKELY LOCATED HERE, BUT COULD NOT BE FOUND												OVERBANK	BURIED	L	50' TO CREEK	IT APPEARS A CULVERT IS LIKELY LOCATED HERE, BUT COULD NOT BE FOUND
	END GOLDCP	-0+80	END OF ROAD																

* Y = YES, N = NO, LT = LEFT, RT = RIGHT, CMP = CORRUGATED METAL PIPE, CONC = CONCRETE, RSD = ROADSIDE DITCH, VEG = VEGETATION
* NLMH = NONE, LOW, MODERATE, OR HIGH
* B1, B2, B3, AND B4 ARE BRIDGE LOCATIONS WHERE HIGH DRIVE CROSSES BEAR CREEK

Appendix C: Conceptual Solutions Matrix

Conceptual Solutions Matrix

***NOTE: Not all solutions presented below are applicable to High Drive Road. This is a comprehensive list for consideration on all gravel roads.**

Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Roadway Improvements - Surface Material						
Asphalt Paving	Reconstruct the roadway with a pavement section consisting of base course and asphalt (or full depth asphalt) to eliminate surface sediment.	This option will eliminate surface sediment and provide a more durable surface. Paving a roadway tends to encourage a higher speed of travel, which for safety, may lead to upgrading the roadway geometrics. Due to the project budget, this may not be feasible at this time.	Pave with Asphalt	Mile	$ 600,000	Moderate
Concrete Paving	Reconstruct the roadway with concrete to eliminate surface sediment.	This option will eliminate surface sediment and provide a more durable surface. Paving a roadway tends to encourage a higher speed of travel, which for safety, may lead to upgrading the roadway geometrics. Due to the project budget, this may not be feasible at this time.	Pave with Concrete	Mile	$ 650,000	Moderate
Chip Seal	Chip seal a base course surface with three layers to stabilize and improve durability.	The road may be too steep for chip seal. Washington County in Oregon uses this technique on many of its gravel roadways with very good results, and some of their roads receive plowing in the winter.	Pave with Chip Seal	Mile	$ 120,000	Moderate
Cementious Additive	Scarify the surface and mix in additives, such as Portland cement, fly ash, or lime.	This treatment stabilizes the roadway, but may have water quality impact concerns.	Treat with Cement	Mile	$ 115,000	Moderate
Magnesium Chloride	Treat the roadway periodically with magnesium chloride to reduce surface erosion.	Magnesium chloride is used by other counties in Colorado to control dust and harden the surface. A potential hazard with the chemical is its reaction with the environment. Product users have stated it produces good results for controlling dust and stabilizing roads. A sample of this is on Cottonwood Pass, south of Buena Vista, CO. Douglas County currently uses a magnesium chloride and lignin mixture.	Treat with Stabilizer (Magnesium Chloride)	Mile	$ 12,000	Moderate
Road Stabilizers	Treat the roadway periodically with commercially available road stabilizer.	This treatment stabilizes the roadway, and some brands claim to be environmentally safe. Products include Gorilla Snot, Road Oyl, Soiltac, and others. Some products have been approved by the Federal Government.	Treat with Polymer Stabilizer (Soiltac)	Mile	$ 20,000	Moderate
			Treat with Stabilizer (Mag/Lignin)	Mile	$ 12,000	Moderate
Roadway Improvements - Geometrics						
Major Realignment	Major realignment includes changing the vertical or horizontal alignment of the roadway.	Due to the narrow road and stream corridor, any major realignment would be costly. Moderate realignment, in order to increase the buffer distance between the road and stream, would also be costly. The impact to the environment during construction would likely outweigh the benefit of an increased buffer.	Varies by location.	--	Varies	Low
