BERTHOUD PASS WEST
SEDIMENT CONTROL ACTION PLAN
US 40 Milepost 232.8 to 244.3

Prepared for:

Colorado Department of Transportation

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

°F	degrees Fahrenheit
AVL	Automated Vehicle Location
BMP	Best Management Practices
C.R.S.	Colorado Revised Statutes
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CSEV	Colorado Soil Evaluation Value
CWA	Clean Water Act of 1977
cy	cubic yard
Denver Water	Denver Board of Water Commissioners
DOT	Department of Transportation
EA	Environmental Assessment
EPA	Environmental Protection Agency
ft-MSL	feet mean sea level
FY	Fiscal Year
GPS	Global Positioning System
I-70	Interstate 70
IGA	Intergovernmental Agreement
Local Agency	Grand County
MDSS	Maintenance Decision Support System
MLOS	Maintenance Levels of Service
mm	millimeters
MOU	Memorandum of Understanding
MP	Mile Post
MPA	Major Program Area
NRHP	National Register of Historic Places
OAHP	Office of Archaeology and Historic Preservation
ROW	right-of-way
RWIS	road weather information system
SCAP	Sediment Control Action Plan
SDWA	Safe Drinking Water Act
SWAP	Source Water Assessment and Protection
SWPPP	Storm Water Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TSS	total suspended solids
US 40	United States Highway 40
USDA	United States Department of Agriculture
USFS	United States Forest Service

EXECUTIVE SUMMARY

Introduction and Purpose

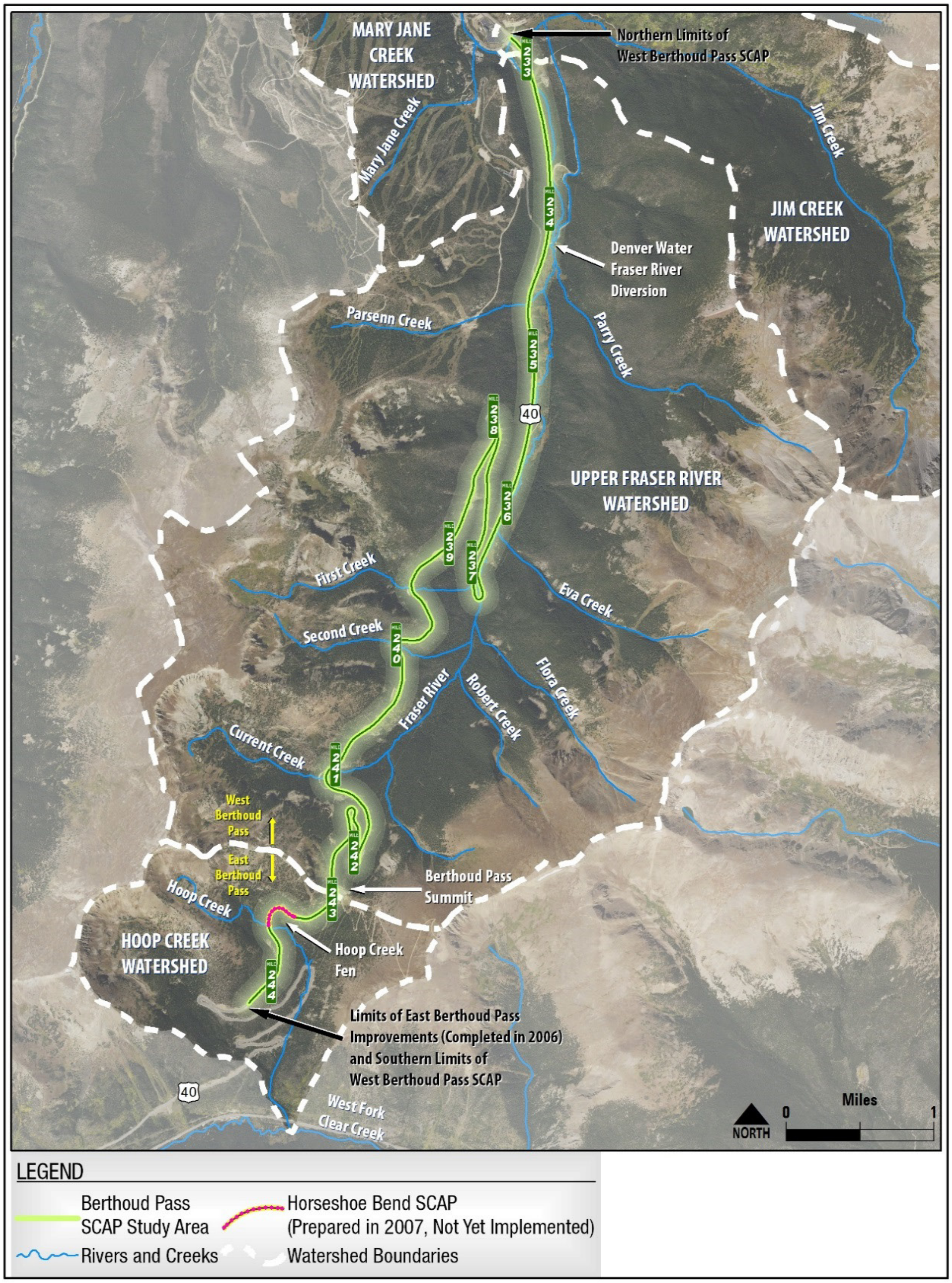
This Sediment Control Action Plan (SCAP) identifies potential sediment control scenarios that could be implemented along US 40 from Milepost (MP) 232.8 to MP 244.3, to supplement current sediment control and maintained practices. The Colorado Department of Transportation (CDOT), working with stakeholders, aims to improve control of sediment along this segment of US 40, which is described in this document as Berthoud Pass West or the study area. As shown on **Figure ES-1**, the study area includes 11.5 miles of US 40. Although this segment of US 40 trends north-south, the highway directions are designated US 40 Westbound for the north direction and US 40 Eastbound for the south direction. The study area extends 10.2 miles on the westbound side and 1.3 miles on the eastbound side of Berthoud Pass.

This SCAP was developed based field investigations within the study area, and previous CDOT experience and research in implementing roadway sediment control measures at high altitudes. CDOT has previously prepared and begun implementing SCAPs for some other high altitude highway corridors. Sediment is produced from the erosion of existing highway road cut and fill areas and from traction sand applied to the roadway during the winter. Large traction sand deposits have accumulated along the shoulders and right-of-way of US 40 Berthoud Pass over a period of many years. Some of this material, collectively referred to as sediment, is transported from the highway by surface water runoff processes and is deposited into streams, lakes, and wetlands. Excessive sediment loading can impair water quality, degrade fish habitat, and inundate wetland vegetation.

CDOT recognizes the need for coordination among stakeholders to discuss water quality concerns and develop sediment control strategies. With the study area spanning Berthoud Pass, a broad group including Federal and State agencies, local communities, water supply interests, and other stakeholders have been consulted. Stakeholder coordination will continue through subsequent implementation steps.

As with previous CDOT SCAPs, this SCAP is a planning level document. Further site-specific analysis, design, and cost estimates will be required prior to implementation of specific sediment control measures. Four potential implementation scenarios have been developed. Detailed design and costs will need to be developed prior to implementation.

CDOT has provided funding to develop this SCAP to identify current impacts and to develop potential sediment control scenarios. However, no additional funding has yet been identified for implementation. Additional funding will be needed for implementation and maintenance. At this time, there is no requirement or schedule to implement the measures identified in this SCAP. This SCAP has been prepared to assist CDOT and stakeholders in developing a proactive approach to improved waterway stewardship of the Fraser River and Upper Clear Creek. The scenarios can be used as a reference and guidance for future planning of the US 40 Berthoud Pass corridor.



3

Figure ES-1. Berthoud Pass West SCAP Study Area

Previously Implemented Berthoud Pass Sediment Control Measures

CDOT has already undertaken a number of actions and implemented procedures, over a period of years, to reduce/control sediment on US 40 Berthoud Pass. These are on-going and include:

Berthoud Pass East Highway Improvements with Sediment Control

A multi-year comprehensive CDOT project to improve the highway on the east side of Berthoud Pass terminating at MP 244.3, including extensive and state-of-the-art sediment control structures, was completed in 2006. The highway segment between MP 249.0 and MP 244.3 was reconstructed with slope retaining walls, large paved shoulders for snow storage, new drainage design and infrastructure, and concrete sediment traps. A highway sediment maintenance plan was also developed and implemented as part of this project.

Berthoud Pass West Sediment and Erosion Control Measures

Sediment and erosion control measures were undertaken by CDOT as part of roadway improvements on the west side of Berthoud Pass in 1997 and 1998. The 2.4-mile segment of US 40 west of Berthoud Pass MP 236.9 to 239.3 has benefited from localized sediment source control improvements. A 3-foot high knee wall and associated concrete pan drain were constructed along this segment to stabilize the cut slope and collect sediment with three concrete basins along the double switchback near the base of Berthoud Pass. Improvements to the collection system are recommended in this SCAP to enhance sediment capture.

Fraser River Diversion Sediment Basin Project

The Fraser River Diversion Sediment Basin Project is a joint effort between CDOT and Grand County, working with other stakeholder agencies. Each year in the fall, CDOT removes approximately 500-700 tons (400 cubic yards) of sediment from the Fraser River Diversion Sediment Basin. Sample results indicate that most of the sediment collected in the basin consists of native geologic material derived from erosion processes. Water supply treatment operators downstream of the sediment basin have noticed a substantial improvement in the quality of the water, and trout populations are showing signs of recovery in certain downstream areas.

CDOT Maintenance Program

Roadway maintenance personnel are responsible for maintaining the operational capability of the highway system. Routine maintenance of the US 40 corridor has focused primarily on maintaining the roadway surface. The clean-up of sand and sediment from the highway corridor is conducted through ditch cleaning, cleaning beneath guard rail, sweeping, and other related activities as work designated under Roadside Facilities.

Each year, a portion of the traction sand and sediment is removed from the roadway by sweeping, culvert maintenance and cleaning, and ditch cleaning. In summer 2015, CDOT contractors removed approximately 6,500 tons (4,300 cubic yards) of historic sediment deposits stored behind guardrails on Berthoud Pass. This effort covered approximately 4.46 miles of guardrail.

SCAP Implementation Scenarios

With funding limitations, it will likely be very challenging to fully implement the comprehensive set of sediment control BMPs and slope stabilization treatments identified in this SCAP. It is anticipated that the measures identified in this SCAP will most likely be implemented over time in a series of implementation steps or scenarios. This will begin with continuation of the traction sand management and sediment control practices that CDOT has currently in place. As funding and resources become available, these measures can be supplemented by a series of actions identified in the scenarios below, complementing and building on previous actions.

Four potential implementation scenarios were developed each representing different levels of effort to address the sedimentation problems on Berthoud Pass. These scenarios provide options and serve to prioritize sediment control actions until funding becomes available for full SCAP implementation.

Scenario 1: Continue Current Maintenance and Sediment Control Practices

Scenario 1 entails continuation of the maintenance practices CDOT has developed and refined over time, and also the sediment collection CDOT has implemented with stakeholders with the Fraser River settling pond. Under Scenario 1, CDOT would continue current practices as follows:

- Continue current traction sand application, ditch cleaning, and sweeping practices
- Continue sediment capture and annual sediment removal at Fraser River diversion settling pond
- Remove accumulated sediment from existing benches and other areas, as appropriate and feasible when highway projects, such as guardrail replacement, are undertaken on adjacent highway segments
- Continue annual record keeping of traction sand application and recovery

Under Scenario 1, an effort to seek additional funding for sediment maintenance activities would be undertaken by CDOT, working with stakeholder agencies, with the goal of initiating Implementation Scenario 2. CDOT would also identify projects that are needed to maintain highway safety and/or slope stability and would undertake these as separate projects, as appropriate.

Scenario 2: Enhanced Maintenance and Sediment Control Practices

Scenario 2 would provide greater sediment control and a reduction of the release of sediment to the environment relative to Scenario 1. As funding becomes available, CDOT would proceed with Scenario 2, which would include:

- Continue existing Scenario 1 activities
- Inspect drainage system and clean/repair existing drainage, sediment collection, and clean water bypass facilities
- Remove accumulated sediment from roadside areas and drainage inlets, where practicable, to reduce sediment available for transport

- Remove shoulder sediment accumulations and repair drainage structures downstream of the Fraser Diversion from MP 234.3 to 232.9
- Consider drainage system improvements, such as additional clean water bypass, tributary channel stabilization in cut slope areas, and slope rundowns in high priority locations, where these can be easily implemented to reduce erosion and sediment transport
- Develop annual maintenance plan and schedule for enhanced sediment control activities

Detailed design would be completed prior to implementation. CDOT would develop an annual sediment control maintenance plan and schedule for enhanced maintenance measures and activities. For planning purposes, costs for implementation of Scenario 2 could range from $1,000,000 to $2,000,000, depending on how many clean water bypass facilities and other drainage improvements are established. This cost would be refined during detailed design.

Scenario 3 – Sediment Reduction through Targeted Drainage Improvements, Sediment Collection BMPs and Slope Erosion Controls

Scenario 3 would include the design and installation of targeted sediment reduction and control actions, which would further reduce the release of sediment into the environment relative to Scenario 2. Scenario 3 would include:

- Implement targeted erosion control actions, such as revegetation, knee wall repair/and other slope stability measures to reduce erosion and sediment generation from oversteepened cut and fill slopes
- Install additional clean water bypass facilities to separate clean tributary and spring water from roadway runoff to improve receiving stream water quality
- Repair and stabilize major tributary channel erosion in cut slope areas to reduce sediment transport
- Install pipe rundown drains in areas with high slope erosion
- Re-route drainage to existing sediment collection basins, where feasible, to enhance sediment capture
- Install drainage and sediment control measures at major tributary crossings and high priority locations including Berthoud Pass Ditch, Horseshoe Bend Fen, Current Creek, Second Creek, First Creek, Fraser River, Parsenn Creek, Mary Jane, and Unnamed tributaries

Costs for implementation of Scenario 3 could vary depending on the actions undertaken. An estimated cost ranging from $3,000,000 to $6,000,000 can be used for planning purposes. The actions to be undertaken under this scenario could be selected based on the funding available, with priority given to actions providing the greatest likely sediment reduction benefit and/or contributing to other objectives such as safety. By targeting the highest priority locations, substantial sediment reductions could be achieved. Costs would be refined during detailed design.

Scenario 4 – Full SCAP Implementation of Permanent Sediment Collection/Treatment BMPs, Drainage and Erosion Controls, and Slope Stabilization Measures
Scenario 4 would entail implementation of the full range of measures identified in this SCAP. This scenario would provide the greatest level of sediment reduction relative to the other scenarios, but the cost would be relatively high as would on-going maintenance costs.

Scenario 4 would include the following:

- Provide comprehensive sediment control through continuation of practices identified in the steps above, plus the implementation and maintenance of a system of permanent sediment collection/treatment best management practices (BMPs). This system would likely be implemented in phases, with monitoring to gauge system effectiveness and focus subsequent phases.
- Implement slope stability projects to mitigate rockfall hazard and slope failure areas

A planning level estimate for engineering and construction cost for the comprehensive system of sediment control BMPs is approximately $12.5 million. Once implemented, annual maintenance costs are estimated to be $150,000 to $200,000 per year. In addition, a planning level estimate for full implementation of the slope stabilization measures is approximately $7.8 million.

Implementation of the all of the identified sediment collection/treatment BMPs and slope stabilization actions in this scenario would take several years and considerable design, construction, and maintenance resources. Given funding limitations, full implementation may not be possible in the near future. One possibility would be that some or all of these actions are deferred to be considered and implemented in conjunction with major roadway reconstruction when that is required at some future date.

1.0 INTRODUCTION AND PURPOSE

The Colorado Department of Transportation (CDOT) Region 1 and Region 3 have identified the need to control sedimentation along the US Highway 40 (US 40) Berthoud Pass. Excessive sediment is produced from the erosion of existing highway road cut and fill areas and from traction sand applied to the roadway during the winter. Large traction sand deposits have accumulated along the shoulders and right-of-way of US 40 Berthoud Pass over the period of many years. This material, collectively referred to as sediment, is transported from the highway by surface water runoff processes and is deposited into streams, lakes, and wetlands. Excessive sediment loading can impair water quality, degrade fish habitat, and inundate wetland vegetation.

This mountain corridor is very steep and high in elevation. The study area begins near Winter Park Ski Area, US 40 milepost (MP) 232.8 at an elevation over 9,000 feet. It progresses east over the Berthoud Pass summit (MP 243) at an elevation over 11,000 feet and continues 1.3 miles east to the point where the East Berthoud Pass US 40 Improvements ended (MP 244.3).

On the west side of Berthoud Pass, the 10.2-mile highway corridor is adjacent to the upper Fraser River and its' tributaries and associated wetlands. East of the Berthoud Pass Summit includes the headwaters of Hoop Creek and an additional 1.3 miles of highway corridor in the study area.

Surface water resources in the upper Fraser River US 40 corridor have been identified as being impacted by roadway-derived sediment. The Upper Colorado River Water Quality Plan (208 Plan) states that "Increases in sediment in the Fraser River as a result of erosion and traction sanding along State Highway 40 (Berthoud Pass), as well as other land use practices, increase sediment movement into water bodies above natural conditions." Sedimentation on the Fraser River has been identified by the Colorado Nonpoint Source Assessment Report as an issue. Division of Wildlife data from 1979-1993 indicates that the coldwater fishery is impacted as a result of stream sedimentation (208 Plan). The 208 Plan states that "High sediment loads in this drainage are associated with erosion of cut and fill slopes along US Highway 40 on the north side of Berthoud Pass, as well as road sanding practices".

CDOT has undertaken efforts to reduce erosion and sedimentation from the highway in some areas. However, no comprehensive study has been conducted in the Berthoud Pass corridor to quantify the extent of sediment impacts or to develop control strategies.

The overall purpose of this SCAP study is to:

- inventory existing conditions within the US 40 Berthoud Pass study area with respect to sediment deposition and transport, drainage and erosion, and slope stability
- identify a comprehensive set of sediment reduction and sediment control BMPs that could be implemented to reduce the release of sediment into the environment from US 40 operations

- develop a prioritized strategy/list of packages with planning-level costs for implementation over time as funding becomes available
- review and refine the identified BMPs and prioritization through stakeholder involvement and coordination throughout the process
- identify next steps for CDOT to prepare for and begin implementation

Similar highway-related water quality impacts were identified by CDOT on the south side of Berthoud Pass. A highway improvement project on Berthoud Pass East included permanent structural sediment controls to reduce sedimentation in Hoop Creek, which falls within the Clear Creek watershed. A highway sediment maintenance plan was also developed and implemented as part of this project. CDOT is undertaking efforts to reduce sediment loading in these watersheds and several Best Management Practices (BMPs) aimed at controlling sediment have been implemented.

CDOT recognizes the need for coordination among stakeholders to discuss water quality issues and concerns and to develop sediment control strategies. Federal and State agencies, local communities, water supply interests, and other stakeholders have been consulted as part of this Sediment Control Action Plan (SCAP) development.

CDOT approved funding to develop this SCAP for Berthoud Pass to identify current impacts and to develop effective control strategies. However, more funding will be needed to support these efforts and to establish an effective preventative maintenance program. In order to facilitate the acquisition of additional funding, a SCAP must be developed that outlines and prioritizes these funding needs.

1.1 Background

Edward L. Berthoud, the chief surveyor for the Colorado Central Railroad during the 1860s and 1870s, discovered what is now called Berthoud Pass in 1861 while performing a reconnaissance for possible railroad and mail routes through the Colorado mountains to Salt Lake City (McGrath 1934). Although the pass was determined to be too steep for a railroad grade, Berthoud suggested that a wagon road could be constructed to provide access over the Continental Divide. Mr. Berthoud was subsequently hired by the Central Overland California and Pikes Peak Express Company to survey this road over the pass.

The original wagon road over Berthoud Pass, completed in 1875, was only serviceable during the summer months due to heavy snowpack. Sometime around 1893 the original wagon road was widened to 10 feet and was converted into a “toll road” that became part of the Midland Trail. This improved wagon road is visible today, mostly on the west side of the pass. This early route over Berthoud Pass is located below the current US 40 alignment on the north wall of Berthoud Pass West. The length of this old road was walked for this study as areas of modern highway traction sand were observed to have collected on this feature below the current right-of-way through the action of debris flow and slope wash processes.

The Midland Trail was one of the first recognized and designated routes crossing the United States. From 1919 to 1923 major improvements were made to the road over Berthoud Pass utilizing power equipment and more modern roadway building techniques to accommodate automobiles. This included realigning the roadway to roughly its current position above the old wagon road incorporating switchbacks to lessen the grades and widening of the route to 20 to 24 feet. The route over Berthoud Pass was not paved until 1938. This alignment is essentially the current US 40 right of way, although adjustments and improvements have been made to the road.

In 1902 the Berthoud Pass Ditch was built on the west side of the pass to divert water from the headwaters of the Fraser River over the Continental Divide into the Clear Creek drainage. The water in this very early trans-mountain diversion was originally used for irrigation but was subsequently purchased by the Front Range cities of Northglenn and Golden as water supply in the mid-1980s. The ditch was blocked by a tunnel collapse under the Berthoud Pass summit parking lot in 1999. Subsequent repairs, including a redesign of the diversion structure under the top of the pass and the addition of sediment mitigation features, have allowed for an estimated yearly diversion of 500 acre-feet (600,000 cubic meters) of water. This SCAP study considers measures to further protect this diversion from influx of highway traction sand.

1.2 Study Area

The Berthoud Pass West SCAP study area is predominantly within Grand County, but also includes a 1.3-mile segment of US 40 on the south side of Berthoud Pass East in Clear Creek County. The SCAP study area covers an approximate 11.5-mile north-south-trending segment of US 40 from the Horseshoe Bend area south of the summit of Berthoud Pass (MP 244.3), to Jim Creek and the northern boundary of the Town of Winter Park (MP 232.8), see **Figure 1-1**.

Although this segment of the US 40 corridor trends north-south, the highway directions are designated US 40 Westbound for the north direction and US 40 Eastbound for the south direction. The upper Fraser River watershed is the receiving basin along the entire study area north of Berthoud Pass, with Hoop Creek and the West Clear Creek watershed being the receiving drainage for the 1.3-mile segment located south of the summit of Berthoud Pass.

The Berthoud Pass highway segment is characterized as a steep mountain environment with hill slopes at the angle of repose and near vertical rock outcrops. US 40 was constructed primarily on the west side of the upper Fraser River drainage by cut and fill methods, with fill material placed on the east-facing slopes well above the valley floor. The Fraser River valley is steep-sided and narrow in the vicinity of Berthoud Pass but becomes more open with a wider valley characterized by decreased topographic gradients towards the north end of the study area near the Town of Winter Park. The cut and fill slopes have largely stabilized since the construction of US 40, although slope erosion remains a problem in many areas. Annual application of highway traction sand and deicer salts is required to maintain safe mobility during winter.

For purposes of this SCAP, the US 40 corridor across the study area has been segmented into two (2) sections: the upper Fraser River watershed north of Berthoud Pass and the upper West

Fork Clear Creek watershed south of Berthoud Pass. As Berthoud Pass is situated on the Continental Divide, drainage to the north of Berthoud Pass (Fraser River) represents western slope Colorado River-Pacific water, while drainage to the south of Berthoud Pass (West Fork Clear Creek) represents eastern slope Platte River-Atlantic water.