Reverse Roadway Cross Slope	Change the roadway cross slope so that the road drains away from the creek.	A cross slope towards the cut slope will allow flow and sediment to be directed to a roadway ditch instead of the creek. This can be accomplished in long tangent reaches and flat curve areas. Sediment may still need to be trapped before reaching the creek. It is assumed that the change in the flow area draining to each culvert is negligible, but should be confirmed if this option is selected. Culvert upsizing or placement of additional culverts may be needed. The presence of subsurface rocks or boulders will impact the construction practicality and cost.	Reverse Roadway Cross Slope (assumes only road base modifications required, does not include additional culverts if needed)	Ft	$ 1.00	High
Rolling Dips	Provide subtle rolling dips along the roadway to shorten the length of road that collects subarea runoff.	Rolling dips may be feasible in some locations. The low points of the dips will need to be stabilized to convey runoff from the road down the embankment. Additional speed control signage may be required.	Varies by location and depends on the type of earthwork involved.	Each	$5,000 to $15,000	Moderate
Flatten Ditch Backslope (hill slope)	Cut the slope back to reduce sediment sloughing into the ditch.	The hill slope would need to be flattened significantly for the sediment sloughing to stop. This would be a very large project with potentially significant impacts. The flattened slope may still be erosive due to the geology and low vegetation coverage in the area. Shotcrete may be used to mitigate the low vegetation and geology where the hill slope was flattened. Retaining walls could also be used to stabilize hill slopes. The costs for this treatment and hauling off excavated material can be significant.	Varies by location.	--	Varies	Low
Water Control						
Swales, Ditches, Gutters	Water conveyance elements that route flow to cross culverts or to rundowns.	Many roadside swales exist along High Drive Road, and are typically V-shaped ditches cut into the natural ground material. The ditches at the time of the site assessment appear to be stable, and not actively eroding. The swales are transporting sediment from the roadway and natural slopes to the culverts and rundowns. These features could be impacted by grading or snow plow operations. Stabilizing the ditches may be required to reduce erosion if combined flows are routed to the ditches.	Construct Roadside Swale (assumes dirt grading, on hill slope side of road)	Ft	$ 0.50	Moderate to High
Inlets	A concrete structure that connects a ditch, swale, or gutter to a pipe.	There are currently no inlets in the project area. Drop inlets can be used as sediment traps. Inlets can be used at rundown or runout locations to capture flow. Mountain roads often use simple inlets (or even a flared pipe end section) and flexible pipe for these purposes. Asphalt, rock, or other material is often used at the inlet or pipe entrance to control erosion.	Inlet, CDOT Type C	Each	$ 5,000.00	Low
Curb and Gutter	Water conveyance elements that route flow to cross culverts, rundowns, or runouts.	These roadside elements have a hardened bottom and side wall to convey flow, increase the conveyance capacity of the road, and provide a barrier. Curbs and gutters are not typically placed on gravel roads.	8" Curb and Gutter	Ft	$ 30.00	Moderate
			Half Buried Type 7 Concrete Barrier	Ft	$ 40.00	
			18" Wide Concrete Swale	Ft	$ 11.00	
			2' Dia Boulders keyed in 6"	Ft	$ 35.00	
Culverts / Pipes / Downspouts	Flow conveyance elements.	Pipes are used to convey flow and can be concrete, metal, or plastic. The number of culverts can be increased or decreased based on the site needs. In some cases, oversized culverts may be desired to capture excess bypass flows from upstream culverts. The USFS prefers the use of corrugated metal pipes to help decrease velocities. Downspouts can be connected to pipes to convey flow down the road embankment. Constructability and stability would also need to be addressed due to the very loose decomposed granite, and soil anchors could be required to stabilize the pipes.	Cross Culvert, 24" CMP	Ft	$ 50.00	Moderate to High

Conceptual Solutions Matrix

***NOTE: Not all solutions presented below are applicable to High Drive Road. This is a comprehensive list for consideration on all gravel roads.**

Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Stabilized Rundown	Use stabilized rundowns to convey flow from the road elevation to a stable location. This applies to roadside ditches and culvert discharges.	Rundown lining includes grass (not applicable here), soil riprap, riprap, concrete, brush/slash lined, and others. In addition to lining, small check dams built of rock or bioengineered products can be used to trap sediment and slow velocities. However, these check dams will fill with sediment quickly and may become maintenance intensive. There are also rundown stabilization products which may be applicable to this area, such as the "SmartDitch". Heavy equipment access may be required for some types of stabilization.	Concrete Rundown	CY	$ 400.00	High
			Soil Riprap	CY	$ 100.00	High
			Straw Bales	Ft	$ 8.00	Low to Moderate
Sediment Trap at Culvert Entrance / Exit	Use an inlet or other device to trap sediment from the roadside ditch before it enters cross culverts.	Inlets can be constructed with depressed inverts, such that sediment is captured inside the inlet. Once sediment fills the depressed area, sediment would then have the potential to be conveyed through the pipe. The inlet grates could be hinged, and a vacuum truck could be used to remove the sediment. A sediment trap could also be placed at the downstream end of the culvert to increase the trapping capacity, and keep the sediment close to the road and accessible by a vacuum truck. Alternatively, small concrete or rock walls could be constructed at culvert entrances to provide the same effect. A geotube could also potentially be used to trap sediment exiting a pipe, while allowing water to continue downstream. The maintenance effort and associated costs for this treatment could be significant.	Depressed Inlet Box	Each	$ 6,500.00	High
Culvert Outlet Protection	Erosion control located at the end of a pipe.	Soil riprap, riprap, rock gabion mattresses, and other hard materials are the most common types of outlet protection. Vegetation, turf reinforcement mat, or other materials may be feasible. Due to the loose soils, undermining of these features could be likely, and appropriate measures would need to be considered.	Soil Riprap	CY	$ 100.00	High
Roadside Stream Protection Barriers						
Curbing	Use curb and gutter to control and convey flow to a stabilized location.	The concept here is to provide a curb and gutter solution for a gravel road. This feature would contain flow and sediment on the roadway, and prevent it from being pushed down the slope and into the creek. A hardened gutter would likely be needed at the base of the curbing (riprap, concrete, other). The curbing could consist of a small structural trench wall, a row of grouted boulders, sheet pile with a concrete cap, or a buried CDOT Jersey Barrier. The features need to be stout to withstand potential impact by grading and snow plow equipment. It is unknown if this concept has been used elsewhere, so its performance is unknown. However, this is a more durable option than using dirt berms for flow containment. The impact to the roadway width would need to be considered.	8" Curb and Gutter	Ft	$ 30.00	Moderate
			Half Buried Type 7 Concrete Barrier	Ft	$ 40.00	Moderate
			18" Wide Concrete Swale	Ft	$ 11.00	Moderate
			2' Dia Boulders keyed in 6"	Ft	$ 35.00	Moderate