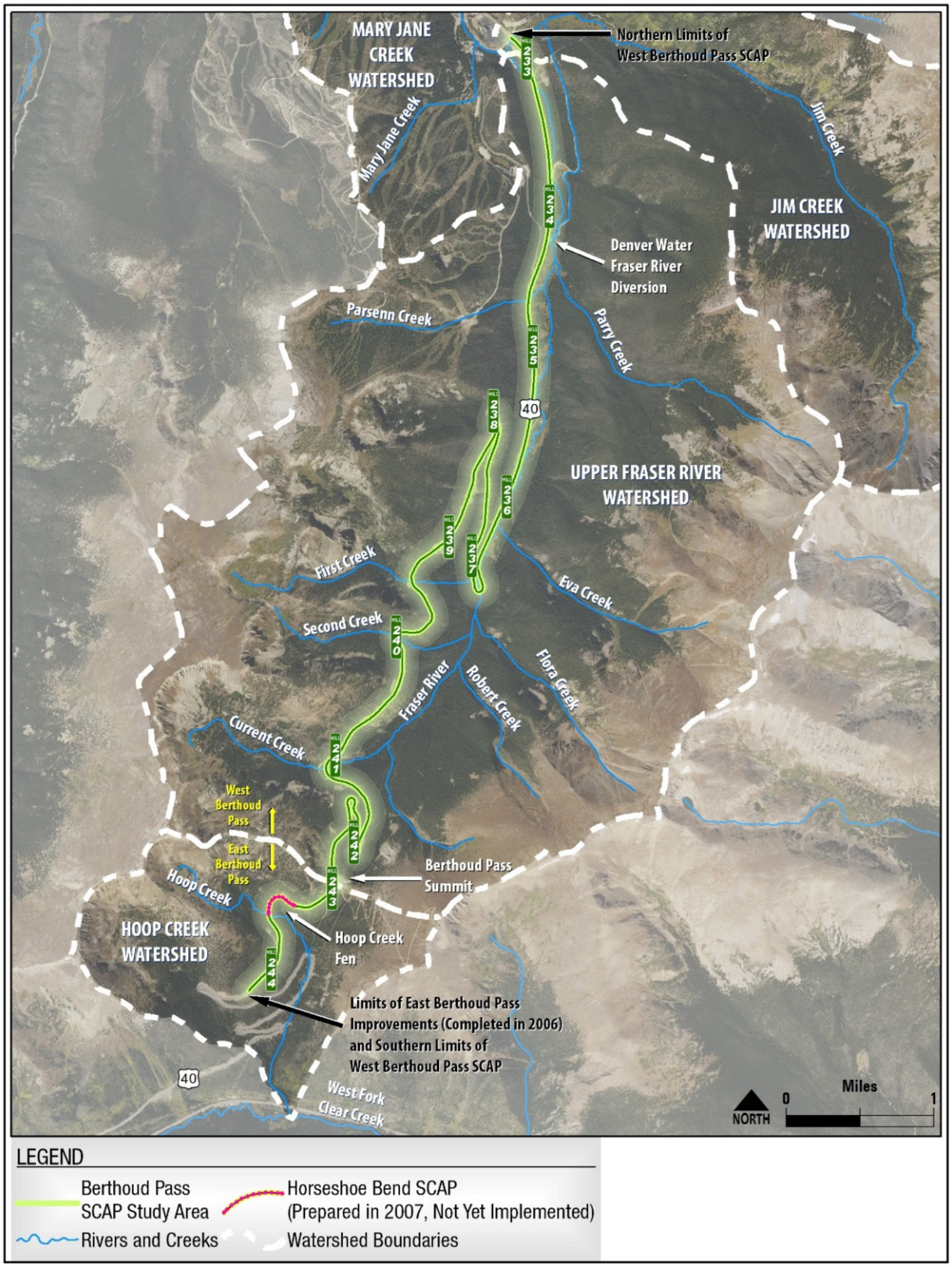


Figure 1-1. Berthoud Pass West SCAP Study Area

Additionally, upper tributaries of the Fraser River and the Fraser River itself are substantially diverted through a number of trans-basin diversion structures within the study area. This "western slope" water is diverted to the "eastern slope" of the Continental Divide to provide water supply to the front range of Colorado.

The Cities of Northglenn, Thornton, and Golden operate the Berthoud Pass Ditch trans-basin diversion high on headwater tributaries of the Fraser River. Water is redirected to the south over Berthoud Pass into the Atlantic (West Fork Clear Creek) drainage through the Berthoud Pass Ditch. The average annual diversion (1999-2009) through the Berthoud Pass Ditch was 614 acre-feet.

The Denver Water Department operates a diversion on the Fraser River above Winter Park. This structure takes water from 35 streams tributary to the Williams Fork, Vasquez and Saint Louis Creek drainages, and the Fraser River. Water at the Fraser Diversion is sent through the Moffat Tunnel to the eastern slope into the Boulder Creek drainage to supply front range communities. The average annual diversion (1999-2009) through the Moffat Tunnel was 59,402 acre-feet (Upper Colorado River Water Quality Management Plan, 2012).

The Moffat Tunnel diversions would supply water for 178,000 homes, or over 500,000 people in the Denver area. Clear Creek supplies water to approximately 350,000 people in that watershed, supports numerous industries, and supports a viable brown trout population along the Interstate 70 (I-70) corridor.

Water remaining in the Fraser River after diversion supports in-stream flow, agricultural uses, trout populations, and other aquatic life. Recreation includes angling and boating, and the river also supports large populations of terrestrial wildlife. The Fraser River and its tributaries supply drinking water for a number of downstream communities including Winter Park and Fraser.

According to the 208 Plan, the permanent population served in the upper Fraser watershed in 2010 was over 3,000 people. However, the 208 Plan states that "permanent population estimates in the NWCCOG region only partially show the extent of development and growth in the region. One variable is the "transient" visitor to the region who relies on infrastructure (e.g. hotels, motels, etc.), which is not part of the population estimate. The other variable is the second homeowner, who maintains a secondary residence in the region, but does not add to the population estimate. These two variables are extremely important considerations in growth and development in the region, and again, are not reflected in the population estimates and census data, and peak population data is inadequate."

1.3 Study Approach

There are several elements required for the development of the Sediment Control Action Plan. The study approach elements include:

- Inventory and documentation of existing sediment deposition and erosion conditions
- Field reconnaissance and mapping of corridor conditions
- Coordination with CDOT maintenance and stakeholders
- Quantification of the applied traction sand as a source of sediment
- Limited geotechnical/soils and revegetation review with regard to slope stability and erosion control
- Identification of conceptual methods for controlling or reducing sediment from erosion and roadway maintenance activities
- Development of conceptual designs for sediment control measures, i.e., BMPs
- Detailed corridor mapping to identify locations for BMP installation
- Screening analysis and prioritization of sediment control areas and options
- Identification of structural sediment control BMPs and quantities
- Development of cost estimates for construction and maintenance of BMPs
- Development of a Sediment Maintenance Plan for annual maintenance activities
- Estimated costs for maintenance activities associated with sediment control (e.g., sediment removal and disposal, reclamation and revegetation, etc.)

This SCAP is designed to address the US 40 drainage system and sedimentation conditions that existed in 2015/2016. It assumes no substantial changes to the existing highway template or drainage infrastructure. In areas where drainage or erosion control infrastructure is in poor condition or has failed, enhancements or repairs are recommended.

Within the consultant team, Clear Creek Consultants (working as a subconsultant to Felsburg Holt & Ullevig [FHU]) was responsible for completing field investigations and developing this SCAP. FHU provided GIS mapping, stakeholder coordination support, and overall project management for the SCAP study. Yeh & Associates provided slope stability evaluation.

1.3.1 Inventory and Documentation of Existing Conditions

CDOT maintenance has extensive knowledge of existing conditions on Berthoud Pass. They recognize problematic or high risk areas not only in terms of maintenance, but also for slope stability and excessive erosion rates. They are familiar with local waterways, cross drains, slope erosion, and other environmental factors. Meetings have been held with CDOT maintenance to better understand site-specific conditions, maintenance challenges and needs, and to explore potential solutions to sedimentation problems. Any existing maintenance plans, practices, and schedules were reviewed. Traction sand application and cleanup data has been complied and reviewed to assess trends.

The inventory includes but is not limited to the collection and compilation of existing environmental information, data, mapping, status of the highway drainage system, streams and near-by water bodies or wetlands, historic traction sand usage, and other related roadway information. This information is used to summarize the current and past conditions of the affected streams and water-bodies, along with assessing past and present highway and maintenance operations.

This inventory utilizes a watershed approach to outlining and analyzing the characteristics typical of a high elevation mountainous watershed such as the upper Fraser River (e.g., snowfall, rainfall, elevation, growing season, local wildlife, etc.). The summary includes an overview of the institutional and regulatory environment, as well consideration of the stakeholders and local community (acknowledging specific stakeholder concerns, e.g., sedimentation, fisheries, wetlands, water supply, etc.).

1.3.2 Corridor Field Reconnaissance and Mapping

Utilizing the available information, a detailed field reconnaissance was conducted for the 11.5 mile Berthoud Pass study corridor from 1.3 miles south of the summit to 10.2 miles north of the summit at Winter Park Ski Resort (MP 244.3 to 232.8). The field reconnaissance was conducted during the summer of 2015 when the ground was free of snow and all sedimentation, erosion, and drainage conditions could be assessed. The purpose of the reconnaissance was to:

- Make an initial assessment of the effectiveness of existing sediment/erosion control measures
- Identify surface water resources that have been impacted, along with potential sediment source areas
- Identify and refine locations for potential site-specific permanent structural BMPs
- Provide a preliminary hydrologic assessment of drainage conditions related to US 40 (review mapping and identify culvert drainage inlet and outfall conditions)
- Identify and prioritize problem areas
- Make an initial assessment of the feasibility of implementation for cleanup measures and installation of permanent BMPs
- Photographic Global Positioning System (GPS) location documentation and mapping of existing conditions and relevant features

Field investigations for the Berthoud Pass West US 40 SCAP were conducted from July to September 2015 by a team of scientists from Clear Creek Consultants. All drainage features, both naturally-occurring and US 40 as-built, along with associated sedimentation patterns were observed and documented between 1.3 miles south of the summit of Berthoud Pass (MP 244.3) and Jim Creek/Winter Park (MP 232.8) along US 40 in Clear Creek and Grand Counties.

Additionally, the areas both above and below the highway right-of-way (ROW) were assessed for sedimentation conditions and dynamics. This inventory and identification of drainage and sedimentation conditions was accompanied by on-site designation of BMPs for mitigation of observed affects.

Field inspection, inventory, and location of drainage features were accomplished by a three-person team walking the 11.5-mile highway-length of the study area. Inventory of both westbound and eastbound directions of US 40 included the cut slope (uphill) and fill slope (downhill) sides of this interval of US 40. Photo documentation and exact location of individual features were achieved through the use of a GPS-enabled Sony DSC-HX5 digital camera. The geo-referenced photography collected in the field was augmented by extensive written notation. A "SCAP Highway Drainage Channel, Erosion, and Sedimentation Inspection Form" was developed and used for this purpose. An example of the SCAP inspection form is included in **Appendix A**. Geo-referenced photographs were subsequently downloaded and plotted in Google Earth and captioned utilizing the field notes and spatial referencing afforded by Google Earth. **Appendix E** (provided electronically) is a KMZ format file with annotated field photos.

Using existing information and additional site-specific observations collected during the field reconnaissance, maps were developed that depict existing and proposed sediment control features and areas of substantial sediment loading. Any problem areas were identified on these maps for use in prioritization of cleanup areas. The US 40 drainage and sediment control BMP features identified during the reconnaissance were migrated into a GIS mapbook with 10 sheets, each covering over one mile of the highway corridor. A legend was produced describing the recommended BMP features for the SCAP. This mapbook is available in **Appendix B**.

1.3.3 Coordination with CDOT Maintenance and Stakeholders

Meetings were held with the local CDOT maintenance patrol to gather information on corridor maintenance and sedimentation conditions. A tour of the study area was conducted with CDOT maintenance in July 2015. Coordination with maintenance will continue through the development of this SCAP. It is anticipated that a maintenance plan will be developed in close coordination with CDOT maintenance as the SCAP is implemented.

CDOT recognizes the importance of coordination among stakeholders to understand land management and recreation activities, discuss the range of water quality issues, identify sensitive resources, and develop sediment control strategies. With the study area spanning both the east and west sides of Berthoud Pass, a broad group of stakeholders was invited to participate in the SCAP planning process. Stakeholders for this study include:

- Central Clear Creek Sanitation District
- City of Golden
- City of Idaho Springs
- City of Northglenn
- City of Westminster

- Clear Creek County
- Clear Creek Valley Water & Sanitation District
- Clear Creek Watershed Foundation
- Colorado Headwaters Land Trust
- Colorado Parks and Wildlife
- Coors
- Denver Water
- Grand County
- Grand County Water and Sanitation District #1
- Grand County Water Information Network
- Henderson Mine
- Town of Black Hawk
- Town of Empire
- Town of Fraser
- Town of Winter Park
- Trout Unlimited West Denver Chapter
- Trout Unlimited/Friends of the Fraser
- Upper Clear Creek Watershed Association
- USFS Clear Creek District
- USFS Sulphur Ranger District
- Winter Park Ranch Water and Sanitation District
- Winter Park Resort
- Winter Park Water and Sanitation District

These stakeholders received updates about the SCAP effort throughout the course of developing the report and were invited to participate in a stakeholder meeting in October 2015. The main focus of the meeting was to inform stakeholders about CDOT’s current effort to develop a SCAP along the US 40 Berthoud Pass corridor. Feedback from the meeting was integrated into development of this SCAP.

As documented in **Appendix C**, the meeting consisted of:

- A presentation of the SCAP study area and development process, existing conditions and constraints, and BMP examples
- A discussion with stakeholders about concerns, questions, and/or comments

To best accommodate stakeholder participation, FHU working in coordination with CDOT, used tele- and web-conference technology to join two meeting locations and other remote participants. The main meeting occurred in Winter Park/Grand County. A separate meeting location was staged in Georgetown/Clear Creek County. During the meeting, stakeholders agreed than an interim meeting is not necessary, but they would like to be kept informed as the SCAP is developed.

Following stakeholder review, revisions were incorporated into the SCAP document to address comments received. Comments and responses are available in **Appendix C**. CDOT and the City of Northglenn are continuing coordination regarding the City's concerns outlined in the City's January 7, 2016 letter (**Appendix C**). CDOT will continue coordination with SCAP stakeholders, as appropriate, through subsequent implementation steps.

1.3.4 Strategic Analysis for Sediment Control Areas and Options

The information gathered was used to identify specific areas for sediment control in the study corridor and develop strategies for:

- Implementing future permanent BMPs
- Identifying priority areas
- Identifying maintenance needs and plans
- Identifying funding needs

A written analysis and recommendations for sediment control and maintenance strategies is provided in the following sections. This analysis provides the basis for identifying problem areas in order to prioritize cleanup strategies. These strategies may include institutional controls and/or capital improvements for BMPs that are effective in sediment control.

The diffuse nature of sediment loading from the highway results in the identification of problem areas that require cleanup, and multiple potential BMPs. An integrated approach to sediment control will be required to provide effective water quality protection. This approach includes the collection and conveyance of sediment-laden runoff to treatment BMPs as described in Section 5.2.

Surface water runoff provides the transport mechanism for sediment. A review of the highway drainage system is required to evaluate alternatives for controlling surface runoff and associated future sedimentation. An assessment of the drainage system is needed to integrate the objectives of positive highway drainage, erosion control, and sediment control.

The drainage review provides valuable information on the feasibility of certain BMPs for the control of sediment. Providing positive drainage away from the highway while at the same time controlling sedimentation (through energy dissipation and detention) can be challenging in high-gradient mountain environments. Drainage alternatives may include re-routing clean water inflows to prevent contamination, or sediment detention basins. Reducing the size of contributing drainage areas by maintaining existing drains, replacing defective drains, or installing additional culvert drains can reduce the volume and erosive energy of the water. Hence, the drainage review is integrated with sediment control objectives to develop effective BMPs.

The progress of any slope stabilization and revegetation activities was assessed. CDOT records were reviewed to determine the status of these activities and their effectiveness in controlling sedimentation. A slope stability evaluation, completed by Yeh & Associates, is included as

Section 7. The slope stability evaluation includes recommendations for mitigation measure for identified areas of surficial slope instability.

Sediment control and cleanup areas and needs were identified based on reconnaissance and mapping information, integrated with the drainage review. Permanent BMPs may include sediment control structures (collection drains and detention basins) or slope stabilization measures. The recommended sediment control features were compiled into a master list that is used to identify future capital improvement needs. This includes the integration and implementation of multiple BMPs in all areas with the objective of reducing sediment loading to receiving waters. Once BMPs are in place, a maintenance plan will be developed and implemented to ensure effective performance of the sediment control system.

The information obtained through this SCAP evaluation will be used as a decision-making tool by CDOT, in coordination with the stakeholder group, to prioritize efforts for future funding. Four potential implementation scenarios were developed each representing different levels of effort to address the sedimentation problems on Berthoud Pass. These implementation scenarios, which are presented in Section 8, provide options and serve to prioritize BMPs until funding becomes available for full SCAP implementation.

1.4 Previous CDOT Berthoud Pass Sediment Control Measures

1.4.1 Hoop Creek Watershed – Horseshoe Bend Area

A multi-year comprehensive CDOT project to improve the highway on the east side of Berthoud Pass terminating at MP 244.3, including extensive and state-of-the-art sediment control structures, was completed in 2006. The highway segment between Berthoud Falls (MP 249.0) and MP 244.3 was reconstructed with slope retaining walls, large paved shoulders for snow storage, new drainage design and infrastructure, and concrete sediment traps. These measures have been effective in reducing sediment loading to Hoop Creek. However, traffic safety issues have emerged in recent years related to some of these BMPs, necessitating changes in procedure and limiting their effectiveness in sediment control. Specifically, snow is no longer stored along the roadway due to the potential for ramping of vehicles over the guardrail. With these limitations, this specific type of BMP is not recommended as part of this SCAP.

The 1.3 mile US 40 highway segment (MP 244.3 to 243.0) east of the summit of Berthoud Pass in the vicinity of Horseshoe Bend represents the remaining unimproved section of roadway between the terminus of the previously redesigned/rebuilt section and Berthoud Pass. This segment does not contain any modern drainage improvements or sediment source control measures and is characterized by large amounts of unrestrained traction sand and road sediment, both on the roadway and deposited below on the fill slope. This 1.3 mile section of roadway is included as part of this SCAP study.

In 2007, a SCAP was developed for a portion (0.2 miles) of this unimproved section and has been updated for this study. The area of Horseshoe Bend is important as it contains a wetland fen and represents the headwaters of Hoop Creek. Hoop Creek is also the receiving stream for the Berthoud Pass Ditch trans-mountain diversion.

1.4.2 Upper Fraser River Watershed

Sediment and erosion control measures were undertaken by CDOT as part of roadway improvements on west Berthoud Pass in 1997 and 1998. The 2.4-mile segment of US 40 west of Berthoud Pass MP 236.9 to 239.3 has benefited from localized sediment source control improvements. A 3-foot high knee wall and associated concrete pan drain were constructed along this segment to stabilize the cut slope and collect sediment along the double switchback near the base of Berthoud Pass. This area is characterized by over-steepened cut slopes and narrow switch-backs, leading to enhanced erosion and sedimentation on the highway. These improvements were enhanced by slope stabilization efforts utilizing erosion netting and rock scaling. Additional slope stability measures are prioritized under implementation scenario 3 (Section 8).

Additionally, three concrete basins were installed to contain sediments captured by the knee wall and pan drain. At the upper switchback (MP 238.0) a round catch basin was built with a diameter of approximately 100 feet and depth of 2 feet. This feature is used predominantly for snow storage at the current time. Two rectangular concrete catch basins with pan drains were constructed further down the double switchback near MP 237. These catch basins are both approximately 65 feet long x 20 feet wide and are equipped with sieved riser pipes and rundown drains. These treatment features help to mitigate erosion and sedimentation in this crucially steep segment of ROW. Improvements to the collection system are recommended in this SCAP to enhance sediment capture at existing treatment facilities. These are outlined in implementation scenario 3 (Section 8).

CDOT conducted slope stabilization work adjacent to Zero Creek on the north side of Berthoud Pass. In addition, the Forest Service and CDOT cooperated on a project at the north base of the Pass in the vicinity of the bottom switchback. This prevented snow storage immediately adjacent to the Fraser River and provided vegetative stabilization of the stream bank.

No other highway-related sediment source control work has been done on US 40 Berthoud Pass West.

2.0 EXISTING CONDITIONS

2.1 Climate and Hydrology

North of Berthoud Pass, US 40 traverses the headwaters of the Fraser River watershed in a north-south direction for approximately 10 miles through the SCAP study corridor. As previously stated, the study area also includes 1.3 miles of US 40 east of the summit of Berthoud Pass. The total highway distance within this combined study area is 11.5 miles. The upper Fraser River basin in the SCAP area is comprised of the tributary streams of Current, First, Second, and Parsenn Creeks on the west and Flora, Parry and Jim Creeks to the east. All of these tributaries join the mainstem of the Fraser River within the study area. To the south of Berthoud Pass the Hoop Creek tributary is part of the West Fork Clear Creek watershed.

The climate is temperate, with warm summers generally extending from May to September and cold winters from October to April. The corridor is classified as a high mountain continental semi-arid climate strongly influenced by elevation and aspect. Elevations across the study area range from approximately 11,315 feet mean sea level (ft-MSL) at the summit of Berthoud Pass to 9,500 ft-MSL at the mouth of Jim Creek and the south edge of the Town of Winter Park.

Altitude has the effect of changing temperature at a rate of 3.6 degrees Fahrenheit (°F) for each 1,000-foot change in elevation. At this rate a temperature of 36°F in Winter Park would correspond to a temperature below freezing (29°F) at the summit of Berthoud Pass. This temperature gradient is a major factor with respect to the operation and maintenance of US 40 within the corridor during the winter months, when ice and snow accumulation is prevalent.

The seasonal temperature and snowfall distribution in the town of Winter Park for period 1980-2010 is shown in **Figure 2-1** (Colorado Climate Center 2015). This data shows the temporal trend in mean temperature with below freezing conditions in winter (November to March) and maximum temperatures in July. The mean annual snowfall in Winter Park was 225 inches with a maximum of 371 inches recorded in 1983.

The elevation and season determine the form and temporal distribution of precipitation. Precipitation is dominated by rainfall during the summer months and snowfall during winter. Snow can remain on the predominantly north-facing slopes across the SCAP study area through the winter, while snow is removed from the highway to maintain safe mobility. The average annual snowfall on Berthoud Pass is 305 inches (CAIC, 1950-2005). The majority of precipitation is snowfall, creating mobility issues for vehicular traffic during winter. CDOT maintenance forces are required to remove snow from the highway to prevent the highway from being closed. Traction sand is applied to the roadway to maintain mobility.

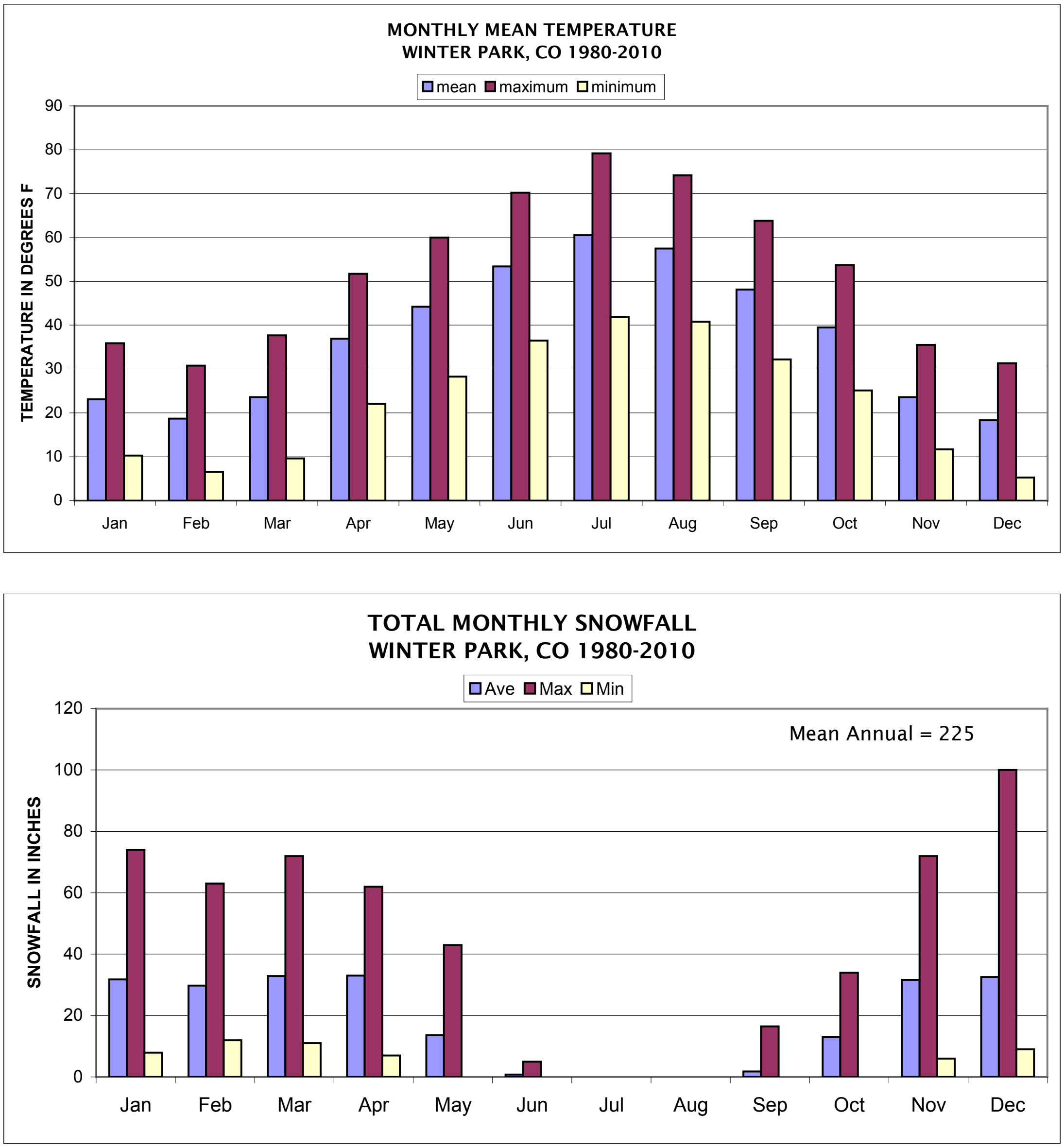
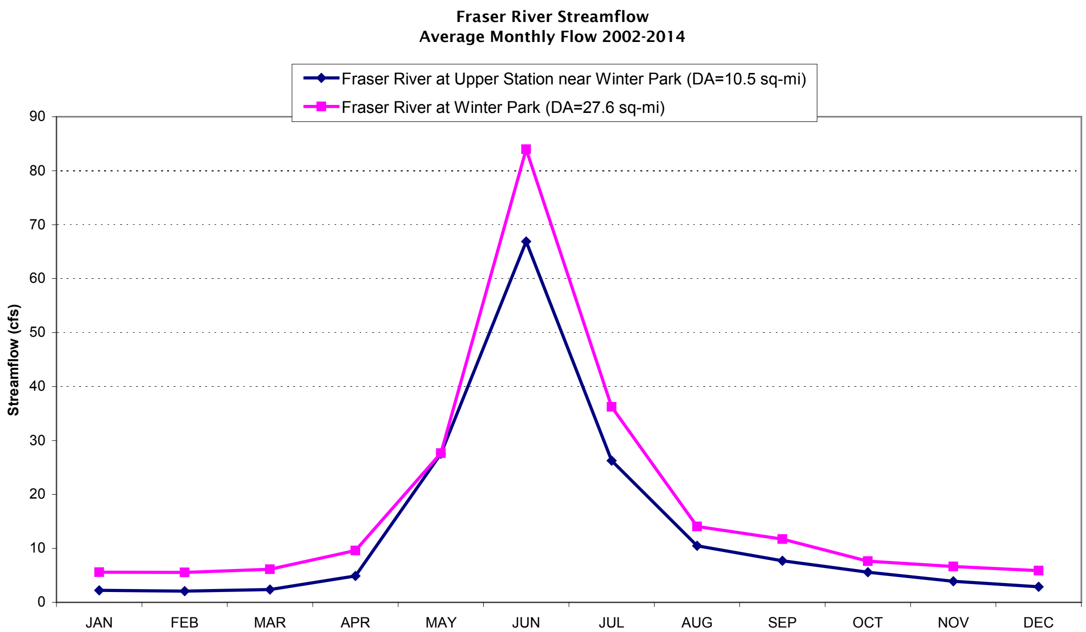


Figure 2-1. Winter Park Temperature and Snowfall

The seasonal precipitation pattern determines highway runoff and streamflow conditions in the study corridor. Other factors that can influence the natural hydrology include trans-mountain water diversions, storage reservoirs, and increases in impervious surfaces resulting from urban, commercial, industrial, and highway development. Snow that accumulates over the winter across the study area melts in the spring and early summer, generating peak flows in the Fraser River during June (**Figure 2-2**). Streamflow generally recedes over the mid-summer and fall, with increases resulting from rainfall-runoff events. Minimum flows occur in late fall and winter.



Source: USGS 2015

Figure 2-2. Fraser River Streamflow

2.2 Fraser River Diversion Sediment Basin Project

NWCCOG was the recipient of a 1997 EPA 319 Grant to coordinate and implement a project designed to reduce the sediment load in the upper Fraser River. After several years of delay, this developed into the Fraser River Diversion Sediment Basin Project as a joint venture between CDOT and Grand County, the local agency. CDOT and Grand County entered into an agreement by a Memorandum of Understanding (MOU) dated July 12, 2011 (CDOT 2011). The project is designed to facilitate the removal of sediment from the Fraser River in Grand County. All parties to this agreement find it mutually beneficial to cooperate on the removal and disposal of the sediment from the Fraser River Settling Basin (MP 234.2), located on National Forest property but under easement by the City and County of Denver Board of Water Commissioners (Denver Water).

Approval, clearance and coordination for the project have been accomplished from and with appropriate agencies, including the Fraser River Nonpoint Source Pollution Control Intergovernmental Agreement (IGA) between the State, Denver Water, Town of Winter Park, the United States Department of Agriculture (USDA) Forest Service (USFS), US Army Corp of Engineers, Colorado Parks and Wildlife, and the Grand County (DWB 2011).

Under the IGA the Fraser River Settling Basin has been modified to allow for removal and transport of sediment by CDOT. Annual maintenance allows for the capture and removal of traction sand and other sediments collected in the basin and an adjacent wetland mitigation site. Construction was carried out by Denver Water in cooperation with CDOT.

A number of years of sampling traction sand from the highway shoulders and sediment traps on US 40 have demonstrated that this material is not hazardous and/or high in salt content, although these materials contain somewhat elevated amounts of oil and grease. All material collected from the basin meets containment limits suitable for unrestricted use (Residential) as specified in the Colorado Soil Evaluation Values (CSEVs) for soil cleanup. Results indicate that most of the sediment collected in the basin consists of native geologic material derived from erosion processes.

Each year in the fall, CDOT removes approximately 500-700 tons (400 cubic yards) of sediment from the Fraser River Diversion Sediment Basin. The first successful removal effort was in 2013. Removal amounts over the past three years are shown in **Table 2-1**. Sediment is hauled to a disposal site in Grand County as agreed upon in the IGA. Water supply treatment operators downstream of the sediment basin have noticed a substantial improvement in the quality of the water, and trout populations are showing signs of recovery.

Table 2.1. Fraser River Sediment Basin Material Amount Removed by Year

Year	No. of Tandem Loads	Tons	Cubic Yards
2013	68	680	453
2014	69	700	467
2015	52	520	347

Source: CDOT 2016

3.0 ENVIRONMENTAL CONSIDERATIONS AND REQUIREMENTS

3.1 Water Quality

Under the federal Clean Water Act of 1977 (CWA), as amended by the Water Quality Act of 1987, the Environmental Protection Agency (EPA) established a framework for protecting and improving the nation's water quality. The broad purpose of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". Its emphasis is to declare unlawful the unregulated discharge of pollutants into all waters of the United States. The CWA makes the States and EPA jointly responsible for identifying and regulating both point and non-point sources of pollution. Point sources are controlled by a permit-based system (water quality standards), while nonpoint sources are approached with a technology-based management strategy (treatment processes and best management practices).

Each state is required to develop and adopt water quality standards that enumerate the designated uses of each water body as well as specific criteria necessary to protect or achieve those designated uses. The Colorado Department of Public Health and Environment (CDPHE), Water Quality Control Commission, Colorado Revised Statutes (C.R.S.) 1973, 25-8-101, as amended, promulgates regulations specifying classifications and numeric water quality standards for Colorado by river basin.

The US 40 Berthoud Pass West corridor is in the Upper Colorado River Basin while the Berthoud Pass East corridor is in the South Platte River Basin, as defined by CDPHE. Water quality is regulated for the Upper Colorado under Regulation No. 33 and for the South Platte under Regulation No. 38 (CDPHE 2015). Each river basin is divided into regions related to watershed divisions and water bodies are further divided into stream segments according to waste load allocations. Within the SCAP study area, the Fraser River and its tributaries fall within Segment 10a of Region 12. Hoop Creek and its tributaries fall within Segment 6 of Clear Creek Basin.

Surface waters of the state are classified according to the uses for which they are presently suitable or intended to become suitable. At a minimum, for all state surface waters existing classified uses and the level of water quality necessary to protect such uses must be maintained and protected. No further water quality degradation is allowable which would interfere with or become injurious to these uses. The classified uses shall be deemed protected if the narrative and numerical standards are not exceeded (CDPHE 2015). The designated use classifications for study area stream segments are listed in **Table 3-1**. Numeric water quality standards apply for protection of these designated uses.

Table 3.1. Stream Use Classifications

Stream Segment Description	Water Supply	Aquatic Life Cold 1	Recreation	Agriculture
Fraser River (Segment 10a)	X	X	X	X
Hoop Creek (Segment 6)	X	X	X	X

Colorado Water Quality Control Commission Policy 98-1 provides guidance for implementation of Colorado's narrative sediment standards, as they apply to sediments that may form deposits detrimental to the beneficial uses. The Basic Standards and Methodologies for Surface Water, Regulation 31 (5 CCR 1002-31) ("the Basic Standards"), are the basis for establishing this guidance.

The narrative sediment standard states that "State surface waters shall be free from substances attributable to human-caused point source or nonpoint source discharge in amounts, concentrations or combinations which; for all surface waters except wetlands; can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud."

The Fraser River is included on Colorado's Section 303(d) List as impaired for aquatic life with a low priority (CDPHE 2016). The Water Quality Control Commission's provisionally listed the Fraser River, as "there is currently no water quality data (for a water quality pollutant of concern) available to indicate impairment." The Commission anticipates that the Division will collect additional data for upper Fraser River segments to continue the investigation into potential sources.

The West Fork Clear Creek downstream of Hoop Creek is included on the Section 303(d) List as impaired for copper. Several other lower Clear Creek segments have been identified as water quality impaired for metals related to historic mining.

Stream segments identified as impaired are those in which one or more classification or standard has not, or may not be, fully achieved. As necessary for the protection of the water resource, Total Maximum Daily Loads (TMDLs) are established to set the maximum amount of pollutant that may be allowed while still complying with water quality standards. TMDLs are implemented and regulated through the issuance of permits for point sources (such as wastewater treatment plants) and the use of BMPs for nonpoint sources such as highway runoff. Sediment from any source is considered a nonpoint source pollutant if deposited in amounts determined to be detrimental to aquatic life.

3.2 Wildlife

The Berthoud Pass West SCAP study area is located in the Winter Park Geographic Area of the Arapaho and Roosevelt National Forests encompassing habitat for a variety of wildlife. The amount of primarily undisturbed terrestrial habitat buffered from motorized and non-motorized travelways, including US 40, results in a habitat effectiveness on Berthoud Pass of 70 percent (USFS 2012).

The study area falls within the Berthoud Pass Linkage Zone, serving as a migratory path for the Canadian Lynx to travel from the Mosquito Range in central Colorado to the Front Range in northern Colorado (Ivan 2012). The Berthoud Pass Geographic Area, which encompasses primarily the east side of the pass but does not differ dramatically in ecosystem type, is considered important habitat for big horn sheep, boreal toad, lynx, and possible Wolverine (USFS 2012).

A USGS 1976-1977 study found that the Fraser River near its headwaters was relatively unproductive, with a diversity index of 1.50 for aquatic organisms (USGS Open File Report 79-420, 1979). Downstream sites had the most organisms collected and similar diversities at about 2.80. The riparian areas and drainages that create the headwaters of the Fraser River have the ability to support populations of Colorado River Cutthroat which often occupy small isolated patches of high elevation drainages (Hirsch 2010).

A 1996 study performed by the USFS showed negative impacts on the Fraser River due to sedimentation from highway sanding practices and erosion on US 40 Berthoud Pass, resulting in effects on fish populations (Apodaca 1999). In addition, the Fraser River was designated as Class III (non-functional) by the USFS in their watershed condition class assessments due to excessive sediment loading. This excessive sediment deposition is expected to have detrimental effects on fish populations by reducing stream pool depths, changing stream channel morphology, and degrading spawning habitat (USFS 1997).

Electrofishing surveys performed by Colorado Parks and Wildlife (CPW) directly downstream of the SCAP study area show populations of mottled sculpin, rainbow, brown, and brook trout (Ewert 2016). However, there were no fish population studies identified for the SCAP study area upstream of Winter Park Resort.

The fish population estimates downstream of the SCAP study area vary depending on sample location. The CPW Fraser River report (Ewert, 2016) covers five fish sampling locations. The Fraser River at Safeway location (in Fraser) has the longest and most consistent history of surveys (2006-2016). The report shows that all subsequent sampling occaisions have produced trout population estimates that are greater than 2006. The period of 2013-2016 saw the highest brown trout biomass.

The Fraser River at Idlewyld Campground location (near Winter Park) has only two fish survey years (2014 and 2016). The report states that "Every parameter of the trout population listed in this table experienced significant declines in 2016. Because this station was a new location surveyed for the first time in 2014, it is impossible to know which of the two years is out of the ordinary. It is possible that the 2016 data reflects a return to “normal” fish densities for the site and that 2014 happened to be a particularly productive year."

The report also states that "This reach has been the recipient of multiple discharge events in recent years that originate from the Moffat Tunnel. High levels of turbidity have occurred and CPW has received multiple reports from the public and other entities. While we have not observed a direct fish kill as a result of these events, this data appears to provide at least circumstantial evidence of some level of environmental stress or disturbance on the trout population here."

In addition, water that is diverted to the eastern slope through the Denver Water Board's Fraser River Diversion reduces the flushing flows needed to support a healthy fishery and impedes the rivers ability to redistribute sediment.

3.3 Historic Cultural Resources

FHU on behalf of CDOT has conducted a file search through the Office of Archaeology and Historic Preservation (OAHP) Compass database to determine whether any previously recorded National Register of Historic Places (NRHP) eligible or listed properties were located within or adjacent to the Berthoud Pass SCAP study area.

A file search through the OAHP Compass database indicates that two intensive-comprehensive cultural resource surveys were conducted in the Berthoud Pass SCAP study area in the past. These two cultural resource surveys were utilized as a reference for this Compass database search, and include:

> *Hunter, Carol C. (2007) Archaeological Assessment of the Berthoud Pass Research Corridor for Universal Design, Clear Creek and Grand Counties. Report prepared by Partners for Access to the Woods. (Report #MC.SHF.R182)*
>
> *Struthers, Sue. (2005) Cultural Resource Inventory for the Berthoud Pass Trailhead Arapaho and Roosevelt National Forest, Clear Creek and Grand Counties. (Report #MC.FS.R372)*

Review of these two previous cultural resource surveys in conjunction with additional review of potential sites in the Compass database revealed seventeen (17) previously recorded historic cultural resources located within the Berthoud Pass SCAP study area. These include four (4) bridges, one (1) retaining wall structure, eight (8) segments of the Empire-Middle Park Wagon Road, one (1) monument sign, one (1) historic site, one (1) ditch resource, and one (1) segment of the Victory Highway/US Highway 40. Sites located at the Berthoud Pass summit were recorded with two site numbers; one for Clear Creek County and one for Grand County since the pass defines the boundary between counties.

The file search includes areas within the Berthoud Pass SCAP study area as well as downhill adjacent areas that might be affected by excessive sediment produced from the erosion of existing highway road cut and fill areas. Sections 14, 23, 26, 34, 35 of T2S, R75W and Section 3, 10, 15, 16 of T3S, R75W in Clear Creek and Grand Counties.

Summary data regarding previously recorded historic cultural resources located within and adjacent to the Berthoud Pass SCAP study area are presented in **Appendix D**.

3.4 Drinking Water Supply and Source Water Protection

Water remaining in the Fraser River after the Fraser Diversion supplies in-stream flow and drinking water for a number of downstream communities including Winter Park. West Clear

Creek and Clear Creek supplies water to approximately 350,000 people in the Denver metropolitan area, supports numerous industries, and supports a brown trout population.

3.4.1 Town of Winter Park/Fraser River Source Water Protection

CDPHE has completed a source water assessment for the Town of Winter Park Water and Sanitation District (Public Water System Identification [ID] CO0125843), as well as a number of other water providers in the upper Fraser River watershed. This is required by the 1996 Safe Drinking Water Act amendments and in accordance with Colorado's Source Water Assessment and Protection (SWAP) program. The SWAP program is a multi-step two-phase process designed to assist public water systems in preventing accidental contamination of their untreated drinking water supplies. These phases include the assessment phase and the protection plan phase.

The purpose of the assessment is to analyze the potential susceptibility of each public drinking water source to contamination, and to supply pertinent information so that decision-makers can voluntarily develop and implement appropriate preventive measures to protect these water sources. The Safe Drinking Water Act (SDWA) requires that the public water system and its consumers be informed of the assessment results. A final CDPHE source water assessment report titled: An Assessment of Surface Water Sources and Groundwater Sources under the Direct Influence of Surface Water for the Town of Winter Park, Colorado was issued on November 8, 2004 (CDPHE 2004).

The subsequent development and implementation of source water protection plans provides an additional level of protection for the drinking water supply. Extensive changes in drinking water regulations have occurred over the past 20 years. These changes make compliance with the requirements of the SDWA and the CWA much more difficult. Protection of source water quality is becoming increasingly critical in order to protect public health, avoid increased treatment costs, prevent aesthetic water quality problems such as taste and odor events, and to meet new regulatory standards.

At the time of the writing of this SCAP, the following water providers - Winter Park Water and Sanitation District, Denver Water, Town of Fraser, Grand County Water and Sanitation District #1, Town of Granby North Service Area, Town of Granby South Service Area, Moraine Park, and Winter Park Ranch Water and Sanitation District - are actively developing a joint Source Water Protection Plan in the Fraser River basin between Winter Park and Granby. A grant awarded by the CDPHE in the fall of 2015 will fund the development and implementation of this work. The Berthoud Pass west SCAP study area is directly adjacent to and south of this proposed source water protection zone. The findings of this SCAP will benefit the Storm Water Pollution Prevention Plan (SWPPP) effort. Additional CDPHE source water assessments in the vicinity of the study area, including the Town of Fraser (Public Water System ID CO0125288) located approximately 10 miles north of Winter Park on US 40, have been issued and are predominantly concerned with groundwater resources.

4.0 CDOT MAINTENANCE PROGRAM

Roadway maintenance personnel are responsible for maintaining the operational capability of the highway system. The purpose of highway maintenance is to preserve and keep all roads, roadsides, structures, and miscellaneous facilities in as close to their original or improved condition as possible. The maintenance employee's primary duty is to keep all highways that are open to traffic in a safe and usable condition, as available resources allow.

In Colorado, snow and ice control is the highest priority of all the maintenance activities in order to protect the safety of the traveling public. The operational capability of a highway system can be greatly diminished by such things as roadway surface deterioration, snow and ice, poor lighting, and inadequate lane demarcation.

Within CDOT, the state is divided into six engineering regions and nine maintenance sections. Each engineering region has project development (pre-construction and construction) responsibilities and maintenance sections. Engineering Region 3 encompasses US 40 west of Berthoud Pass and Region 1 encompasses the east side of Berthoud Pass.

The Maintenance Sections are further divided into Foreman Areas and each Foreman Area is divided into work groups called patrols. These patrols perform maintenance on specific roadway sections. This SCAP includes two patrols: Patrol 39 extending west from the summit of Berthoud Pass; and Patrol 40 extending east from the summit.

Public pressure is being placed on the CDOT maintenance to meet customer needs with increased traffic volumes, limitations on resources, and greater expectations. Not only does US 40 contain some of the most heavily traveled portions of the highway system within the state, these personnel maintain the roadway network that service some of the most popular ski areas in the state during the winter months.

The routine maintenance of the US 40 corridor has focused primarily on maintaining the roadway surface. When US 40 was constructed, the higher level of maintenance work needed to meet the growing needs was not anticipated. Public expectations for maintaining the highway to a certain level have increased substantially since the completion of US 40. The scenarios presented in this SCAP would require substantial additional resources for roadway maintenance in order to provide the same level of service to the traveling public.

4.1 Maintenance Activities and Funding Mechanism

Maintenance personnel are responsible for a number of tasks and activities. These activities are divided into Major Program Areas (MPAs) and are funded according to established targets. CDOT uses a system of budgeting for maintenance based on Maintenance Levels of Service (MLOS) and MPAs. The Transportation Commission has established targets for the level of service for each MPA. The target rating drives the funding for the activities in each MPA. The rating ranges from "A+" being the top of the scale to "F-" being the bottom. For example, if an MPA is targeted at an A level of service it will receive more funding than if it is targeted at a C level of service.