Guard Rail with Curb or Running Board	Use a roadway guard rail and running board to control sediment.	Guard rails are often installed in combination with curbs. In some cases, a running board consisting of a 6" to 12" tall barrier is placed on the guard rail support posts to control sediment. A sample of this is on Highway 24 west of Colorado Springs, CO. With this solution, the curb or running board would be protected from grading or snow plow equipment by the guard rail. However, the cost and roadway width needed to construct this feature are significant.	Guard Rail with Running Board	Ft	$ 25.00	Moderate
Roadside Infiltration	Place a device along the road to allow runoff infiltration.	The devices used here could be a vegetative strip, a rock trench, soil wraps, or other components that would capture runoff and let it infiltrate, as opposed to allowing the flow to run down the roadway side slope. Plugging and maintenance needs of these devices would need to be considered.	Rock Trench	CY	$ 100.00	Moderate
Roadway Operations and Maintenance Changes						
Remove Roadside Berms, Grade and Snow Plow Away from Creek	Grade and snow plow away from the creek.	In order to not push sediment and contaminants into the creek, operational crews should manage equipment in a way to push road material and snow away from the creek. It is understood that this may be more time consuming and difficult, but is a cost effective solution. Removal of roadside berms on the low side of the road will allow less erosive sheet flow to run off the road. Removal of roadside berms on the high side of the road will prevent the broadcasting of excess sediment onto the fill slope, which can bury vegetation.	Berm Removal	Mile	$ 500.00	High
Culvert Cleaning	Control sediment removed from culverts.	As culverts are cleaned by jetting water or using a vacuum truck, additional sediment control measures should be considered to minimize the loss of sediment. BMPs consisting of coconut logs, filter socks, or geotubes (dewatering tubes) could be used to trap sediment close to the end of pipe. A geotube could be temporarily attached to the end of the culvert prior to flushing, to ensure all sediment is captured. Alternatively, an excavator bucket or other device could capture the flow and sediment.	12" Erosion Log	Ft	$ 5.00	High
Establish Grading Limits	Delineators, boulders, or other features to identify maintenance limits.	Grading of dirt roadways can cause road widening, development of roadside berms, broadcasting of sediment onto vegetation, and excavation of the toe of unstable slopes. Establishing grading limits can help limit unnecessary damage from maintenance operations.	Reflective Markers and Posts	Each	$ 30.00	High
Identify Critical Habitat Areas	Identify critical habitat areas for awareness during road operations.	Use USFS posts, reflectors, boulders, or signage to identify critical habitat areas to operational crews. The markers would designate where operational crews should perform certain activities, such as grading to the uphill side of the road.	Reflective Markers and Posts	Each	$ 30.00	High
Slope Stabilization - Roadway and Natural Slopes						
Seeding, Plantings	Plant native, noxious weed-free seed to establish vegetation for erosion protection.	Due to the lack of topsoil and the erosive nature of the geology in the area, seed establishment will be difficult. Import of noxious weed-free topsoil would likely be needed, but even with that, seeding success rates may be low. Seeding of flatter slopes, the creek overbanks, and the riparian corridor would have higher success rates. Additional riparian vegetation would trap additional sediment and increase water quality, even for relatively narrow buffer areas.	Upland Seeding	Acre	$ 5,000.00	Low
			Riparian Seeding	Acre	$ 7,000.00	Moderate
			Willow Staking	Each	$ 5.00	Low
			Wetland Plugs	Each	$ 3.00	Moderate