Maintenance equipment, building maintenance, and sand shed allocations are managed separately. Routine maintenance activities under the current MLOS program will continue to be accomplished with existing personnel. The Maintenance MPAs are further defined below:

- **Snow & Ice Control** – Snow removal, traction application (sanding & deicers), ice control, snow fence maintenance & repair, avalanche control, chain station operations, snow removal (special equipment), etc.
- **Roadway Surface** – Patching, seal coating, blading, restoring shoulders, crack sealing, etc.
- **Traffic Services** – Maintenance and installation of signs and guardrail, and pavement striping, etc.
- **Roadside Facilities** – Maintenance of drainage structures, maintenance of ditches, slope repair, litter & trash clean-up, mowing, sweeping, sound barrier maintenance, etc.
- **Roadside Appearance** – Vegetation control, bridge/structure maintenance & repair, maintenance of deck expansion devices, etc.

In order to track the management of maintenance expenditures, CDOT's SAP computer tracking system is used statewide by each CDOT Region. The SAP computer program is designed to track materials, equipment, and labor expended on highway maintenance activities. This system provides information regarding the efficiency and effectiveness of resources, and is used to plan for activities and associated future costs. With this system, field personnel report their maintenance activities and inventories, which are then entered into a computer database.

Although sand cleanup can fall into many MPAs, such as Traffic Services for guardrail work or Roadway Surface for ditch cleaning, the majority of the environmental cleanup work falls under the Roadside Facilities MPA. Roadside Facilities typically includes mowing, fence repair, litter and debris control, sweeping, drainage structure maintenance, rock runs, slope repair, and streambed maintenance. These are considered routine maintenance activities.

Maintaining BMPs, collecting and hauling material, and data collection and reporting are all part of the environmental requirements, but these are not considered routine maintenance activities. Implementation of this SCAP as a part of "routine" operations within the context of the activities performed by maintenance personnel would require an entirely new focus and prioritization of maintenance operations under MLOS. In order to accomplish this, the extra work must be fully integrated into the maintenance program.

The clean-up of sand and sediment from the highway corridor is conducted through ditch cleaning, cleaning beneath guard rail, sweeping, and other related activities as work designated under Roadside Facilities. The MLOS for Roadside Facilities has determined funding levels for this program area, including sand clean-up and other "environmental-related work" such as erosion and drainage control, constructing boreal toad habitat, maintaining sediment ponds, collecting and reporting data, and other similar activities.

The MLOS system was implemented largely to improve accountability and is tied to the annual budgeting process. Maintenance funds are limited since they are made up entirely of state funds and must cover a wide variety of activities within a given maintenance area. Winter operations to maintain the safety of the traveling public and the roadway surface remain two of the highest maintenance priorities where large portions of the funds are allocated. Maintenance staffing, equipment needs, and annual maintenance priorities are established by CDOT management, the Transportation Commission and state law, and are all tied closely to the MLOS system.

The relatively new environmental-related maintenance activities, such as additional sand cleanup beyond the routine work and implementing and maintaining source controls, were not funded or accounted for prior to Fiscal Year (FY) 2007. However, there is no new source of funding nor have changes been made in the MLOS to provide additional resources for addressing these environmental components. The demand placed on existing maintenance forces to meet the full responsibility of the maintenance activities alone is worth noting. For maintenance personnel, it is an additional burden on their already taxed resources to address these relatively new environmental concerns, which is additional labor intensive work that can require specialty equipment and is expensive.

CDOT and other stakeholders are working to increase the level of sediment control and cleanup, particularly in the I-70 mountain corridor, but in others as well. On US 40, maintenance is required to address sediment related and water quality related problems that exist on Berthoud Pass from Empire to Winter Park. A more extensive maintenance program is needed to continue to make progress in addressing highway-related water quality issues.

The majority of the roadway surface treatments such as paving and seal coating are done in July and August when temperatures for these activities are optimum. Shoulder and ditch cleaning, and rock removal are performed primarily during May, June and September. Snow begins falling in September and roadside work becomes very sporadic in October. Additionally, maintenance must repair safety devices, perform structure work, slope repair, vegetation management, and many other required activities within the short summer months. The options for maintenance are large increases in overtime, adding full-time employees, or contracting out more maintenance related work such as paving or sand clean-up.

The maintenance patrols make an effort to sweep after snow events whenever possible during winter, spring and summer operations. Due to lack of specialized equipment, adverse weather conditions, and extreme temperature fluctuations during late winter and spring, it is often not possible to sweep after every storm event. Since snow and ice control is the highest priority for maintenance crews, they must respond quickly. When snowstorms are predicted, the affected patrols are preparing for adverse weather conditions by making sure all snow removal equipment is in good working order, important safety matters are addressed, and existing snow is pushed back to ensure adequate room for additional accumulations.

With the current allotment of funds in the maintenance budget for this work, maintenance forces can continue to maintain the shoulders, ditches, drainage structures, and eroded areas to the extent possible, but are typically unable to undertake more activities.

In order to accomplish what is being requested of maintenance forces during the summer months to clean-up sediment material, maintain BMPs, and other environmental-related activities along the US 40 corridor, the maintenance program may require a new approach and philosophy regarding maintenance priorities and responsibilities. To be effective, sediment control needs to receive a high priority under the MLOS program during the summer months, as snow and ice control is during the winter months. Responsibilities within the current MPAs would need to be expanded to include resources for accomplishing these additional activities.

4.2 US 40 Maintenance Material Clean-up

CDOT maintenance forces are actively involved in meeting MLOS requirement for sediment control. Each year, a portion of the traction sand and sediment is removed from the roadway by sweeping, culvert maintenance and cleaning, and ditch cleaning. The amount of material removed by Patrol 39 from US 40 Berthoud Pass West between MP 233 and 243 (10 miles) is listed by FY in **Table 4-1**.

Table 4.1. US 40 Berthoud Pass West Sand/Sediment Removal Data Summary

Period	Milepost Range	Removed Sand/Solids (T)	Removed Sand/Solids (CY)
FY 2008	233-243	9,024	6,016
FY 2009	233-243	91	61
FY 2010	233-243	707	471
FY 2011	233-243	119	79
FY 2012	233-243	597	398
FY 2013	233-243	675	450
FY 2014	233-243	1,300	867
FY 2015	233-243	3,247	2,165

Source: CDOT 2015

In summer 2015, CDOT contractors removed 4,361 cubic yards (6,542 tons) of historic sediment deposits stored behind guardrails on Berthoud Pass. This effort covered 23,550 linear feet or 4.46 miles of guardrail.

5.0 BMP ANALYSIS FOR SEDIMENT CONTROL

This section provides information on reviewed literature and highway impact studies, sediment control BMPs, sediment sources, annual traction sand volume estimates, sediment control strategies, drainage review, a menu of sediment control BMPs, and proposed BMP summary and costs for the Berthoud Pass study corridor. The BMPs proposed in this SCAP were developed based on previous CDOT experience and research in implementing roadway BMPs at high altitudes.

It is important to note that this is a planning level document only. Further site-specific analysis, design, and cost estimates will be required prior to implementation of specific sediment control measures. Four potential implementation scenarios have been developed and summarized in Section 7. Detailed design and costs will need to be developed prior to implementation of any of these scenarios.

5.1 Literature Review

The following is a synthesis of reviewed literature.

5.1.1 Environmental Effects of Traction Sand and Chemical Deicer

The environmental effects of highway traction sands and deicers have long been a concern. Excessive highway sands and roadway embankment erosion can clog streams, bury habitat, and asphyxiate fish eggs and benthic macro invertebrates (CDPHE 2014). Excessive sediment with particle sizes less than 2 millimeters (mm) blocks the movement of oxygen into stream substrates and harms the reproduction of aquatic species which lay eggs in these streambeds.

Chemical deicers may also build up in streams with low flows, in wetland areas, in the soil, and in groundwater (CDOT 2013). CDOT studies in the I-70 mountain corridor have shown that in-stream chloride concentrations can exceed water quality standards from roadway salt (CDOT 2015). The long term chronic effects of environmental salt build up are concerning but are not entirely understood. These findings suggest that the impacts of chloride-based deicers may be watershed specific, based upon the specific hydrology, loading rates, and aquatic species present in the basin.

Most of the chemical deicers in use are chloride-based and soluble in water; as a result, they are transported quickly with water and are quite difficult to remove in solute form. On the other hand, traction sands can be removed relatively easily with sedimentation and tend to accumulate near roadways and in the beds of receiving streams.

Two non-environmental issues associated with chloride salt usage which are also concerning are the contamination of subsurface drinking water supplies and the corrosion of vehicles and infrastructure caused by road salts.

5.1.2 Highway-related Stream Impact Studies for Adjacent Mountain Corridors

Studies have been conducted and monitoring results evaluated for adjacent mountain highway corridors, as described below.

5.1.2.1 Berthoud Pass East – Hoop Creek

Phases 1 and 2 of the US 40 Berthoud Pass East reconstruction project were completed by CDOT in 2002-2003, while Phase 3 was completed in 2006. This project covered east Berthoud Pass from MP 244.3 (1.3 miles east of the summit) to MP 249 at Berthoud Falls. This area falls mostly within the Hoop Creek watershed which is tributary to West Clear Creek. Hoop Creek water quality was monitored and evaluated by CDOT from 1997 to 2009 pursuant to the requirements of an Environmental Assessment and Section 404 Permit for the Berthoud Pass East reconstruction project (D&M/JFSA 1997). No sediment control BMPs have been implemented between the summit and 1.3 miles east of the pass.

Traction sand and salt from highway operations is transported in surface runoff into Hoop Creek and its tributaries, increasing contaminant loading and degrading aquatic habitat. The purpose of the monitoring was to assess the effects of US 40 winter maintenance operations and improvements associated with implementation of BMPs on stream water quality along Berthoud Pass East. Monitoring data was evaluated and presented in annual reports through 2009 (CDOT 2010).

Water quality data were collected in the Hoop Creek drainage from 1997 to 1999 to define pre-construction conditions. Data collected from 2001 through 2006 generally represented the construction phases of the project. Permanent sediment control structures were installed as part of the new highway design. The effectiveness of these permanent BMPs was evaluated with respect to highway maintenance and stream sediment loading.

Post-construction maintenance BMP data indicated that approximately 50 to 60 percent of the traction sand applied to Berthoud Pass East in the project area was captured and removed, a substantial improvement from previous years. A maintenance plan titled "East Side Berthoud Pass US Highway 40 BMP Maintenance Manual" was developed in 2005 that serves as a guidance document for winter and summer maintenance operations as they relate to highway sanding and sediment control (CDOT 2005).

Continuous recorded turbidity data collected from 2002-2009 was used to predict suspended sediment loading in Hoop Creek by establishing a robust correlation between suspended sediment and turbidity. Sample data showed a continuing trend of lower suspended sediment concentrations in Hoop Creek tributaries, with the exception of the Berthoud Pass Ditch branch.

The total sediment load in Hoop Creek was generally correlated with May-June rising snowmelt flows when higher sediment transport takes place (**Figure 5-1**). Higher Hoop Creek flows during this period were caused by inflows from the Berthoud Pass Ditch trans-mountain diversion. Ditch flows typically comprised 40 to 70 percent of the flow in Hoop Creek, but can comprise over 80 percent of the Hoop Creek flow. The higher sediment loads measured in 2007 were not primarily associated with greater snowmelt flows, but instead were largely related to discharge from the trans-mountain diversion and associated stream channel erosion (CDOT 2010). CDOT and the City of Northglenn are continuing coordination to address sediment in this area resulting from trans-mountain diversion as well as traction sand.

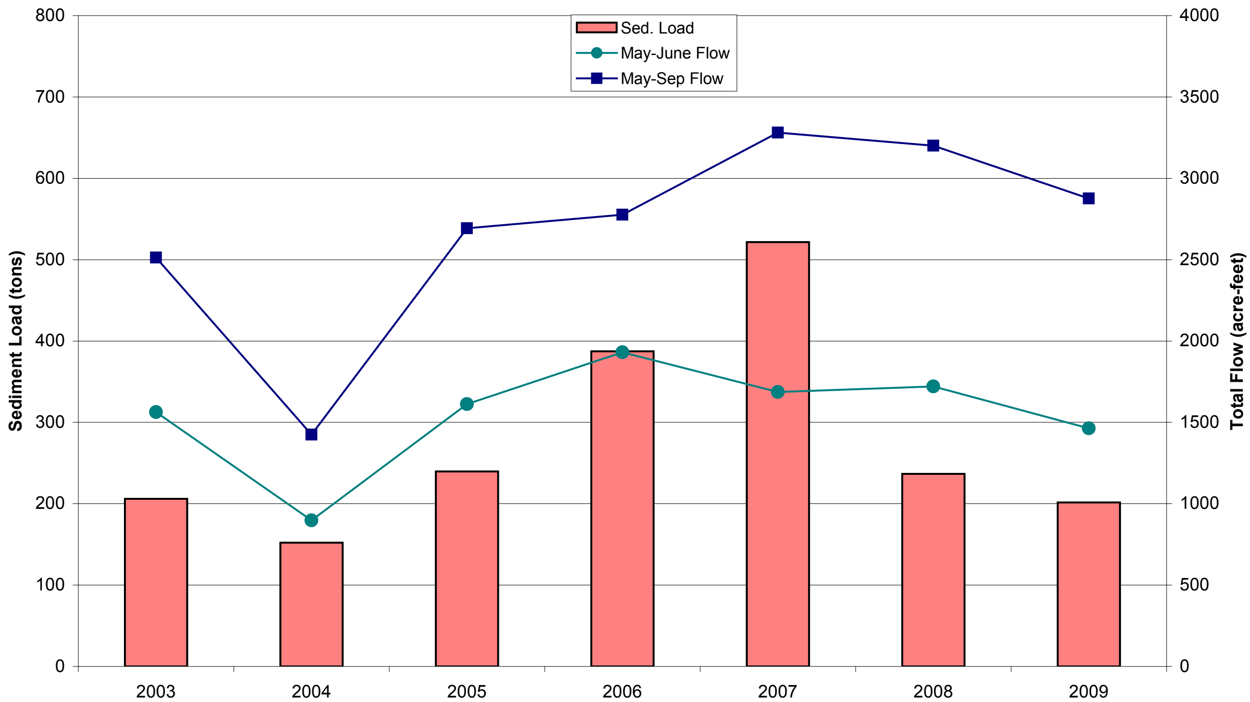


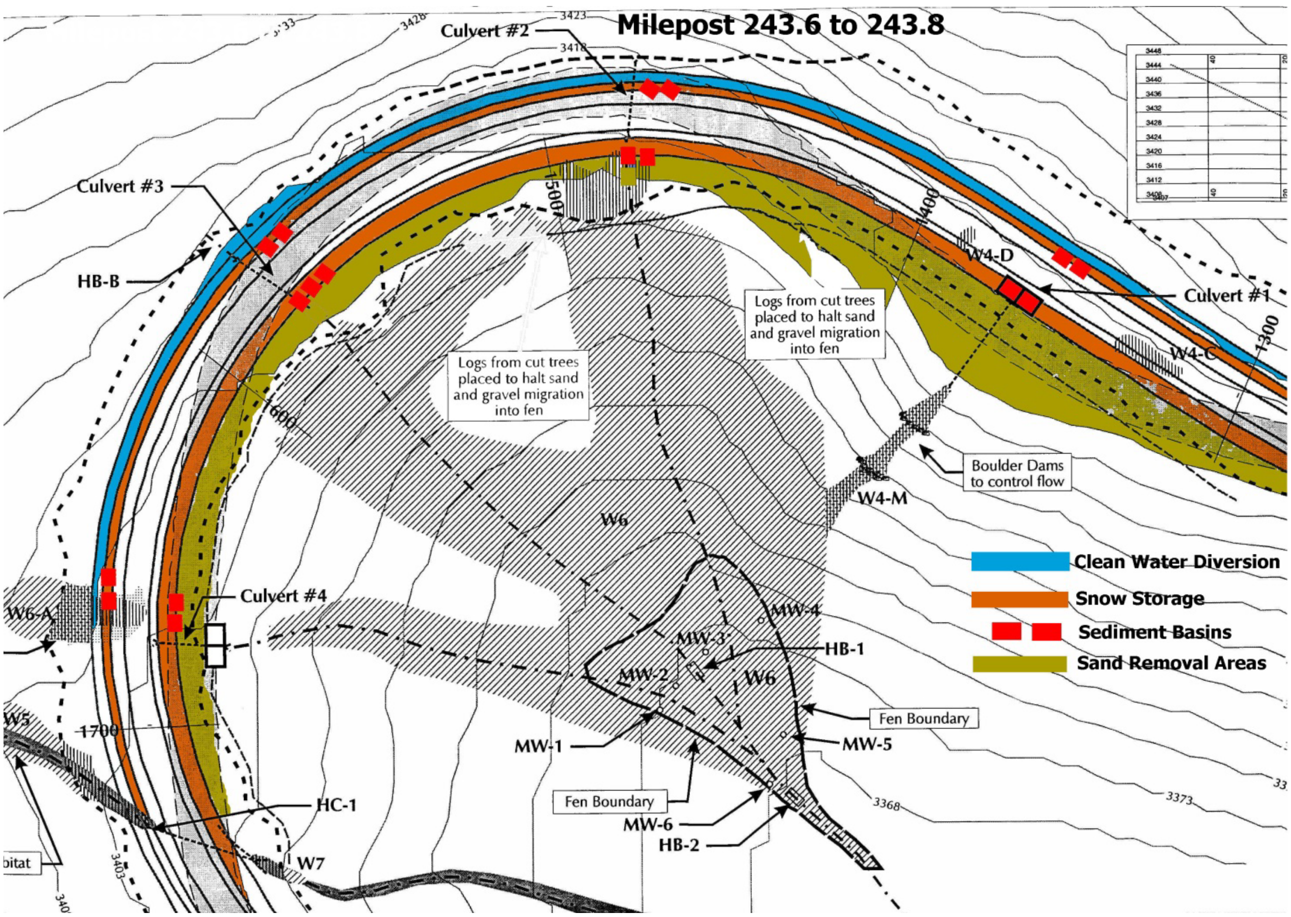
Figure 5-1. Hoop Creek near Mouth (HC-5)
Total Sediment Load and Flow (2003-2009)

Hoop Creek specific conductance (a measure of dissolved salt concentration) was elevated approximately one order of magnitude higher than background tributaries in the Hoop Creek watershed, especially during the winter and early spring. Salt concentrations consisting primarily of sodium-chloride were elevated in Hoop Creek and in the Horseshoe Bend Fen from the use of sand/salt mixtures associated with winter highway maintenance. A robust positive correlation was established between chloride and specific conductance for the Hoop Creek watershed using regression analysis. Results showed a trend of higher stream chloride concentrations along with an increased frequency of standard exceedance in Hoop Creek (CDOT 2010). Both ambient and runoff event dissolved metal concentrations (copper, manganese, zinc) were low or below detection limits in Hoop Creek samples throughout the study.

The Horseshoe Bend Fen, located beyond the 2006 project area near MP 243.5 but part of this SCAP, was monitored as part of the Hoop Creek water quality study. The fen showed a seasonal variation in groundwater-surface water interaction, with a decreasing trend in groundwater levels in some areas. The ground surface elevation increased in several areas of the fen as a result of traction sand deposition. This modified the hydrology by lowering the groundwater table and drying-out certain areas of the fen, which will alter the vegetation type over time.

5.1.2.2 Summary of 2007 SCAP for Horseshoe Bend Area

As part of the phased multi-year 4.7-mile reconstruction project on Berthoud Pass East (MP 244.3 to 249), an Environmental Assessment (EA) was conducted to address potential impacts. A wetlands fen was identified during the EA downgradient of the Horseshoe Bend area of US 40 near Berthoud Pass (**Figure 5-2**). Fens are considered unique in Colorado and are protected by the provisions of Section 404 of the CWA. The fen requires special protection measures during both construction and operation of the highway. Monitoring for hydrologic and water quality conditions in the fen was specified in Permit No. 199780633 issued to CDOT by the U.S. Army Corps of Engineers for the Berthoud Pass highway improvement project.



Source: CDOT 2007

Figure 5-2. US 40 Horseshoe Bend Sediment Control BMPs (2007)

Fen hydrology and water quality monitoring stations were established and parameters were measured in the fen, and in contributing upstream areas along the highway, prior to construction from 1997 through 1999 to define existing water quality and hydrologic conditions (D&M 1999). Two Parshall flumes and six shallow ground water well points were installed within the fen to monitor hydrologic conditions. Fen monitoring continued from 1997 to 2007 to provide data that documents hydrologic and water quality conditions, pursuant to monitoring requirements incorporated into the Hoop Creek Monitoring Plan.

Traction sand migrating downslope from US 40 and transported in ephemeral snowmelt flow channels has deposited in the fen. The sand deposition is causing an increase in the ground surface elevation (aggradation) within the fen (CDOT 2010).

A SCAP was developed in 2007, but has not yet been implemented, for the 0.2 mile Horseshoe Bend area of US 40 (near MP 243.5) for the following purposes:

1) Reduce sedimentation rates in the fen from highway sources
2) Maintain existing hydrologic conditions in the fen to support wetland function
3) Fulfill the fen protection requirements in the 404 permit

Recently re-constructed highway segments of Berthoud Pass East (1999-2006) have incorporated sediment control BMPs to reduce water quality impacts to streams and wetlands. The sediment controls outlined in the Horseshoe Bend SCAP (CDOT 2007) are similar in concept and employ some of the same structural BMPs recommended in this SCAP. These BMPs include paved snow storage zones draining to sediment basins, retaining walls to reduce slope erosion, separation of clean water to prevent contamination from roadway runoff, and a BMP maintenance program and schedule to ensure long-term success of the sediment controls. The proposed structural sediment controls for the Horseshoe Bend area of US 40 are described below and depicted on **Figure 5-2**.

There was no digital mapping of the Horseshoe Bend section of US 40 at the time the SCAP was developed in 2007. The base drawing used was originally developed for the EA but is no longer available electronically for editing. Mileposts used for the sediment control features are approximate, with the Horseshoe Bend SCAP area extending 0.3 mile from approximate MP 243.5 to 243.8.

The Fen receives substantial surface and ground water inflows from the entire radius of Horseshoe Bend (CDOT 2010). This inflow supports the hydrology required for fen development and maintenance. There are four cross drain culverts beneath the roadway that provide seasonal surface water flows into the fen at multiple locations as shown in **Figure 5-2**. It is critical that these flows remain intact at their present locations for maintenance of the fen hydrology. There are also ground water inflows throughout the Horseshoe Bend area that support the hydrology.

Clean Water Separation

The clean upslope surface water and ground water springs that report upgradient (cutslope side) of the roadway must be kept separate from the traction sand/roadway runoff to prevent sediment mobilization and transport into the fen. The areas of substantial clean water flows are shown in blue in **Figure 5-2**. With implementation of the Horseshoe Bend SCAP, this water would be collected behind a knee wall and piped in a drain tile into each of the four existing cross drains. Energy dissipation is required at each culvert outfall to prevent erosion of the fillslope. After dissipation, the clean water would be released into existing channels for conveyance to the fen. Small check dams may be required in the drainage channels to the fen to prevent channel erosion.

Snow Storage Zone
This area of Berthoud Pass receives substantial snowfall and the roadway requires frequent snow removal in winter. Maintenance forces need a controlled area to plow and store snow. The area on the inside radius of Horseshoe Bend (westbound lane) is sufficiently wide (8 to 16 feet) in most locations to provide snow storage (**Figure 5-2**). Large turnouts exist at MP 243.5 and MP 243.7 that are 20 to 50 feet wide. These shoulder areas would be paved with a pan that drains into sediment basins at each culvert inlet. Retaining walls with drainage pans/curb would be installed on the outside of the storage zone to prevent downslope migration of sand. Note: the current SCAP does not recommend these retaining walls.

The eastbound shoulder is relatively narrow ranging from 8 to 16 feet in most locations. This area would be paved with a pan drain and knee wall. Roadway drainage would be routed to sediment basins installed upstream of each of the four cross drain inlets.

Sediment Basins
Concrete sediment basins with outlet works would be constructed below grade, similar to other basins on Berthoud Pass East. The basins would be designed to capture and store 80 percent of the average annual traction sand applied to this segment of roadway. Where space is limited, multiple basins would be installed in series to obtain the necessary sediment capture volume.

Sand Removal Areas
Traction sand has accumulated on fillslopes and adjacent forested areas over many years. Some of this sand will require removal to prevent future downslope migration into the Fen. Construction of retaining walls to stabilize the fill slope areas will determine the amount of sand removal required. Note: the current SCAP does not recommend construction of these retaining walls.

Maintenance Work Plan
In order for the proposed structural sediment control BMPs to be effective, the snow storage zones must be utilized to the extent practical. Snow should not be cast over the outside guardrail and into the forest below. Following snowmelt in May, sand accumulated in the snow storage zones must be removed by sweeping. A portion of the sand deposited on the pan drain will be washed into the sediment basins by snowmelt runoff. However, a substantial amount of sand will remain in the storage zones that must be removed before rainfall runoff in June.

Sand should be removed from the sediment basins at least once annually in May or June following snowmelt runoff. The basins should also be inspected in September prior to the winter season to ensure sufficient capacity remains for winter storage.

5.1.2.3 Interstate 70 Mountain Corridor

Three streams along the Interstate 70 mountain corridor have been studied by CDOT to determine the impacts from I-70 on water quality. These include Clear Creek, Straight Creek (west approach to Eisenhower Tunnel), and Black Gore Creek (west Vail Pass).

Total suspended solids (TSS) and phosphorus concentrations were low in I-70 study streams during ambient (non-runoff) conditions. High concentrations were measured during storm event/snowmelt conditions in I-70 highway runoff samples and in streams receiving highway runoff (CDOT 2015). This was particularly true at higher elevations of the corridor where more traction sand is used and erosion rates are higher.

Stream data indicate sediment transport is occurring as a result of both snowmelt and rainfall runoff processes. Data shows a strong correlation between turbidity and suspended sediment in each of these streams. The use of continuous recording in-stream turbidity probes has provided detailed information on sediment transport mechanisms and volumes.

The primary source of TSS at higher elevations is traction sand deposits along I-70 that are mobilized and transported into streams by snowmelt and rainfall runoff. Rill and gully erosion along I-70 cut/fill slopes and at culvert outfalls also increases sediment transport from the disposal of highway runoff. Elevated TSS loading associated with I-70 runoff is widespread throughout the study corridor, including Eagle, Summit, Clear Creek, and Jefferson Counties. Results indicate that sediment control BMPs would be effective and measurable if applied at the highway source to reduce sediment erosion, transport, and channel deposition. This condition can be remedied through effective highway sediment control BMPs (CDOT 2002).

The I-70 study sample results show elevated chloride concentrations in both highway runoff and in stream runoff samples when compared to background conditions (CDOT 2015). Sodium-chloride concentrations in highway runoff were generally higher during snowmelt conditions when compared to rainfall-runoff. The source of elevated sodium-chloride is rock salt used in traction sand for winter highway maintenance. Magnesium-chloride concentrations were lower than sodium-chloride concentrations in receiving stream samples.

A strong positive correlation exists between specific conductance and chloride in the I-70 study streams (CDOT 2015). Results demonstrate that stream conductance can be used to predict chloride concentrations with a high degree of accuracy. Continuous recording conductivity probes installed at stream monitoring stations are providing a low cost method of monitoring stream dissolved salts conditions year round.

Streams receiving runoff from I-70 respond by exhibiting elevated chloride concentrations above background levels, particularly during winter and early spring. In-stream chloride concentrations can exceed water quality standards in upper Clear Creek, Straight Creek, and Black Gore Creek under these conditions. As the type and quantity of I-70 deicing compounds change over time, the chloride loading in these streams will respond with higher or lower levels. There has been an increasing trend in chloride concentrations and loads in I-70 study streams in recent years, with the exception of Black Gore Creek which shows a decreasing trend.

5.1.2.4 Summary of Interstate 70 SCAPs

An I-70 SCAP for Clear Creek was completed and published in 2013 while SCAPs for Black Gore Creek and Straight Creek were both published in 2002. The Clear Creek SCAP covers 33 miles from the Eisenhower-Johnson Memorial Tunnel to Floyd Hill. Black Gore Creek flows northwest along I-70 for 8 miles from Vail Pass until it joins with Gore Creek east of Vail. Straight Creek flows west from the Eisenhower-Johnson Memorial Tunnel along I-70 for 8 miles to its confluence with the Blue River in Silverthorne.

The primary focus of the Clear Creek SCAP was sediment control and maintenance of related BMPs that are designed to capture the sediment before reaching Clear Creek (CDOT 2013). It was documented that total phosphorus and total metals associated with sediment can also be controlled with adequate BMPs. Dissolved salts related to I-70 cannot be easily mitigated by conventional sediment control BMPs. However, retention of salt-laden runoff in control structures will also reduce direct salt loading to Clear Creek.

The following primary sediment control measures were proposed for the Clear Creek I-70 corridor based on past research and experience in high elevation snowfall traction sanding areas in Colorado:

- Sedimentation basins and traps (ponding areas) to capture sediment
- Paving of shoulder areas to reduce rill erosion and provide a surface for cleaning
- Rundowns to control erosion from concentrated stormwater runoff
- Valley pan drains to store snow and sediment, and control and route highway runoff
- Knee walls to prevent cut slope erosion
- Curb and gutter to contain sediment on the paved surface and reduce migration of sediment directly onto fill slopes
- Controlled snow storage/sand deposition areas
- Revegetation program
- Maintenance BMPs
- Sediment Maintenance Program

In the Straight Creek SCAP it was documented that excessive sediment loading had been occurring over the thirty years of I-70 operation in the Straight Creek corridor (CDOT 2002). Sedimentation is caused by both cut and fill slope erosion and winter maintenance traction sand, when I-70 is sanded for traction to maintain safety for the traveling public. This material, collectively referred to as sediment, is transported into the natural environment from the I-70 ROW by surface water runoff, depositing into streams, lakes, and wetlands. Excessive sediment loading can impair water quality, increase nuisance nutrient concentrations, reduce fish habitat, and inundate wetland vegetation. This situation is largely due to inadequate sediment source controls and drainage along I-70.

The Black Gore Creek SCAP found that highway sanding and embankment erosion were damaging and destroying aquatic and riparian habitat. Even though Black Gore Creek can carry substantial sediment loads naturally (especially during spring runoff and summer rainstorms), sediment was accumulating in riparian and wetland areas. Sand deltas had also formed where highway runoff enters the creek. The SCAP identified six factors contributing to erosion and stream sedimentation:

- On-site soil loss from landslide areas
- Inadequate drainage control system
- Unstable cut and fill slopes
- Failure to establish and maintain adequate vegetation on disturbed areas
- Lack of adequate sediment control structures
- Ongoing traction sand loading from winter maintenance operations (CDOT 2002).

It emphasized the need for source controls to capture highway traction sands and recommended the use of snow storage areas and parallel snow storage to capture sediments from plowed snow before snowmelt is allowed to carry them downstream. It also recommended paving shoulders and routing runoff to treatment facilities - which work in combination with parallel snow storage. The report advocates slope repair and revegetation efforts, as they have been very successful in reducing sediment loading from other highway slopes on I-70 (CDOT 2002).

The focus of both the Straight Creek and Black Gore Creek SCAPs was related primarily to drainage improvements and sediment source controls along the highway. Both are planning documents that include relevant background information, an evaluation of I-70 sediment sources, sand volume estimates, hydraulic/drainage analysis, and maintenance practices to develop a source control strategy. Both structural and non-structural sediment control BMPs were proposed. To assist in the planning and decision making process, four implementation scenarios with cost estimates were developed: (1) Existing Maintenance Program (baseline); (2) Enhanced Maintenance Program; (3) Capital Construction and Maintenance Program; and (4) Prioritized Capital Construction and Maintenance Program.

5.1.2.5 Highway Sediment TMDLs

Straight Creek was listed on Colorado’s 303(d) list of impaired waters due to sediment loading from I-70 in 1998 and Black Gore Creek was added in 2002 (CDPHE 2016). Straight Creek received a TMDL assessment for sediment loading in 2000 (CDPHE 2000).

Straight Creek was listed on Colorado’s 303(d) list of impaired waters due to loss of habitat and aquatic life resulting from excessive sedimentation from the I-70 corridor. Most of the debris jams and beaver ponds in Straight Creek were filled with sediment, and fish populations had been reduced due to the filling of pools and burial of natural stream substrate. I-70 traction sands and highway embankment erosion were found to be the predominate sources of sediment in the Straight Creek watershed. An estimated 46% of applied highway sand was determined to make its way to the stream.

The 2000 TMDL assessment for Straight Creek identified four water quality targets and three sediment control practices to be implemented by CDOT as follows:

1) Revegetation of at least 70 percent of cut and fill slopes to 70 percent of potential ground cover

2) Cleaning and maintenance of twelve sediment control basins and sediment control structures on the I-70 roadway

3) Removal of at least 25 percent of the traction sand applied yearly to the I-70 roadway between the Blue River and the west portal of the Eisenhower Tunnel

In 2007, a TMDL Monitoring Results report found that channel morphology conditions were improving in Straight Creek and that some standards had been partially attained (USFS 2007). However, the targets set forth in the TMDL had not been attained (habitat, biological and stable channel targets). The report further listed several possible reasons as to why targets had not been met including:

- Maintenance of the sediment ponds is inconsistent. In some years the ponds are cleaned while in other years they become entirely filled
- Several BMP failures occurred between 2003 and 2006 including: a culvert failure, a sediment basin mistakenly drained and sediment flushed downstream, and an overtopping failure of a basin
- The existing sediment basins did not capture a large enough percentage of the annual sand applied to I-70
- The irregular nature of sediment supply from the highway and from sand stored behind obstructions in the stream channel. It may take many years for the prior sediment stored in the channel to flush through the system and for the stream substrate to recover
- A longer period of record may be necessary before a trend becomes substantial
- The sediment targets given in the TMDL may be inappropriate and unattainable in Straight Creek. The report stated that a review of the TMDL targets should be conducted

The findings of this report demonstrate two important things: first the challenges of BMP implementation and maintenance along mountain highways; and second the importance to develop realistic water quality goals.

The Black Gore Creek 303(d) listing requires the development of a TMDL with the goal of attaining the State's Narrative Standard for sediment. The State's narrative Standard states that "surface waters shall be free from substances attributable to human-caused point source or nonpoint source discharge in amounts, concentration, or combinations which can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials that include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud". The Standard applies to sediment impacts on aquatic life.

5.2 Discussion of Potential Sediment Control BMPs

Sediment control BMPs are divided into two categories for this SCAP: *structural* and *non-structural* BMPs. Non-structural BMPs are defined as institutional measures or maintenance BMPs, while structural BMPs are defined as constructed measures.

5.2.1 Structural BMPs

Structural BMPs are divided into two categories; Collection and Treatment BMPs. This SCAP assumes no changes to the highway template or drainage design. As such, space is limited for structural BMPs on Berthoud Pass. Only those BMPs deemed feasible for the existing Berthoud Pass roadway and drainage infrastructure are listed here.

5.2.1.1 Collection BMPs

The conveyance of highway snowmelt and runoff to treatment BMPs can be difficult in steep mountain environments. Collection BMPs are only effective when pollutant laden runoff is actually directed into them. Therefore, it is especially important to implement and integrate collection type BMPs into highway drainage design.

A. Pan Drains with Curb or Short Retaining Wall – Concrete pan drains with curbs or short retaining walls (knee wall) are important for trapping sediment along the highway rather than letting it runoff down the hillside in an uncontrolled manner. ***They also prevent erosion of the drainage ditch and toe of slopes in cutslope areas.*** If drainage pans are large enough sediment can be removed using sweepers. A curb and gutter drainage pan is effective in areas where space is too limited for the installation of large pans or sedimentation detention areas. A curb can range in height from 6 inches to short 3 feet knee walls in areas where stabilization of the cut slope is important. Curb and gutter concentrates flows which can create highly erosive areas where it is discharged from paved areas. The use of curb and gutter requires regularly spaced inlets or sediment traps and rundowns to convey concentrated flow to the receiving waterway without eroding the slope.

B. Clean Water Bypass – Clean water bypasses or diversions separate clean upland drainage (tributary and groundwater seepage) flows before combining with contaminated highway runoff. This is accomplished by piping upland flows under and past the highway. They reduce the volume of highway runoff requiring treatment (CDOT 2002, 2013). In groundwater seepage areas this is simply a small drain pipe embedded in gravel upslope from the knee wall or curb. At perennial tributary stream crossings, an extension is added to the cross drain inlet to prevent tributary water from comingling with contaminated highway runoff. ***Clean water bypasses are a common construction BMP and also work very well as a permanent BMP.***

C. Snow Storage – Areas such as turnouts and extra-wide shoulders can function as parallel snow storage where the snowplows can easily push snow into them. Although these areas are limited in number on Berthoud Pass, CDOT maintenance currently utilizes turnouts to store snow. Snow storage areas allow plowed snow to melt in a contained area where the snowmelt can drain to a treatment BMP. In some locations, such as switch-back areas, it may be helpful to have central locations to pile snow. It is important that these areas are configured with inlets and drain systems to convey contaminated snowmelt and highway runoff to a treatment BMP. CDOT has successfully implemented parallel snow storage along the shoulder on Berthoud Pass East. However, storage areas also need to consider traffic safety issues and prevent snowmelt from returning to and icing the highway.

5.2.1.2 Treatment BMPs

Treatment BMPs are structural systems which trap and treat runoff through sedimentation, infiltration, or adsorption. These BMPs address both the rate (velocity) and quality of runoff.

Runoff pollutants can be divided into two categories: suspended and dissolved. Traction sand and deicer salts are the two primary pollutants of concern in highway runoff. Sand particles are suspended constituents, and deicer salts are mostly dissolved pollutants. The removal of suspended solids, particularly sand and eroded sediment, can be effectively accomplished through settling. Settling is less efficient at removing finer silt and clay particles, but few of these are found in traction sand or in eroded geologic material along the Berthoud Pass corridor. Deicer salts are difficult to remove from runoff; however, detention can lower salt peaks and infiltration can reduce direct discharge into waterways. This section is devoted to BMPs which remove and control sediment from reaching receiving waterways.

A. Detention/Sedimentation Basins – Detention based BMPs include dry detention basins that remove pollutants primarily by settling. Detention basins are very effective at removing suspended solids, and sediment removal efficiency can be increased with the addition of berms and baffles to lengthen flow paths and prevent short-circuiting. On Berthoud Pass West these traps are constructed in concrete with debris screens and riser pipes that drain water from the basin. CDOT also uses detention dry basins on I-70 west approach to Eisenhower Tunnel. A hard surface forebay will help with regular maintenance and energy dissipaters will prevent accumulated sediments from being re-suspended during heavy rains. Maintenance for dry basins can be simple with regular debris removal and cleaning of the forebay. ***Outlets should be inspected annually for clogging and sediment removal.***

Dry detention basins perform very well in cold climates and can remain effective during winter months. The effects of freezing should be considered in the outlet structure design with open channel weirs preferred rather than pipes. Dry basins can also be used as snow storage.

B. Loading Dock Sediment Trap – The loading dock style sediment trap is a sedimentation basin that resembles a loading dock and functions similar to a forebay. This type of sediment trap functions for removal of large volumes of coarse sediment. A layer of filter fabric or a rock gabion composes the back wall (or side wall) which detains, filters, and releases the highway runoff. This system captures coarse sediment but does not hold the runoff for a long period of time to allow settling of fine particles.

Advantages of the loading dock are that it has a large storage volume for large sediment deposits, is typically installed at or below grade, and can be easily cleaned out with heavy equipment such as a front-end loader or grade-all. It does require more space than an inlet sediment trap but can often fit in the shoulder area. CDOT uses loading-dock traps on Berthoud Pass East. Issues with them have been clogged drainage outlets and a design too narrow for the loader buckets. ***It is important to install clean water bypass around the trap if perennial flow is present.***

C. Inlet Sediment Traps and "Sand Cans" – Inlet sediment traps consist of a standard inlet with the outlet pipe raised up towards the top of the structure, creating a sump in the bottom. They have been shown to be effective for small volume sediment capture and as pre-treatment for other BMPs. These have the advantage of being low cost, easy to install, and require little space. ***However, they do not have large storage volumes and may require more frequent maintenance unless used in lower sediment loading areas.*** CDOT has used Modified-D inlet traps on west Vail Pass; however, high sedimentation rates have resulted in limited effectiveness. An inlet can also be modified to create a small sediment basin or forebay immediately upstream of the inlet by elevating the inlet grate above the ground surface or installing low curbs creating a storage volume in upstream of the inlet.

D. Bench Traps – There are extensive areas adjacent to the roadway, typically on fill slopes behind guardrail, that can be utilized as bench traps to capture and store sediment. Large sand deposits have accumulated in these areas from years of snow plow cast. Plow cast can extend up to 10 feet from the roadway, but most material is deposited within 6 feet. Benches that are between 6 and 10 feet wide behind guardrail and slightly below highway grade can be graded and maintained for sediment collection. ***Bench traps are mostly suitable in areas where the roadway is super-elevated and runoff reports to the opposite shoulder, as they cannot handle concentrated flows***.

E. Erosion Control – The erosion of cut and fill slopes adjacent to highway and along highway drainage channels in steep mountain environments is quite common. Many of these erosion problems can simply be avoided by good drainage design practices. Narrow "V" shaped ditches on steep slopes tend to erode rapidly. ***Highly erosive drainage channels require rock or concrete lining on steep slopes.*** Rock, concrete, or culvert pipe drainage rundowns can prevent fill slope erosion in many locations. Pipe rundowns have been used extensively by CDOT on steep fill slopes along I-70 west approach to Eisenhower Tunnel and have been effective in eliminating slope erosion. Maintaining adequate vegetation cover is important to prevent development of rill and gully erosion on steep slopes. In some cases soil netting and other types of armoring is required to maintain vegetation cover.

Common Problems with Structural BMPs

Common problems reported with treatment BMPs implemented to capture traction sand and eroded sediment are:

- Lack of energy dissipation at the inlets to structures
- Scouring out and re-suspension of accumulated sediments. Causes may include lack of maintenance and improper design
- Facilities not designed for easy maintenance or accommodating to existing maintenance equipment
- Facilities that stay wet and do not drain properly – outlets and weep drains often clog or clean water is not diverted around the structure (CDOT 2010)
- Undersized BMPs that do not hold an adequate volume of traction sands based upon the annual load and maintenance schedule, or BMPs that require excessive maintenance
- BMPs lacking pretreatment to capture easily removed particles
- Lack of maintenance. Regular and proper maintenance is critical to upholding the effectiveness of treatment BMPs. Many structural BMPs fail for lack of proper maintenance. Maintenance should be performed on BMPs at least twice a year, in late spring and fall.

5.2.2 Non-structural BMPs

Non-structural BMPs are generally maintenance or sediment clean-up plans, but can also be institutional measures which reduce the use of highway sanding and deicing materials. Effective implementation of maintenance plans is essential in reducing sediment loading and maintaining drainage and roadway infrastructure. Non-structural BMPs can lessen the need or dependence on treatment BMPs and will often lead to reduced costs of winter road maintenance.

5.2.2.1 Maintenance BMPs

A. Sweeping – Highway sweeping removes sediment and debris from roadways that have accumulated in the shoulders, curbs, and drainage pans before they are washed downstream by the next large storm. Highway sweeping on the Colorado mountain highways should take place immediately after spring snowmelt has finished (May), when sediment build-up is at its highest, and before heavy monsoon rains occur (CDOT 2005). Advancements in sweeping technologies include vacuum-assisted, regenerative air, and high speed sweepers.

B. Cleaning of Drainage Infrastructure – The use of traction sand over a period of many years on high mountain passes such as Berthoud has resulted in partial or complete burial of drainage inlets and culverts in many locations. CDOT maintenance forces have attempted to clear sediment from inlets at most locations but the amount of material is overwhelming. This, in combination with a lack of maintenance funding and planning, has resulted in an ineffective drainage system that can exacerbate channel erosion between inlets – the water cannot drain properly. Cleaning of the existing drainage infrastructure, including any collection and treatment BMPs, is essential for sediment control.

C. **Vacuum Truck** – CDOT invested in a high performance vacuum truck in 2005 to clean sediment traps and culverts along high elevation highways in Colorado. This machine has proven to be versatile and effective in removing sediment from difficult access areas.

D. **Anti-Icing and Deicing** – Conventional deicing practice is to apply granular sand and salt deicers to a roadway after snow has fallen and ice has formed; deicer granules penetrate through ice and break the bond between ice and roadway, then the ice is plowed off. Over the last 15 years, a proactive method called anti-icing has developed which seeks to prevent ice from bonding to pavement. By applying liquid chemical deicers before snowfall, snow and ice are prevented from bonding to the roadway which increases the effectiveness of plowing. This strategy can reduce the amount of deicers, traction sands, and plowing needed while saving money and improving roadway level-of-service. The effectiveness of anti-icing practices however, hinge on accurate and specific weather forecasts.

E. **Improved Sanding Practices** – Improved sanding practices can prevent inadvertent excessive sanding and reduce the amount of sand and salt immediately lost during application. The first step is to calibrate sand and deicer spreaders; this can be done for any piece of equipment regardless of its technological age. State-of-the art application regulators are being used in the snowplow trucks, and they may pay for themselves in a number of years. Reducing the speed of sanding trucks increases the amount of sand and salt that stays on the road. Pre-wet sand and salt to help the granular materials stick to the roadway. Only loading the amount of material needed for the route helps to reduce excessive sanding since drivers tend to use what they load which is often more than what is needed.

5.2.2.2 Training and Technology

A. **Training** – The biggest challenge with non-structural BMPs is implementation; training is the key to successful implementation. Getting crews to buy into new ideas is the first step. Conducting yearly training classes, particularly in the fall, may be beneficial to both new and veteran employees. This also provides opportunity for feedback from crews and refinement of operation practices. Non-structural BMPs and new technologies are continually developing and will require continual training to test and successfully implement future ideas.

B. **Environmental Staff** – Several state Departments of Transportation (DOTs) have incorporated environmental staff into their departments to support and train crews in implementing sediment and erosion control practices.

C. **Road Weather Information Systems (RWIS)** – A road weather information system (RWIS) is a network of weather stations, forecasting services, and roadway data that provides real-time information about road conditions and site-specific forecasts. This information is extremely useful for DOT winter maintenance managers to plan snow fighting operations, particularly when to deploy anti-icing operations.