Conceptual Solutions Matrix

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Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Mulch	Weed-free straw scattered or crimped into the ground.	Mulch is typically used in combination with seeding to establish vegetation and prevent erosion until the seed is established. The existing loose granite slopes will be a challenge to support vegetation, and the mulch may not be stable. Crimping the mulch into the soils in this area is likely not practical. Unless importing topsoil is an option, this is not recommended for further consideration. Mulch can consist of straw, bark, shredded wood, or other materials.	Mulch, Crimped Straw	Acre	$ 1,500.00	Low
Erosion Control Blanket	Use erosion control blanket and seeding to reduce sediment from the slope.	Erosion control blanket is used to temporarily stabilize an area until the underlying seed is established. Blankets must be placed on smooth ground, keyed in, and have staking and check slots appropriate for the ground conditions. Incorrect installation can lead to erosion under the blanket. The existing loose granite slopes will be a challenge to support vegetation, and the blanket could be a hazard to the PMJM and other animals. Unless importing topsoil is an option, this is not recommended for further consideration.	Erosion Control Blanket	SY	$ 6.00	Low
Turf Reinforcement Mat (TRM)	TRM is more stout than erosion control blanket, may have a significant thickness, and has a longer life span.	TRM must be installed similar to erosion control blanket, but is more resistant to flow, is more sturdy, and does not rely on the underlying vegetation for erosion control. TRM can be a reasonable replacement for soil riprap or riprap. TRM can be used for outlet protection, lining gullies, and other uses. However, the unstable soils in this project area may make TRM impractical.	Turf Reinforcement Mat	SY	$ 8.00	Moderate
Hydroseed / Hydromulch	Spraying seed or mulch from a nozzle for large area applications.	These products are common, but result in mixed opinions. Many of the products do not work well on loose soils, on steep slopes, or where concentrated flow will occur. Also, many metro Denver agencies do not allow their use. It is assumed that due to the conditions in the area, these products would not have the anticipated success rates needed for implementation.	Native Seeding with Hydromulch	Acre	$ 3,000.00	Low
Soil Riprap and Riprap	Angular rock used to stabilize swales, ditches, and streams.	Riprap is angular rock categorized by its D50 particle size. Riprap is often placed on a layer of more finely graded angular rock (filter material) or on geotextile, to prevent piping of smaller particles through the riprap. Soil riprap is riprap that has all of its void spaces filled with the native soil. Soil riprap is compacted, and typically has an additional layer of soil placed on top, then seeded with noxious weed-free seed. After the seed has established, the soil riprap is no longer visible and the area mimics the natural vegetated surroundings. These features can be used for slope stabilization, toe scour protection, creating small drop structures in streams, and more.	Soil Riprap	CY	$ 100.00	Moderate to High
Geogrid	A plastic grid system used to stabilize soils.	Geogrid for slope stabilization could consist of 3-dimensional plastic geogrid cells that help prevent soil from sloughing down slopes. The cells are typically filled with soil and vegetated. The stability of geogrid on the decomposing granite and steep slopes would need to be considered.	Geogrid	SY	Varies	Moderate
Boulder Walls / Terraces	Stack boulders, gabions, or other features to prevent erosion of the slope, or to allow a flatter slope.	For stream protection, boulders are placed at the edge of the stream, stacked to the height needed, and then backfilled from the top of boulder back to the tie in grade. This is a method often used to provide both stream stabilization at the toe of a slope, while also creating a flatter slope to the top of the boulders. Grout or concrete can be used to make the boulders much more sturdy, and prevent piping of soil from behind the boulders. When grout is used, the grout is typically kept to 1/2 to 3/4 the boulder height, so that the grout is not seen. Other features such as soil wraps, gabion walls, crib walls, live retaining walls, brush layers, and sheet pile can be used to create walls on steep slopes to create flatter slopes.	2' diameter boulders, single row, ungrouted	Ft	$ 35.00	Moderate
Soil Stabilizers, Tackifiers	Treat the slope periodically with a product to reduce slope erosion.	These products stabilize the slope, and some brands claim to be environmentally safe. However, due to the erosive nature of the geology in the area, the success rates for these products may be low.	Soil Binder	Acre	$ 650.00	Low
Slope Interceptors	Barriers, perforated pipes, or ditches placed on long slopes to minimize flow concentration and erosion.	These features may consist of bio-logs, natural logs, and ditches. Ditches are often placed at a slope to direct slope runoff to one side of the slope to a stabilized location. Due to the erosive nature of the soils in the area, the applicability of these features is limited.	12" Erosion Log	Ft	$ 6.00	Moderate
Sediment Control						
Sediment Barriers	Sediment barrier used to capture sediment at the toe of a slope.	Silt fence is a very good product for trapping sediment, but it is typically not a long term solution. The sediment will need to be removed, and the fabric and posts have a relatively short life span. Silt fence is a great product to use during construction to limit sediment dispersion. Live vegetative barriers, brush fences, and other features work similar to silt fences. More permanent features such as boulders, jersey barriers, or other devices can be used to allow sediment to accumulate behind them. These could be used to keep erosive cut slope material from entering roadside ditches. If the sediment collection capacity behind the wall is exceeded, sediment may overtop the wall.	Silt Fence	Ft	$ 4.00	Moderate
Check Dams	Small dams used to slow down velocities and trap sediment.	Small dams could be placed on overbank areas, in swales, or in gullies to slow velocities and trap sediment. The most common material used is riprap, but logs, coconut logs, willow bundles, brush, and other materials can be used as long as they can withstand the hydraulic forces in the stream or gully. Undermining of the check dam needs to be considered.	Riprap Check Dam	CY	$ 100.00	Moderate
Proprietary Water Quality Devices	Sediment traps and water quality devices.	There are many proprietary sediment trap and water quality devices on the market today. However, they often have small flow rate capacity, can be expensive, and their function is often questioned. It is recommended that depressed inlets, settling ponds, and other proven features be used. Proprietary devices have not been considered at this time.	N/A	N/A	N/A	Low