GIS based decision support systems with real time information from weather stations, road cameras, weather forecasting services, and "pavement pucks" in the road provide useful weather data to maintenance staff. Pavement "pucks" are imbedded in the roadway and provide pavement temperatures and if the road surface is wet or icy. The Federal Highway Administration has developed a Maintenance Decision Support System (MDSS) to help winter maintenance managers collect and process information from different sources and proactively respond to changing weather conditions.
http://www.rap.ucar.edu/projects/rdwx_mdss/

D. **Smart Overlays** – Research at Michigan Technological University has led to the development of a polymer pavement overlay that absorbs anti-icing chemicals for a length of time. The deicer chemicals do not easily wash off from the overlay but are still effective at preventing ice from bonding with the pavement. There have been proprietary installs at 21 sites in 13 states, including tests performed by the Minnesota DOT and at Chicago O'Hare International Airport. The Minnesota DOT tests evaluated installs at four bridge locations and found that the product performed very well initially with accident reductions at all sites.

E. **Snowplow Technologies** – Advancements in technology have provided many new tools that can be added to snowplows to increase the effectiveness and management of their operations. Infrared pavement temperature sensors help drivers match application rates and deicer types with road temperatures. GPS and Automated Vehicle Location (AVL) technology can provide real-time information on operations and material application. There have also been advances in collision avoidance equipment combining GPS, radar sensors, magnetic sensors, and onboard geospatial databases which can give the driver information and warnings on heads-up displays.

5.3 Berthoud Pass Sediment Sources and Control Strategies

Sources of sediment along Berthoud Pass include traction sand, hillslope erosion, mass wasting and erosion of cut and fill slopes from poor drainage disposal, and sediment transport in ephemeral tributary flow. Ephemeral tributaries can exhibit high erosive velocities seasonally during heavy snowmelt and summer rainstorms. These sources can contribute to sediment loads in surface runoff from US 40 and in the Fraser River and its tributaries.

Large deposits of traction sand have accumulated along the shoulders, behind guardrail, and above culvert drain inlets in many areas. These deposits are generally not removed and have developed into large accumulations along the roadway shoulders. While some of this material remains in place, it is also available for transport to receiving waters during runoff events. Sediment from highway runoff is deposited on the shoulders and at drainage culvert outfalls which are often some distance away from the roadway.

Sediment carried in US 40 runoff continues to bury organic soils in wetlands. Other highway outfalls discharge directly onto fill slopes that form the bank of the Fraser River in the lower portion of the study area, where US 40 is immediately adjacent to the stream. As described previously, a wetland fen, identified approximately 0.5 mile down the east side of the pass, has been partially buried by traction sand deposits from US 40 (CDOT 2010).

The primary strategy of this SCAP is to capture highway sediment near the source before it has an opportunity to leave the highway template (approximately 30-feet from edge of pavement). The sediment must be controlled in this area to reduce the potential for off-site transport and deposition. Observations indicate that most of the initial deposition of sand occurs near the template and at drainage outfalls (e.g., the snowplow cast on shoulders is about 10 feet). Sediment is lost into the stream or the riparian zone if it is not collected near the highway. It is therefore essential to gain control of sediment at the source before it is transported beyond the highway template.

5.3.1 Sediment Source Estimates

All sediment sources associated with US 40 need to be considered when determining the type and size of sediment control BMPs. The two primary sources identified are large sand accumulations along the roadway and the annual traction sand applied by maintenance. Secondary sources of sediment are hill slope erosion and stream channel erosion from ephemeral and perennial tributary flows.

The primary sources have been quantified for this SCAP to provide an estimate of the volume of existing material that may need to be handled and the amount of material that needs to be captured each year. Sediment derived from channel and slope erosion would be reduced or eliminated through drainage improvements such as channel armoring, pipe rundowns, and settling by energy dissipation structures or treatment BMPs. Large amounts of sediment have been deposited along the shoulders and behind guardrail over a period of many years. Some of this material is readily available for transport to receiving waters. Erosion and transport of this material takes place as a result of rainfall runoff processes each year.

5.3.1.1 Traction Sand

CDOT tracks the use of solid material (sand and salt) and liquid deicers used on Colorado roadways through their SAP management system. Winter maintenance material application rates are non-linear in the Berthoud Pass corridor due to highly variable snowfall, temperatures, and solar exposure, as well as steep roadway gradients in certain areas (Andy Hugley personal communication, July 2015). Sand usage information was provided by CDOT Fiscal Year (FY) 2002-2015 for the Berthoud Pass area and has been summarized in **Table 5-1**. The Fiscal Year spans from July 1 to June 30, and thus includes each winter season.

Table 5.1. US 40 Berthoud Pass Sand/Solid Application Data Summary

Period	Milepost Range	Total Miles	Applied Sand/Solids (tons)	Applied Sand/Solids (cubic yards)	Application Rate (tons/mile)	Application Rate (cy/mile)	
FY 2002	243-249	6	1,661	1,107	277	185	
FY 2003	243-249	6	1,973	1,315	329	219	
FY 2004	243-249	6	1,540	1,027	257	171	
FY 2005	243-249	6	1,796	1,197	300	200	
FY 2006	233-243	10	**8,897**	**5,931**	**890**	**593**	*Maximum*
2002-2006			**3,174**	**2,116**	**410**	**273**	Average
FY 2007	*No data*	*No data*	*No data*		*No data*		
FY 2008	233-243	10	**7,045**	**4,697**	**705**	**470**	*Maximum*
FY 2009	233-243	10	4,794	3,196	479	**319**	
FY 2010	233-243	10	3,755	2,503	376	**251**	
FY 2011	233-243	10	3,547	2,365	355	**237**	
FY 2012	233-243	10	1,684	1,123	168	**112**	
FY 2013	233-243	10	2,228	1,485	223	**149**	
FY 2014	233-243	10	1,968	1,312	197	**131**	
FY 2015	233-243	10	2,959	1,973	296	**197**	
2008-2015			**3,498**	**2,332**	**350**	**233**	**Average**

Source: CDOT 2015; using CDOT maintenance estimate of 1.5 tons/cubic yard

CDOT data shows *average* annual traction sand/salt application rates ranging from 350 to 410 tons/mile and *maximum* rates ranging from 705 to 890 tons/mile in the study corridor. Planning for design based on the average sand application rate will not provide adequate capture volume in many years and would increase maintenance requirements. There is also considerable uncertainty regarding the type of winter maintenance material that will be used and the maintenance level of service required on US 40 in the future. Conversely, maximum application rates would overestimate the capture volume needed in most years and may result in an overly-conservative design basis.

CDOT's approach for long-term sediment maintenance is treatment BMPs should have enough capacity for 2 to 3 years of accumulation to reduce cleaning intervals and maintenance costs as specified in Section 6.1. The sediment capture design criteria for this SCAP assumes an annual solids application rate between the average and maximum loading scenario for annual sediment control needs. A design base sediment loading rate of **600 tons/mile/year** (400 cubic yards [cy]/mile) will be used for this SCAP. Based on other SCAPs developed by CDOT this is reasonable design goal for the Berthoud Pass study corridor that also addresses maintenance concerns.

In addition to traction sand, sediment is generated from erosion of cut and fill slopes and shoulder drainage, particularly in steep gradient areas of the roadway. Sediment capture volume estimates must also consider variable annual winter weather conditions and sand application rates, the temporal distribution of sediment transport (snowmelt and summer storm runoff events), and the frequency of required structure maintenance and cleanout. These combined factors justify a loading capture estimate of 400 cy/mi as a reasonable design goal that addresses these uncertainties. In many years the amount of traction sand use and sediment loading will be less than this estimate, and therefore the frequency of cleaning sediment control structures will be proportionately less.

5.3.1.2 Sediment Stored behind Guardrails

The amount of traction sand accumulated behind guardrail that is accessible for proposed bench trap locations was quantified as part of the Berthoud Pass reconnaissance survey and mapping effort. The proposed bench trap locations and estimated capacities are listed in **Appendix A**.

As part of the 2015 US 40 Berthoud Pass guardrail replacement and re-paving project, CDOT contractors removed an estimated 4,361 cubic yards of material stored behind guardrail. Much of the material removed in 2015 came from guardrail locations that are not wide enough for permanent bench traps. The SCAP survey estimated 6,000-7,000 cubic yards of additional material in proposed bench trap locations, some of which is currently available for transport to receiving streams and wetlands.

5.3.1.3 Slope Erosion

Slope erosion is common on Berthoud Pass along the highway shoulder and where highway drainage is discharged to steep fill slopes. Large rills and gullis have formed in many areas that deposit sediment into forested areas, wetlands, and receiving streams. In switchback areas this material can be deposited on the highway below, overwhelming culverts and causing drainage problems.

Field surveys indicate that sedimentation rates are higher in areas below steep roadway gradients and along the highway shoulder where slopes are greater than four percent. Detailed reconnaissance in these areas shows substantially higher erosion rates. This can be highly variable due to the many factors contributing to sediment transport and the source of sediment (traction sand or natural soils). In addition to higher traction sand use in steep roadway gradient areas, sediment from erosion of cut and fill slopes is estimated to contribute to the sediment loading. The uncertainties regarding the volume of sediment generated from all source areas is the primary reason that sediment collection structures need to be sized with adequate storage capacity.

Slope erosion caused by the flow of water from roadway ditches and drainage pipes is addressed in the sediment control design. This erosion currently takes place each year during spring snowmelt and summer rainstorm runoff. The primary goal is to reduce erosion and sedimentation by conveying highway runoff in hardened collection systems and dissipating energy to settle sediment in treatment basins.

The heavy snowpack in the Berthoud Pass area generates substantial seasonal snowmelt conditions. This snowmelt saturates hill slopes and shallow groundwater reports to the surface at bedrock outcrops. In areas where the soil mantle is thin, this can result in debris slides and mass wasting in some years. If a slope failure occurs, this material can enter drainage ditches along the roadway as well as stream channels which transport sediment to the Fraser River and its tributaries.

Unstable slopes can be found in over-steep highway cut and fill areas along the study corridor. In some cases, these areas can generate slope failures and rockfall hazards. Hill slope failures and rockfall events typically occur at a lesser frequency but can produce substantial amounts of sediment. The sediment collection and treatment recommendations in the SCAP are not intended to control sediment from these events. Instead, these conditions and events are addressed with slope stability measures as covered in the slope stability report with recommendations for the study area (**Section 7)**.

5.3.1.4 Channel and Gulley Erosion

Bedrock is shallow in most areas of Berthoud Pass and the highway was cut into rock in many areas. Snowmelt and rainfall produces rapid runoff in bedrock areas that causes high erosion rates along the highway shoulder. The steep highway gradient also generates higher erosive energy in surface water runoff that can result in substantial gulley erosion along the highway shoulders.

Several tributary streams bisect US 40 in a perpendicular fashion, including Current Creek, Second Creek, First Creek, Parsenn Creek, and several other un-named tributaries. In the Berthoud Pass area, these tributaries are naturally steep with average gradients in excess of 4 percent. As such, they generally have a high sediment transport capacity resulting in a large substrate of cobble and small boulder with minimal fine-grained material (sand and silt). However, highway traction sand deposits were noted in the Current Creek and Second Creek channels downstream of US 40.

Substantial channel erosion was noted where these tributaries bisect the roadway template. Tributary channels are over-steepened in road cut areas resulting in high channel erosion rates and sediment transport. Sediment derived from channel erosion is transported rapidly to lower-gradient areas including wetlands and the Fraser River.

5.3.2 Sediment Control Strategy

Sedimentation caused by traction sand usage was not anticipated to be an important concern at the time of Berthoud Pass construction. As the highway template has increased in size over the years, the primary method of controlling sediment has been through slope stabilization and revegetation to prevent hill slope erosion. However, field data collected for this study indicates that erosion and sedimentation from highway runoff and traction sand are the primary sources of sediment on Berthoud Pass. This SCAP proposes permanent sediment control measures, as well as a more intensive maintenance programs to manage sediment transport into the environment.

Several sediment control measures are considered in this study including both structural and non-structural controls. Structural sediment controls include features that are placed in the drainage pathway to dissipate hydraulic energy and settle mobilized sediment. This includes hydraulic control of highway runoff to reduce erosion of drainage channels and cut and fill slopes. A continuation of slope stability measures is also recommended to reduce slope failures and rockfall hazards. Non-structural sediment controls include revegetation to prevent soil erosion and maintenance BMPs such as sweeping and sediment removal. A proactive maintenance program involving BMPs such as utilization of controlled snow storage areas, and scheduled sand cleanup activities including sweeping and removal is integrated into this plan.

The primary sediment control strategies in this plan include:

- Minimize the application of traction sand through improved technologies
- Capture and remove sediment within the roadway right of way to the extent practical
- Capture and contain traction sand and eroded sediment in easily maintained areas
- Bypass clean tributary water to prevent contamination by highway runoff
- Minimize the volume of water requiring treatment wherever possible
- Increase the number and size of sediment capture areas, especially in critical areas near tributary streams and in steep roadway sections
- Provide controlled snow/sand storage areas where possible
- Improve the highway storm drainage network and outfall areas to reduce erosion
- Reduce cut slope and fill slope erosion caused by highway runoff
- Reduce rill erosion in shoulder areas
- Continue slope stability measures to reduce slope failures and rockfall hazards
- Maximize vegetation cover as necessary to prevent slope erosion
- Develop preventative maintenance programs (Sediment Maintenance Program)
- Increase funding to afford effective BMP maintenance

Highway drainage design plays a major role in the sediment control strategy. Several areas exist where the original drainage design is inadequate, or the drainage system has been altered by sedimentation to the extent that it no longer functions properly. This has resulted in massive rill and gully erosion where runoff is concentrated on the highway shoulders and discharges on steep slopes.

There are several locations in the Berthoud Pass west study corridor where large gullies have formed in the fill slope caused by erosion from drainage outfalls. Rill formation is common in shoulder areas where highway runoff sheet flow is concentrated in unconsolidated sediments. In some areas, culverts are plugged with sediment and no longer function, resulting in concentration of large flow volumes that exceed downstream drainage system capacity.

By incorporating drainage design considerations, this SCAP also serves to resolve many of the highway drainage problems currently experienced in the Berthoud Pass corridor. Runoff water must be managed in a controlled manner through adequate drainage design. Designs that dissipate hydraulic energy also help to control sediment transport.

Paving of the shoulder areas, installation of pan drains, and concrete curbs or retaining walls placed to control highway runoff have all proven to be effective methods of controlling erosion. A 1990 study by the U.S. Forest Service on Straight Creek concluded that revegetation, coupled with construction of a collection ditch (valley gutter) had stopped the majority of erosion on test fill slopes (CDOT 2002).

Vegetation has the ability to bind soil particles, provide organic enrichment, and maintain soil moisture. Adequate vegetation cover is widely recognized as a key element in stabilizing soil and preventing erosion. Most of the areas along US 40 have been successfully revegetated. However, vegetation in many areas remains under stress due to annual smothering by highway traction sand. An annual revegetation assessment program for the hill slope areas along Berthoud Pass is proposed in an effort to improve and maintain adequate vegetation cover to prevent soil loss.

A preventative maintenance program is proposed to control annual sediment transport by collection and removal of accumulated sand and colluvial material. A cleanup and disposal plan will be required as part of the maintenance program. These aspects should be integrated into a Sediment Maintenance Plan as described in **Section 6**.

Based on past research and experience in high elevation snowfall traction sanding areas in Colorado, the following primary sediment control measures are proposed for the Berthoud Pass corridor:

- Basins and traps to capture sediment
- Paving shoulder areas to reduce rill erosion and provide a durable surface for cleaning
- Pan drains to store snow and sediment, and collect and route highway runoff
- Knee walls to prevent cut slope erosion
- Curb and gutter to reduce migration of sediment onto fill slopes
- Controlled snow storage/sand deposition areas
- Revegetation program
- Maintenance BMPs
- Sediment Maintenance Program

5.3.3 Drainage Review

The hydrology of the Berthoud Pass area is dominated by the annual cycle of snowmelt runoff. The winter snowpack effectively stores water for release to streams during spring and summer when daily temperatures increase. This process drives the hydrology of the Fraser River and Hoop Creek and the tributary streams that feed them. This includes both surface and groundwater flows that cross US 40 within the study corridor. Another factor that influences the natural hydrology is the increased impervious surfaces resulting from US 40 pavement. Unpaved parking/turnout areas that are unvegetated also increase runoff.

Many drainage problems were identified as part of the site reconnaissance. The overall drainage design for US 40 was simple and functional when constructed. However, the drainage system has been altered from sand deposition along the shoulders. In some cases, cross drains are buried with sediment causing excessive flows downstream. Maintenance is needed to reduce transport of deposited material and to provide adequate runoff conveyance. Present-day drainage and erosion problems occur primarily in locations of:

- Sheet flow from the highway that concentrates causing erosion of unprotected slopes
- Unpaved shoulder turnout/parking areas and unvegetated cut slope areas
- Terminus of guardrails where runoff is concentrated along the roadway with no formal inlet drains
- Areas where the inlet drains or cross-drain culverts are plugged with sediment
- Areas where culvert cross drains daylight on fill slopes with no erosion protection or energy dissipation
- Culvert outfalls where no energy dissipation is provided
- Turn-out and parking areas where sheet flow is concentrates for long distances

Highway runoff should be routed along concrete curbs or into concrete pan drains to sediment capture structures before release to existing tributary inlets. Treated runoff water will then be conveyed through existing culvert cross drains wherever possible. In fill slope areas with no cross drains, treated water will be released to existing channels. Culvert rundowns with energy dissipation should be installed where necessary to eliminate hill slope erosion and stabilize fill slopes.

5.3.4 Clean Water Bypass

US 40 bisects several perennial tributary streams and groundwater springs that flow perpendicular to the highway. Several ephemeral tributaries and groundwater springs and seeps that flow during the spring and early summer are also intercepted. The highway was designed to allow passage of these tributary flows through culvert cross drains. The culvert inlets and cross drains for perennial tributaries were generally in good condition. Each of the major tributary flows were identified and mapped for this study.

A primary objective of this SCAP is to separate the clean tributary flows from highway runoff flows to the extent practical in order to:

- Keep clean tributary water from becoming contaminated with highway runoff and sediment
- Reduce the volume of water requiring treatment
- Maintain sediment basins as dry as possible between runoff events to improve trap efficiency and facilitate cleaning

All of the existing clean tributary culverts will remain at their present locations and no hydraulic modifications are proposed as part of this plan. No off-site areas contributing to highway runoff flows were evaluated. The only alteration proposed is to extend the existing culvert inlets upstream as needed to collect the tributary flow before it reaches the shoulder of US 40.

The goal is to isolate clean water from highway runoff, thereby reducing the amount of water than needs to be treated. Channel armoring, energy dissipation, and outfall protection is also needed at some of the tributary crossings. Groundwater seeps and springs will be collected in pipes or otherwise separated from highway runoff before being released to clean tributaries.

5.3.5 Sediment Capture Volume Estimates

The sediment control strategies described above, when combined, will result in a substantial decrease in sediment loading from the study area. The SCAP design goal is to capture at least 80 percent of the sediment generated from the entire study corridor. Drainage improvements will reduce or eliminate hill slope and channel erosion. Sediment sources remaining after erosion controls are in place include areas of deposition and storage, along with the annual application of traction sand.

The installation of bench traps, as described in Section 5.2.1 and illustrated in Section 5.4.1, would result in the removal of some of the existing material. Additional material will be removed from the system as part of construction for permanent structural BMPs, including regrading for drainage pans and sediment basins. Sediment deposited more than 50 feet beyond the highway template will largely stabilize in place once drainage and erosion control measures are implemented.

There are no plans to reconstruct the highway template or to change the drainage area of the roadway as part of this SCAP. Therefore, the existing highway drainage infrastructure will remain in place. If an existing cross-drain culvert is plugged or in disrepair, it will be cleaned or replaced. Culvert rundowns will be sized to match existing culverts. Sediment basin inlet and outlet works will be sized according to the current (as-built) highway drainage design for the US 40 study area.

Based on historical CDOT sand usage data and the other sediment sources described above, a design base sediment loading rate of **400 cy/mile/year** is used for this SCAP. The detailed reconnaissance of the study corridor resulted in location of existing drainage infrastructure and sedimentation conditions and identification of specific BMPs that will be effective in mitigating sediment loading. These BMP locations were migrated into a spreadsheet for quantitative analysis.

The overall goal is to collect, capture, and remove at least 80 percent of the annual sediment loading rate of 400 cy/mile. Several assumptions were used in the analysis as follows:

- 600 tons/mile/year sediment loading rate (see Section 5.3.1)
- 400 cy/mile based on 1.5 tons/cy (CDOT maint. estimate for moist sand)
- Basin or Inlet trap efficiency = 80 percent
- Bench trap or Pan trap efficiency = 50 percent (1/2 can be captured)
- Inlet trap capacity = 4 cy
- Small basin capacity = 10-15 cy
- Large basin capacity = 35-40 cy

For sediment capture volume calculation purposes, the BMP dimensions listed in **Table 5-2** were used. These dimensions are generally based on sediment treatment BMPs used by CDOT and others. For example, the large concrete loading-dock style traps installed on Berthoud Pass East range in capacity from 37 to 49 cy. A modified Type-D Special inlet has a capacity of 3-4 cy and can be installed in series. It is important to use the maximum possible flow length in the structure to provide effective sedimentation. These estimates were developed for planning purposes only; actual design of sediment control structures may vary from those listed.

Table 5.2. BMP Capture Volume and Efficiency Estimates

BMP	Dimensions WxLxD (feet)	Volume (cy)	% Efficiency
Large Basin	10x20x5	37	80
Small Basin	6x20x3	13	80
Inlet Trap	3x10x4	4	80
Pan Trap	3xLx0.17	(0.02)L	50
Bench Trap	6xLx0.33	(0.07)L	50

Specific treatments were selected for each BMP location according to site-specific conditions and loading analysis. There are many areas along Berthoud Pass where no sediment control BMPs are feasible due to steep narrow conditions. Treatments were selected based on site conditions, space requirements, and existing drainage infrastructure (cross-drain culverts, rundowns, pan drains, etc.). Clean water bypass is specified for seep and spring areas that produce perennial flows as well as tributary stream crossings. The BMP type and quantities are listed in **Table 5-3**.

Table 5.3. BMP Quantity Estimates

BMP	Quantity	Unit
Small Sediment Basin	81	Each
Large Sediment Basin	72	Each
Inlet Trap	35	Each
Bench Trap	14,940	Linear Feet
Pan Trap	3,696	Linear Feet
Pan Drain	48,590	Linear Feet
Pan Drain/Knee Wall	16,550	Linear Feet
Concrete Curb	4,520	Linear Feet
Clean Water Bypass	19,620	Linear Feet
Pipe Rundowns	36	Each

The above assumptions were used to calculate the total sediment capture volume for four segments covering the entire study corridor. A summary of sediment loading and capture data are provided by highway study segment in **Table 5-4**. The location and type of BMP proposed in the accompanying SCAP mapbook, (**Appendix B**) can capture a total of 81 percent of the highway sand and road side erosion along this study corridor based on the sediment loading rates presented above. Percent capture rates vary by highway segment, which is dependent upon space requirements for the various proposed BMPs. A detailed breakdown of these numbers can be found in **Appendix A**.

Table 5.4. Sediment Capture Volume Estimates

US 40 Segment	Sediment Generated (cy)	Sediment Captured (cy)	Percent Recovery
Eastbound 232.8 to 243	1984	1414	71
Westbound 243 to 232.8	1996	1808	91
Eastbound 243 to 244.3	260	208	80
Westbound 244.3 to 243	270	215	80
Overall Study Corridor			81

5.4 Structural Sediment Control BMP Measures

Based on the literature review a menu of structural BMP control measures has been developed. The structural BMP menu (**Figure 5-3**) focuses on those which remove suspended solids, will function in mountain environments, and will be easy to maintain. These include both collection and treatment system BMPs. Routine inspection and proper maintenance are vital to structural BMP success.

Menu of Structural BMP Control Measures

Collection System BMPs:

- Curb & Gutter or Concrete Pan Drain
- Snow Storage Areas and Parallel Snow Storage
- Drainage Rundowns
- Slope Stabilization and Revegetation
- Clean Water Bypass (clean water separation)

Treatment System BMPs:

- Detention/ Sediment Basins
- Loading Dock Sediment Trap
- Inlet Sediment Traps
- Bench Trap
- Pan Trap

Figure 5-3. Structural BMP Control Measures

The following pages outline the best uses, advantages, and disadvantages of each BMP. More detailed information and discussion of these BMPs including BMPs which are not recommended can be found in the literature review.

5.4.1 Collection System and Snow Storage BMPs

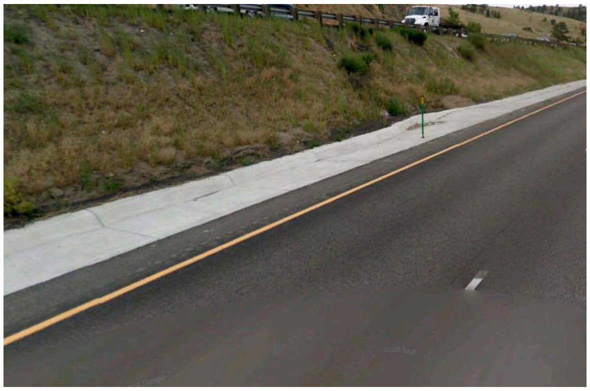
5.4.1.1 <u>Curb & Gutter or Concrete Pan Drains</u>

Best Use: Conveying highway stormwater and snow melt runoff to treatment and outfall facilities in areas of limited space.

Advantages	Disadvantages
• Does not require extra ROW – fits in narrow areas • Captures and redirects runoff to treatment facility • Prevents ditch and embankment erosion	• Curb and gutter can create safety problems on high-speed roads. May need to be integrated with a guard rail • Expensive to install over large lengths of highway • Will require periodic to frequent sweeping

Other:

- Larger curb and pan designs may need to consider equipment ability to effectively remove sediment
- Vane-type inlets can be installed to convey material to treatment structure

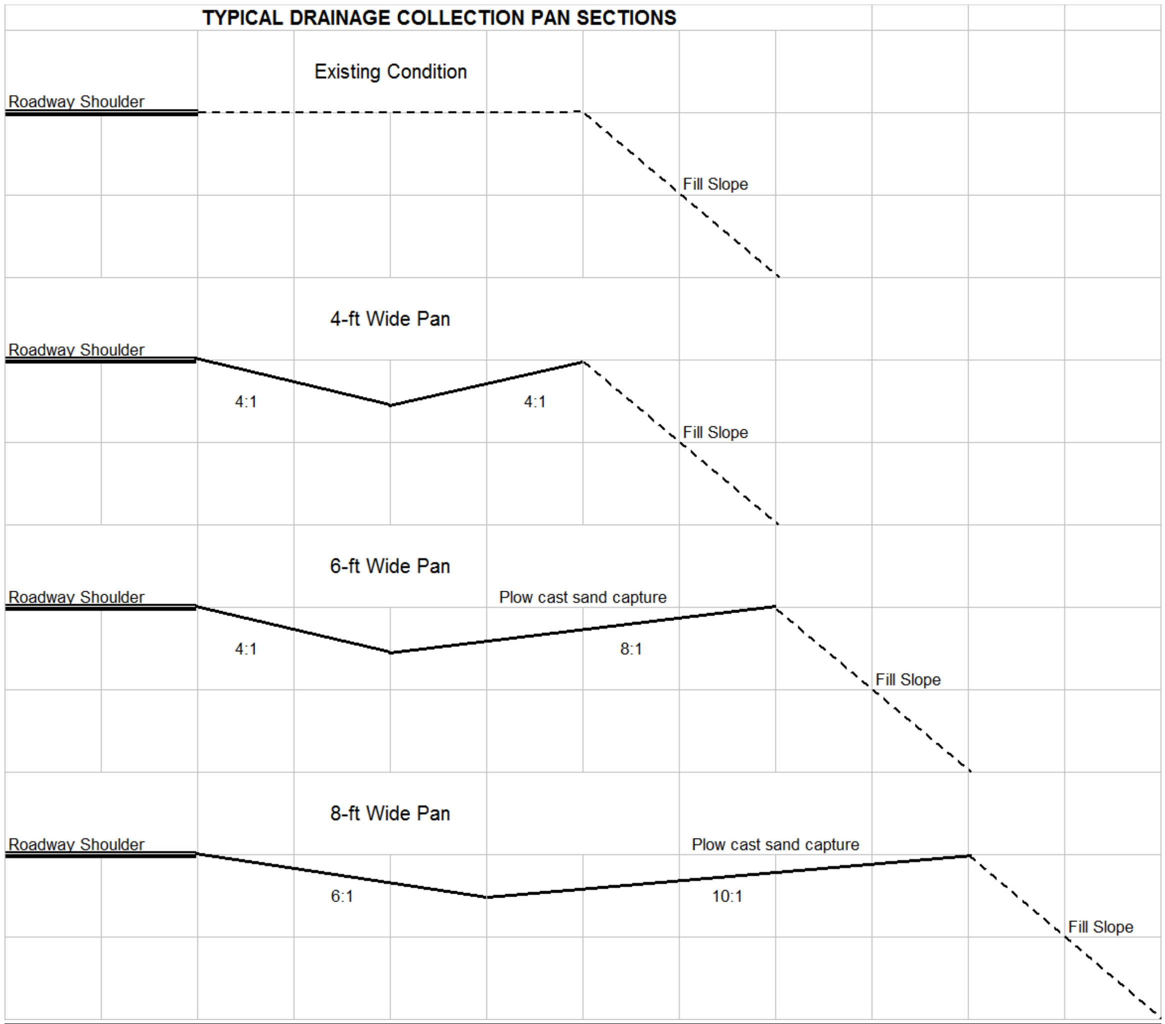


Pan Drain with Curb (Mt. Vernon Canyon)

Valley Pan Drain west of Eisenhower Tunnel

Curb & Gutter with Guardrail (Berthoud Pass)

Pan Drain Inlet with Knee Wall (Berthoud Pass)



5.4.1.2 Snow Storage Areas and Parallel Snow Storage

Best Use: Storing plowed snow adjacent or near to highway.

Advantages	Disadvantages
• Allows plowed snow with traction sand to melt in a contained area which drains to a treatment facility • Snow storage areas can be easily swept and cleaned • May double as treatment facility	• Requires space – this BMP will be difficult in some narrow areas • May be expensive to install • Plowing or moving snow into these areas will be more difficult than conventional plowing • Snowmelt from parallel storage areas may freeze on highway – this will need to be addressed in site-specific design

Other:

- Will need to be swept and/or cleaned out each year.

Sediment accumulation in snow storage area on Berthoud Pass East

5.4.1.3 Drainage Rundowns and Slope Drains

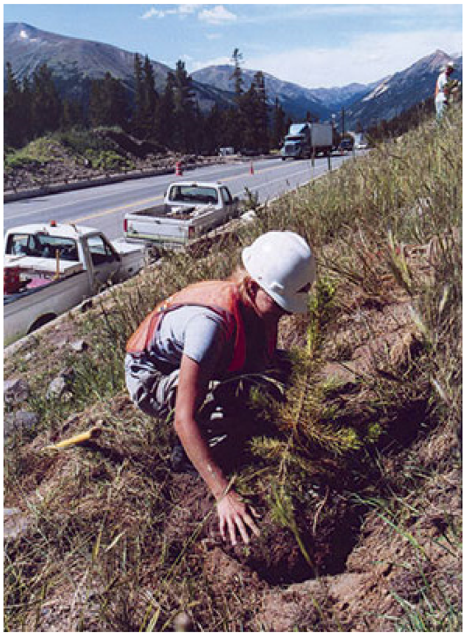
Best Use: A permanent BMP that conveys concentrated flows from top to bottom of an embankment. Stabilizes slope and eliminates embankment erosion. These may be constructed as a grouted boulder structure or a buried culvert pipe system. Excellent for long slopes.

Advantages
• Eliminates erosion on highway embankments • Protects upstream improvements from undermining • Allows revegetation of slope and reduces aesthetic impacts
Disadvantages
• Expensive to construct • Difficult to install on steep slopes

Buried Culvert Rundown with Riprap Outfall
(Source: CDOT Straight Creek SCAP 2002)

5.4.1.4 Slope Stabilization and Revegetation

Best Use: Stabilizing slope and eliminating embankment erosion at locations of slope instability. Vegetative methods may be used on less-steep slopes. Structural methods may be needed on steeper and highly unstable or rocky slopes.



Slope Revegetation
(Source: CDOT)

Advantages
• Reduces erosion on highway embankments • Natural vegetation is aesthetically pleasing
Disadvantages
• Short growing season in high altitude areas • Difficult to establish vegetation on steeper or rocky slopes, and arid south-facing slopes • Structural stabilization methods may be expensive • Not effective in areas of high traction sand deposition

5.4.1.5 Clean Water Bypass (Highway Bypass)

Best Use: Bypass clean water from upper watershed around highway.

Advantages	Disadvantages
• Keeps clean water from upper watershed from being contaminated by highway pollutants • Reduces the volume of water to treatment facilities • Can be used for groundwater seeps and to reduce water in road subgrade • Important as a source water protection measure for water supply	• Need space to install bypass systems • May be expensive to install

Other:

- Tributary diversion culverts need to be extended far enough upstream to capture clean water before mixing with highway runoff.
- Highway runoff should be captured and treated before flowing into clean tributaries.
- In many cases, this may simply mean extending an existing culvert further upstream to make room for BMPs to treat highway drainage.

Clean Water Diversion at Loveland Ski Area Zip Creek Water Supply

5.4.2 Treatment BMPs

5.4.2.1 Detention/ Sediment Basins

Best Use: Removing large amounts of sediment from runoff in locations with available space for treatment facility.

Advantages	Disadvantages
• Large storage volume • Promotes infiltration if soft bottom is used • Does not have to be directly adjacent to highway; can be located away from traffic • Treats large volume of water • Low cost if earthen embankment and rock spillway are used	• May require large amount of space • May be expensive to construct depending on material and design • Rubber-tired loaders and backhoes have trouble cleaning soft bottom basins

Other:

- Design needs to consider maintenance access and equipment required
- Construction of a maintenance access road may be necessary
- Designed to drain within 24-48 hours
- Maintenance: Clean once and inspect twice annually

CDOT Highway Sediment Basins

5.4.2.2 Loading Dock Sediment Trap

Best Use: Removing large amounts of sediment from runoff in areas with medium amount available space for facility.

Advantages	Disadvantages
• Large storage volume • Easy to maintain – may be cleaned with loader or skid steer • Above ground • Can be located in shoulder below grade or adjacent to highway with concrete barriers or guardrail separating traffic	• Difficult to maintain if they do not drain properly • Expensive to construct (typically concrete)

Other:

- May require access road
- Concrete wall at end is helpful for loader to scoop against
- Caltrans puts replaceable filter fabric over the upstream side of the rock gabion.
- Needs to be wider than 6-feet to accommodate loader or skid steer bucket for maintenance
- Maintenance: Annually clean and replace filter fabric (if used). Inspect twice annually


Berthoud Pass East Loading Dock Sediment Traps (not proposed for west side)
(Source: CDOT)

Downstream end of Caltrans Loading Dock Sediment Traps
Note: Concrete bollard backstop and rock gabion
(Source: Caltrans)

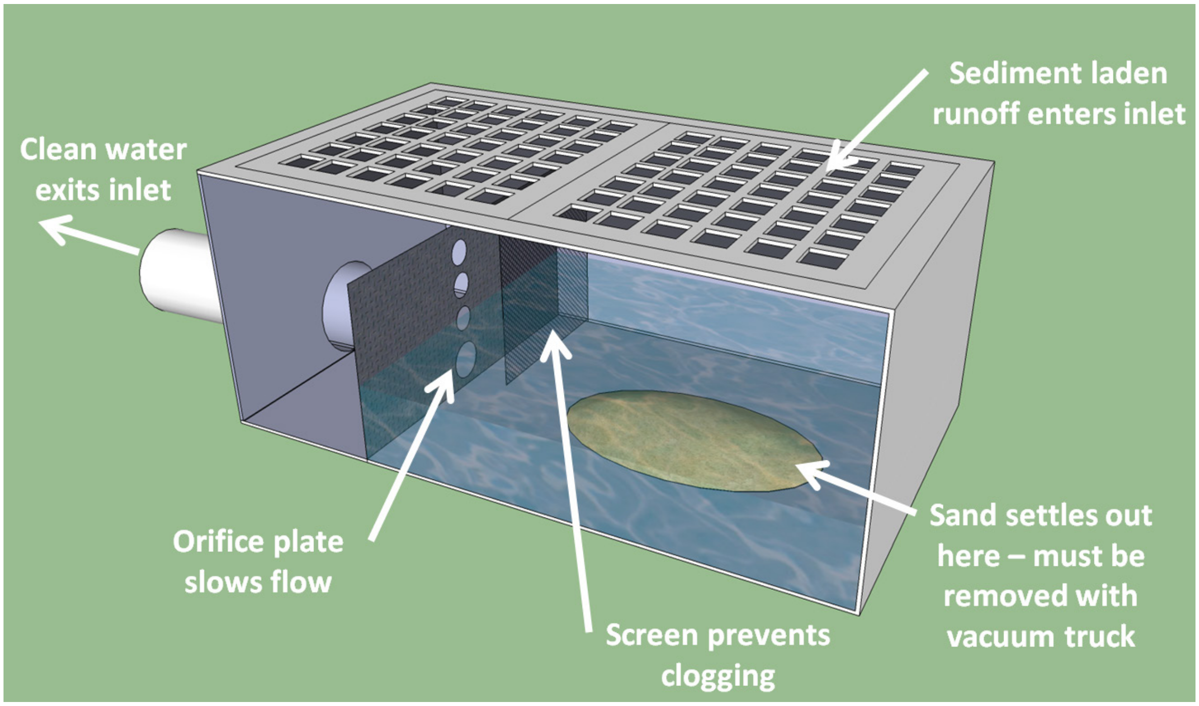
5.4.2.3 Inlet Sediment Traps and Sand Cans

Best Use: Removing smaller amounts of sediment from runoff in areas with lower sediment loading or limited space for treatment facilities.

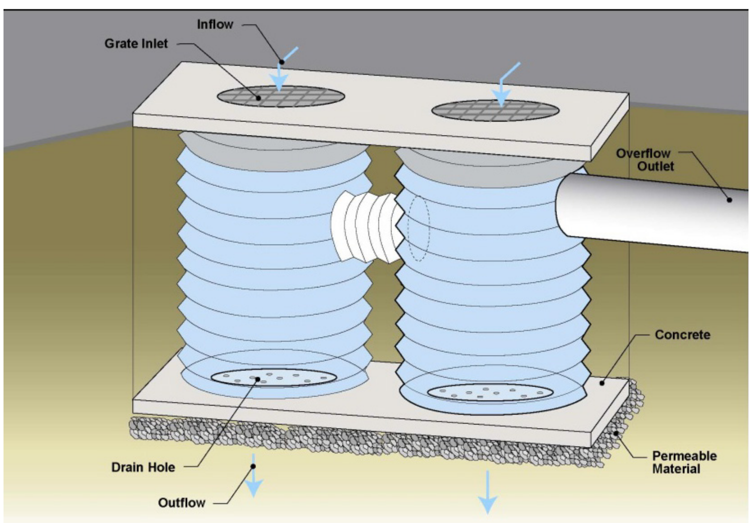
Advantages	Disadvantages
• Fits in small space • Works well with curb and gutter • Easy to clean and inspect • Can be cleaned with vacuum truck • Simple to construct (pre-fabricated) • Some designs may be driven over • Suitable for lower sediment loads • Can be installed in series for higher sediment loads • Can be designed with open bottom to allow infiltration of water in coarse or rocky soils	• Small storage volume • May require many in series to achieve necessary storage volume or may require more frequent maintenance • Plugging of weep drains can be problematic • Requires vacuum truck to clean. • Some designs prone to washout and re-suspension of sediments in higher flows

Other:

- Two types: CDOT Modified Type D Special, and Sand Cans (Caltrans Type)
- Pullout area for maintenance trucks is helpful – otherwise traffic control and lane closures may be necessary for maintenance
- There are many similar proprietary devices available which will have higher removal efficiencies and are less prone to scour and re-suspension
- Maintenance: Inspect twice annually and clean annually. More if necessary.



CDOT Modified Type D Water Quality Inlet Trap



Caltrans Sand Can Sediment Trap (Double Barrel Modified CMP)
(Source: Caltrans)

5.4.2.4 Bench Trap

Best Use: Capturing sediment from plow cast and overland flow along hillside.

Advantages	Disadvantages
• Easy to construct and maintain with conventional equipment • Does not have to be directly adjacent to highway; can be located away from traffic. • Does not need collection system • Captures overland flow • Low Cost	• Needs space between highway and waterway • Cannot handle concentrated flows

Other:

- Basically a ditch or flat area graded behind guardrail near top of fill slope
- Must be at least 6 feet wide to accommodate cleaning with a skid steer; a backhoe is required for narrow areas
- Maintenance: Yearly inspection and can be maintained by excavation and re-grading when excessive sediment accumulates.

Potential Bench Trap Areas

Pan Drain needed at guardrail

5.5 Non-structural Sediment Control BMP Measures

Non-structural BMPs (**Figure 5-4**) are institutional measures which prevent or reduce the use of highway sanding and deicing materials. Effective implementation of non-structural BMPs often will lead to reduced costs of winter road maintenance and lessen the need or dependence on treatment BMPs.

Menu of Non-Structural BMP Control Measures

- Staff Training
- Street Sweeping
- Road-Weather Information System (RWIS)
- Improved Sanding Practices
- Advanced Snow Plow Technology

Figure 5-4. Non-Structural BMP Control Measures

The following pages outline components of each recommended non-structural BMP. More detailed information and discussion of these BMPs can be found in the literature review.

5.5.1 Staff Training

The biggest challenge with non-structural BMPs is implementation; training and increased resources are keys to successful implementation. Annual training classes should be held in the fall (before the winter season) and have the following goals:

- Explanation of the impacts of sands and salts
- Training and review of anti-icing, deicing, and improved sanding practices
- Training with new technologies and application rates
- Provide opportunity for feedback from crews and refinement of operation practices
- Testing and successfully implementing future ideas

Several DOTs, including CDOT, have successfully used environmental staff working with maintenance departments to support and train crews in implementing sediment and erosion control practices. They are also helpful in developing more effective and practical methods.

5.5.2 Roadway Sweeping

A successful sweeping program will substantially reduce sediment loading on downstream BMPs and receiving streams by removing roadway sediment before it enters the drainage system. A successful sweeping program may include the following:

- Sweep when possible during the winter season and as soon as possible after spring snow melt has finished
- A routine sweeping schedule considers variable annual snow conditions
- Consider purchase of newer, more efficient sweepers

- Sweepers need to be compatible with curb and gutter and paved pan sections
- Some places may have deeper sediment deposits and need to be cleaned with a skid steer loader before sweeping

5.5.3 Road-Weather Information System

RWIS is a network of weather stations, forecasting services, and roadway data that provides real-time information about road conditions, pavement temperatures and site-specific forecasts. This data may be collected and analyzed in a GIS-based decision support system and is an integral part deciding when to deploy winter maintenance operations.

5.5.4 Improved Sanding Practices

Improved sanding practices can prevent inadvertent excessive sanding and reduce the amount of sand and salt immediately lost during application. Improved sanding practices include:

- Calibration of spreaders
- Application regulators
- Reverse throw spreaders
- Pre-wetting sand/ salt mixture
- Applying sand and deicer at slower speeds

5.5.5 Advanced Snowplow Technology

Advancements in technology have provided many new tools that can be added to snowplows to help drivers match sand/salt application rates and deicer types with road temperatures. These include:

- Infrared pavement temperature sensor
- Friction sensor
- Freeze point sensor
- GPS and AVL technology provide real-time information on operations and material application rates.
- Onboard computer system with geospatial databases which can give the driver information and warnings on head-up displays

5.6 BMP Summary and Costs

The field work completed for this study identified opportunities for sediment control BMPs along the US 40 Berthoud Pass corridor. The recommended BMPs are shown on the accompanying mapbook (**Appendix B**). The intent of this SCAP is to recommend capture opportunities for traction sand and other sources of sediment within the study corridor. The number and extent of BMPs are not dependent upon any numeric goal or regulatory criteria. However, the volume capture of all the BMPs identified was compared to the estimated sediment loading rates for various study segments (see **Appendix A**) to show that the proposed water quality BMPs could contain on average at least 80 percent of the sediment load.

The total number and type of BMPs recommended over the 11.5-mile corridor as shown in the accompanying mapbook (**Appendix B**) are summarized below in **Table 5-5** along with their estimated construction cost. Planning level unit construction costs were identified for each item based on previous SCAPs, CDOT cost data, and conversations with CDOT managers. If all of the BMPs are implemented, a planning level total cost of the BMP infrastructure in 2015 dollars is estimated to be approximately $8 million. Engineering and contingency would add an estimated $3 million for a total of $11 million. This planning level cost is provided for preliminary budgeting purposes and would be refined at the preliminary and final design stages.

At this time, there is no requirement or schedule to implement these recommended BMPs. However, the proposed improvements are shown to assist CDOT for budgeting purposes with a proactive approach to improved waterway stewardship of the Fraser River and Upper Clear Creek. The suggested BMPs can be used as a reference and guidance for future planning of the US 40 Berthoud Pass corridor.

Table 5.5. Planning Level Construction Cost Estimate

BMP	Quantity	Unit	Unit Construction Cost	Total Item Cost
Small Sediment Basin	81	ea	$15,000	$1,215,000
Large Sediment Basin	72	ea	$25,000	$1,800,000
Inlet Trap	33	ea	$10,000	$330,000
Bench Trap (cleaning only)	14,940	LF	No Construction Cost	$0
Pan Trap	8	ea	$2,000	$16,000
Pan Drain	48,590	LF	$40	$1,943,600
Knee Wall/Pan Drain	16,550	LF	$72	$1,191,600
Clean Water Bypass	16,030	LF	$40	$641,200
Knee Wall/Pan Drain with CWB	3,590	LF	$112	$402,080
Concrete Curb	4,520	LF	$20	$90,400
Pipe Rundowns	36	ea	$6,400	$230,400
Cross Drains	3	ea	$3,200	$9,600
SUBTOTAL CONSTRUCTION COSTS				$7,869,880
Engineering & Contingency				
Traffic Control	5%			$393,000
Contingency	20%			$1,574,000
Prelim. Engineering	10%			$787,000
Final and Construction Engineering	22.5%			$1,771,000
SUBTOTAL ENGINEERING COSTS	57.5%			$4,525,000
TOTAL				**$12,395,000**

6.0 BMP MAINTENANCE PROGRAM

The purpose of a BMP Maintenance Plan is to establish standard maintenance practices for managing snow, sediment, and salt/sand materials along the US 40 corridor to reduce off-site transport of contaminants. The objective is to control highway-induced sedimentation and erosion as near to the highway source as possible while utilizing maintenance practices that achieve this objective. The plan should be a working document to provide flexibility as new maintenance practices and procedures are implemented. As a working document, it is anticipated that revisions will be made as maintenance forces determine the best methods of managing erosion and sedimentation.