Conceptual Solutions Matrix

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Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Sediment Basin / Settling Ponds	Surface features that trap large amounts of sediment.	These ponds could be placed adjacent to the road or in wider overbank areas, and receive flow from the road ditches, rundowns, or natural swales. The ponds could be lined with rock or concrete to allow for excavation, and have perimeter vegetation installed to visually hide the ponds. A vacuum truck or excavator could be used to dredge the ponds. An overflow area should be provided and stabilized to prevent erosion in large storms.	Settling pond costs will vary by site based on access to the pond, pond depth, and erosion control required.	Each	$3,000 - $15,000	High
Filter Strips	Control sediment on flatter slopes using vegetation or bioengineered products.	Where flatter slopes exist and sediment needs to be controlled, filter strips can be used to trap the sediment. Filter strips can consist of vegetative strips (willows, etc.), strategically placed logs, coconut logs, or other products. These products must be installed to create a "sheet flow" effect over them to minimize flow concentration and erosion on the downhill side of the feature. As sediment builds up, additional features can be added on top of the collected sediment.	12" Erosion Log	Ft	$ 5.00	Moderate
Beaver Dams	Utilize existing beaver dams.	Beaver dams act as excellent sediment traps. When ponds fill in, they could be excavated, such that the sediment trapping capacity is restored. The excavation would need to not impact the stability of the dam or surrounding slopes. The beaver population should be protected. However, there are no active beaver dams in this study area.	Beaver Pond Sediment Removal & Disposal, varies by site conditions and disposal haul distance.	CY	$15 - $50	Moderate
Stream Improvements						
Channel Realignment / Buffer Width	Move the stream to increase the buffer between the road and the stream.	The project stakeholders have stated that channel realignment is not desired. The environmental impact can be significant. The costs associated with channel realignment or increasing the buffer width will vary depending on the site.	Varies by location.	--	Varies	Low
Bank Stabilization / Toe Protection	Stabilize the toe of the bank to control stream bank erosion.	Bank stabilization typically consists of laying back an eroded slope and using stabilization such as vegetation, erosion control blanket, turf reinforcement mat, soil riprap, or riprap. Access to erosive bank locations can be difficult, and it is recommended that if stabilization of the reach is desired, a TRM and vegetation controls are used. These materials can be hand carried to the site, are cost effective, and will not damage the surrounding area. Willow staking and riparian seed at the water's edge would provide additional bank stability.	Soil Riprap	CY	$ 100.00	Moderate
Drop Structures / Velocity Reduction	Drop structures are regularly used to flatten a stream's longitudinal slope and decrease flow velocities.	Drop structures can consist of rock, boulders, sheet pile, concrete, logs, or other components. Drop structure heights and locations are based on a stable longitudinal channel slope.	Varies based on drop size, materials, and needed erosion protection.	Each	$1,000 to $20,000	Low
Habitat Improvements	Use the Streamside Systems Wand for selective sediment removal in localized areas.	If additional habitat is desired, such as deeper pools for fish habitat, the Streamside Systems Wand could be used. However, it is recommended that the sediment input be controlled first, and let natural processes clean the system of excess sediment. Habitat improvements may then result without additional effort. Based on the site testing on Sugar Creek, the Streamside Systems Bed Load Collector may not be applicable for this site.	In-Stream Sediment Removal - Sand Wand (excludes sediment disposal).	CY	$ 100.00	Low

NOTES:

1. Costs are for planning purposes only, and do not include engineering, permitting, mobilization, water control, contingencies, or adjustments for current economic conditions.
2. Costs (2011 dollars) are based on CDOT, Urban Drainage and Flood Control District (UDFCD), and Engineering Judgment. Costs were increased to account for increased costs associated with the site conditions and location.
3. Benefit to Cost Ranges are based on a basic, qualitative review of each feature for the site conditions, and account for the feature's cost, ability to control sediment, longevity, stability in the site conditions, and anticipated success rate.