Maintenance BMPs are those practices that must be integrated with the structural controls to achieve successful sediment control. For example, the snow storage areas should be properly utilized to avoid unnecessary off-site deposition of snow/sand. Sediment collection basins must be cleaned regularly to maintain effectiveness. Both winter and summer maintenance activities are necessary to adequately maintain the effectiveness of the drainage, erosion, and sediment control system in an effort to reduce off-site sedimentation. Maintenance BMPs taken from the CDOT's "Berthoud Pass East BMP Maintenance Plan" are provided below as an example:

- Reduce plow speed adjacent to the fill slope to 25 miles per hour or less to prevent excessive snow/sand throw distance
- Avoid plowing snow over the fill slopes
- Utilize existing snow storage areas to the extent possible
- Maintain drainage system, including culverts, inlets, and rundowns
- Avoid broadcasting snow over the top of knee walls
- Notify appropriate personnel and follow the appropriate maintenance procedures when snow storage zones build up and require removal
- Conduct sweeping and removal operations on regular basis (develop schedule)
- Clean out sediment basins on regular basis (develop schedule)
- Remove sand/sediment material to permanent disposal areas
- Identify and report areas where revegetation is needed
- Keep track of the volume of sand/salt material applied and collected
- Report any difficulties encountered to allow for timely actions to be taken

A maintenance plan can be developed and effectively implemented with or without structural controls in place. CDOT already implements routine sediment removal operations each year in the Berthoud Pass corridor with few structural controls in place. This includes sweeping, culvert cleaning, shouldering, and rock removal. If timed properly, routine maintenance can be very effective in reducing sediment transport.

As more structural BMPs are installed, the maintenance plan can be expanded to include new BMP features and methods as conditions warrant.

6.1 Structural BMP Maintenance

The following outlines key components of a BMP Maintenance Plan that may apply to the Berthoud Pass corridor (adapted from CDOT 2013):

1. A simple drawing of the BMP site, showing locations of all key components such as forebays, inlets, outlets, low flow channels or other components that require inspection or maintenance. The drawing should be kept in a location that is easy to access by maintenance managers and should be in the possession of inspection or maintenance crews when they inspect or perform maintenance of a BMP. Any changes to the facility over time should be noted on the drawing.
2. Numbering of the sediment basins and other treatment BMPs for easy reference.
3. A brief description of the inspection procedures and frequencies.
4. A brief description of the maintenance procedures, requirements and expected frequency of actions. Include instruction on how to access each component of the BMP and with what equipment.
5. An inspection form or checklist for each BMP facility. A log of inspection forms should be kept to demonstrate that routine inspections and maintenance are occurring.
6. Other items as appropriate for specific conditions.

6.1.1 Shoulders, Pan Drains and Curbs

General maintenance of shoulders, paved drains and curbs consists of sediment removal by grading, sweeping, or other methods.

- **Inspection** - Inspect twice annually for sediment accumulation.
- **Sediment Removal** - Remove sediment twice annually or as needed based on inspections. Sweeping should take place as soon as possible after spring snowmelt has finished (May) and before summer monsoon rain storms begin (July). Inspection and sweeping in fall (October), before snowfall accumulates is also recommended.

6.1.2 Drainage Rundowns, Slope Drains, and Culverts

Drainage rundowns, slope drains, and culverts require inspection and maintenance as-needed, but if installed correctly should not accumulate sediment.

- **Inspection** – Inspect and clean the drainage systems every one to two years for clogging, sediment and debris accumulation, and structural integrity. Be sure to inspect downstream outlet for erosion and development of head-cuts in the downstream channel. These should be repaired as soon as possible to prevent further erosion and damage to drainage structures.

- **Sediment Removal** – Remove sediment and debris as necessary to ensure proper functionality of drainage structure. If sediment removal becomes routine at a given structure, upstream sediment capture BMPs may be necessary (such as a loading dock trap or sediment basin).

6.1.3 Bench Traps

Routine maintenance of bench traps is not necessary; sediment removal activities will be needed every 3 to 5 years.

- **Inspection** – Inspect every one to two years for sediment, trash, and debris accumulation. Check for evidence of concentrated flows and repair if necessary.
- **Debris and Litter Removal** – Remove litter and debris annually.
- **Sediment Removal** – Sediment removal operations will be needed once bench trap has reached storage capacity, or a sediment depth of about 1-foot. This will consist of excavation, disposal, and re-grading of bench trap. These activities are expected once every 3 to 5-years.

6.1.4 Sediment Detention Basins and Traps

Sediment basins and sediment traps require routine inspection and maintenance to ensure optimal functionality and prevent captured sediments from being re-suspended and transported downstream and into the Fraser River.

- **Inspection** – Inspect at least twice annually, observing the amount of sediment accumulated and checking for debris and clogging at the outlet structure.
- **Debris and Litter Removal** – Remove debris and litter from the detention area as required to prevent clogging of the outlet.
- **Sediment Removal** – Sediment basins are estimated to require cleaning every 2 to 3 years. However, wet years with high applications of traction sand may increase the frequency of cleaning. Excessive sediment accumulation found by inspections may also warrant more frequent maintenance as well. BMPs should be maintained before accumulated sediment is in danger of being re-suspended with heavy stormwater runoff. Generally, this is when accumulated sediment reaches 50 percent of the design volume or when sediment accumulation results in poor drainage or ponded water. Sediment removal from above ground detention basins can usually be accomplished with a loader or excavator. Sediment removal from small concrete traps may require a vacuum truck. Ensure that sediment is disposed of properly and not placed where it can be mobilized into the waterways.

- **Erosion and Structural Repairs** – Repair inlets, outlets, trickle channels, and all other structural components required for the basin to operate as intended. Repair and vegetate eroded areas as needed following inspection.

6.1.5 Inlet Sediment Traps

Maintenance of inlet sediment traps requires cleaning of accumulated sediment to keep the inlet functioning. If these are not maintained, the inlets clog and become ineffective.

- **Inspection** – Inspect and clean the outlet screens, trash racks and orifice plates frequently to remove clogged debris. These tiny openings can clog easily. Inspect the vault structure at least annually. Look for excessive sediment accumulation and upstream debris that could cause bypass of the inlet. Specifically look for standing water in the inlet sediment traps indicating a clogged weep drain, screen, or orifice plate.
- **Sediment and Debris Removal** – Vacuum traps annually as needed, based on inspections.
- **Traffic Control** – Inspections and sediment removal may require traffic control depending on the location of the BMP.

6.2 Operations and Maintenance Cost

Operations and maintenance costs are a large portion of the life cycle cost for any structural BMP. These costs will be especially substantial for BMPs which receive high sediment loads, such as those in the Berthoud Pass corridor. These BMPs will require frequent and thorough maintenance to maintain proper functionality.

Maintenance costs were estimated for the BMPs specified in the SCAP Map Book. These include sediment basins, inlet sediment traps, and bench traps. The following data and figures present these estimates.

6.2.1 Operations and Maintenance Assumptions

The following assumptions were made to establish an annual cost for the BMP Maintenance Program.

- Sediment removal costs will be based on 80 percent of the sediment loading rate of **600 tons/mile/year** (400 cubic yards/mile). See **Table 6-1** for yearly traction sanding data.
- Maintenance includes the entire study corridor of 11.5 miles (MP 232.8 to 244.3).
- Sediment removal activities are expected to be required every two years on average.
- Sediment removal and disposal unit cost is estimated at $95 per cy as reported by CDOT Patrol 39 maintenance personnel. This includes traffic control, sediment removal, hauling and disposal, and equipment usage.

- This average cost also includes sweeping and vacuuming costs which are generally higher than the average, but these costs are offset by sediment basin excavation which can be completed at a lower cost.
- A semi-annual BMP maintenance training program is provided for maintenance crews.
- The sediment disposal program identifies any necessary permits or agreements and maintains disposal sites for the recovered sediment.
- Specialized maintenance is required for the vacuum truck and sweeper equipment. The vacuum truck maintenance and repairs are estimated at $75,000/year and the sweeper is $38,000/year. This results in $113,000/year to maintain 1 vacuum truck and 1 sweeper. However, it is assumed that these pieces of equipment will be used one-third of the time on the Berthoud Pass corridor every other year, so the equipment maintenance costs related to this SCAP are estimated as $19,000/year.

6.2.2 Annual Operations and Maintenance Cost

Based on the above assumptions, **Table 6-1** presents the estimated annual operations and maintenance costs for the BMP Maintenance Program. When all of the BMPs have been constructed along the Berthoud Pass corridor, the annual cost to maintain these BMPs is estimated to be $162,000 using 2015 dollar costs. For partial implementation of the recommended BMPs, the annual maintenance budget should be prorated accordingly.

Table 6.1. Annual BMP Maintenance Program Costs

Annual Item Costs	Total Item Cost
Sediment Removal and Disposal [1]	$138,324
Training Program	$5,000
Equipment Maintenance [2]	$19,000
TOTAL	**$162,324**

Notes:

[1] Based on current costs with 10-mile haul; longer hauls in the future will increase costs. These costs are based on full build-out of BMPs including: 33 Inlet Traps, 153 Sediment Basins, and 2.8 miles of Bench Traps. These costs assume 1.5 tons/CY sediment density.

[2] This cost is estimated for maintaining 1 vacuum truck and 1 sweeper. Total estimated maintenance cost for this equipment is $113,000/year; they are assumed to be used roughly 1/3 of the time in the SCAP area. Standard equipment such as loaders and backhoes are maintained separately.

6.3 Equipment

Meetings were held with CDOT maintenance personnel for this SCAP to gain an understanding of their issues and needs for sediment control. A recurring issue was the need for more equipment to clean up sand and sediment from the roadway. CDOT typically uses a multitude of equipment including excavators, front loaders, graders, and sweepers (brooms) to pick up sediment. This equipment fleet is shared among patrols and is used for other purposes in addition to sediment cleanup.

A high performance vacuum truck, designed to be effective at high elevations, was purchased by CDOT. There has been very high demand for use of the vacuum truck throughout the region to clean culverts and sediment basins.

The sweepers typically in use by CDOT are not efficient at picking up sand and sediment; a better sweeper which is designed to collect sand is needed. In view of the high demand for suitable sand and sediment cleanup equipment, it is recommended that each patrol maintain a fleet of essential equipment. This is particularly important when considering the need to have equipment available for sand cleanup at specific times of the year for effective sediment control.

6.4 Disposal of Sediment

An existing agreement for the disposal of sediments recovered from the Fraser River Diversion Sediment Basin is detailed in a MOU dated July 12, 2011 (CDOT 2011). This MOU document establishes that all sediments collected from Fraser River Diversion Sediment Basin are approved for transport to the Benson Pit west of Fraser. Grand County operates the Benson Pit, which has storage space for all sediments collected. As material from the Fraser River Diversion Sediment Basin have been previously sampled, tested and cleared as non-hazardous waste, Grand County is allowed to reuse some of the material. The reuse of these materials saves both County and State taxpayer funds by minimizing fuel and labor while protecting water quality in the upper Fraser watershed.

The MOU stipulates the following parameters for disposal of sediments at the Benson Pit:

1) The State (CDOT) will collect all material from the Sediment Basin.

2) Prior to transport to the Benson Pit, all trash will be removed from the sediment. Wet material will be stockpiled and dried.

3) The State (CDOT) will convey all material to the Benson Pit and place it in a location directed by Grand County.

4) Grand County may request sampling and testing of collected sediments to insure that characteristics are as described. This will be paid for by the State (CDOT).

5) The State (CDOT) will notify Grand County at least 7 days prior to transport of sediment to the Benson Pit. Notification will be provided by email to the Grand County Road and Bridge Supervisor, which will be saved to ensure time-stamp of such notification.

7.0 SURFICIAL SLOPE STABILITY EVALUATION

This section presents the result of the sediment control evaluation for the western portion of Berthoud Pass. The evaluation assessed the soil erosion potential at the time of investigation and consisted of field reconnaissance and review of existing literature.

7.1 Investigation and Literature Review

The investigation, by Yeh & Associates, consisted of two site visits on September 21, 2015 and October 31, 2016 and review of the following literature:

- Geologic map of the Berthoud Pass quadrangle, Clear Creek and Grand Counties, Colorado, U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-443 by P. Theobald, 1963.
- Colorado Rockfall Hazard Rating System, Colorado Department of Transportation, Report No. CTI-CDOT-2-94 by R. Andrew, May 1994.
- Evaluation of Slope Stabilization Methods (US-40 Berthoud Pass), Colorado Department of Transportation, Construction Report by D. Price, March 1996.
- Evaluation of Slope Stabilization Methods (US-40 Berthoud Pass), Colorado Department of Transportation, Report No. CDOT-DTD-R-2002-10 by M. Banovich and W. Outcalt, July 2002.
- Erosion Control and Stormwater Quality Guide, Colorado Department of Transportation, 2002.
- Modifications and Statistical Analysis of the Colorado Rockfall Hazard Rating System, Colorado Department of Transportation, Report No. CDOT-2008-7 by C. Russel, P. Santi, and J. Higgins, September 2008. U.S. Highway 40, Berthoud Pass, Colorado—Effective Preservation and Restoration, Colorado Department of Transportation, by M. Banovich and I. Zisman, 2004, in Proceedings High Altitude Revegetation Workshop No. 16.
- CDOT Landscape Architecture Manual, Prepared by DesignWorkshop, 2014.
- "Berthoud Pass." 39°47'53.77"N and 105°46'40.03"W. **Google Earth.** Images dated October 2012, September 23, 2011 and accessed October 6, 2015.
- Soil Survey Staff, Natural Resources Conservation Service, U.S. Department of Agriculture. Web Soil Survey.
- "Berthoud Pass." 39°47'53.77"N and 105°46'40.03"W. Google Maps, available online at https://www.google.com/maps**.** Street View images dated October 2007, October 2012, and October 2015, and accessed October 28, 2016.

Google Street View imagery, available through Google Earth and Google Maps, was an important tool for comparing the existence and condition of erosional features. Generations of

Street View images taken prior to what is currently shown through Google Earth are only available through Google Maps.

7.2 Regional Geology

The bedrock in the region of Berthoud Pass is igneous in origin and is shown on the referenced geologic map as Silver Plume Granite and Boulder Creek Granodiorite. Along Berthoud Pass, these rocks have been partially covered by till, which is coarsely graded sediment directly deposited by glaciers. Soils formed from decomposition and weathering of the igneous bedrock and glacial deposits are part of the Leighcan Family of soils. The bedrock and till have identical typical soil profiles, from cobbly silt loam at surface to extremely stony loamy sand between 45 to 60 inches deep. These soils are low-clay, have high runoff and therefore have poor water retention.

7.3 Site Conditions

The summit of Berthoud Pass is at an approximate elevation of 11,307 feet. The sites visited are north of the summit at elevations between approximately 9,900 to 11,000 feet. The slopes of interest are northeast- to southeast-facing. At the time of our first site visit, the asphalt roadway had been recently resurfaced and no damage from previous roadway events could be assessed. Most of the sand to fine-gravel sized material observed during both site visits alongside the travel lanes and in ditches appears to be roadway sand placed for traction.

7.3.1 Milepost 242.35

At milepost 242.35 are two sites, A and B, which may be contributing to sedimentation. Site 242.35 A is an existing drainage channel with shallow bedrock overlain by glacial till and alluvium (**Figure 7-1**). Site 242.35 B consists of weathered igneous bedrock that is less resistant than adjacent slopes, which suggests the presence of a fault (**Figure 7-2**). This site has little vegetation and is covered with grus, or coarse grained, angular, sand and gravel sized material resulting from the chemical and mechanical weathering of granitic rocks. No erosion control structures were observed at these two sites at the time of investigation. Site 242.35 A is approximately 300 feet long by 20 feet high. The dimensions of site 242.35 B are approximately 50 feet by 50 feet.

Figure 7-1. Drainage channel at 242.35 A

Figure 7-2. Weathered bedrock and possible fault shedding sediment at milepost 242.35 B

7.3.2 Milepost 242.1

At milepost 242.1 the cutslope consists of extremely weathered bedrock (residuum) and alluvium (**Figure 7-3**). Some smaller fir trees and thin grassy vegetation is growing on the slope. There is some minor raveling at the brow and minor undercutting of the base of the slope by seasonal runoff flowing in the shoulder ditch. This site is approximately 450 feet wide by 75 feet high.

Figure 7-3. Milepost 242.1

7.3.3 Milepost 241.95

The slope at milepost 241.95 consists of highly weathered bedrock with a pocket of glacial till (**Figure 7-4**). The brow and upper area including both till and bedrock is oversteepened. At the time of investigation, there were active seeps in the lower, bedrock portion of the slope and no erosion control measures were observed. The dimensions of the oversteepened area of this slope are approximately 600 feet width and 30 feet height.

Figure 7-4. Milepost 241.95. The pocket of glacial till (gray) which was deposited in a channel or valley in the igneous bedrock (orange-brown)

7.3.4 Mileposts 241.75 and 241.48

The sites at mileposts 241.75 and 241.48 are east-facing slopes of weathered igneous bedrock. The slopes consist of grus and minimal topsoil with a thin cover of grassy vegetation and sparse short trees. The conditions along this stretch of roadway during the site visit appear to be similar to conditions visible in Google Street View imagery dated October 2012. Seasonal seeps and springs have caused surficial slope failures and local disturbance of the topsoil and vegetation. No existing erosion control structures were apparent at these two sites at the time of investigation.

At milepost 241.75, a previously-existing natural drainage channel has apparently weakened and collapsed, causing vegetation and rock at the top of the slope to fall into the drainage (**Figure 7-5**). A corrugated metal culvert outlet pipe opposite the slope across the road and to the east was trickling water at the time of investigation. No culvert inlet was visible at the time of investigation. The collection of rock and sediment at the base of the drainage has apparently buried the inlet. No moving water was observed on the slope at the time of investigation, but the fine sediment resting at the base of the drainage was wet. The site at milepost 241.75 is approximately 330 feet wide by 50 feet high.

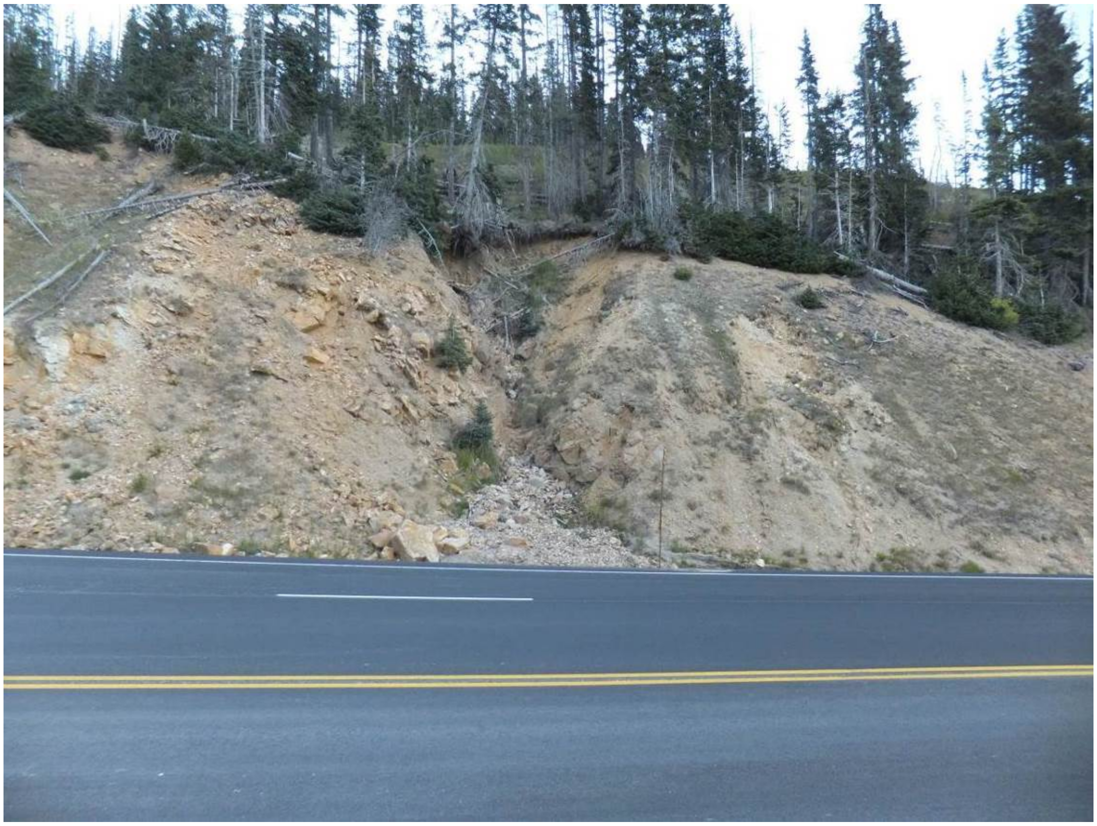


Figure 7-5. Slope failure at exiting drainage at milepost 241.75. Culvert inlet is buried by rocks and sediment at base of failure

At milepost 241.48, the igneous bedrock has collapsed as rockfall along a joint plane parallel to the roadway (**Figure 7-6**). This failure has formed a chute that is partially filled with rocks from the collapse. An alluvial fan of rockfall material has formed at the base of the chute. This chute has created a channel that could direct water and sediment into the naturally-formed stream parallel to the roadway, northward, and downslope. The chute is approximately 15 to 20 feet from the edge of asphalt. The wall of rock that remains standing between the road and the chute could also collapse. An additional investigation would be required to determine the impact of rockfall from this area onto the roadway. There may be enough area between the wall and the roadway to act as a rock catchment zone and buffer the roadway from most of the rockfall material, but that is unknown at this time. The site at milepost 241.48 is approximately 100 feet wide by 70 feet high.

Figure 7-6. Milepost 241.48

7.3.5 Mileposts 241.3 and 241.28

The sites at mileposts 241.3 and 241.28 are north-facing slopes of glacial till. The oversteepened slope at milepost 241.3 has a thin layer of topsoil supporting tufts of grass and conifer trees (**Figure 7-7**). Near the top of the slope, some glacial material has failed as slopewash, or possibly as a small earthflow. Slopewash occurs during abundant rainfall or rapid snowmelt washes the surface rocks and soils downslope. Earthflow can also occur during abundant rainfall and rapid snowmelt, though the failure is the result of oversaturation and is typically a mass movement rather than a slow, continuous removal of material. The slopes on either side of the failure are supporting slightly more vegetation and larger fir trees. An outcrop of igneous bedrock forms part of the lower half of this slope, which appears to have minimal impact on the stability or movement of the glacial material above and adjacent to it. The slope at milepost 241.28 (**Figure 7-8**) has a thin layer of topsoil supporting abundant tufts of grass, conifer trees, and small bushes. Some small boulders were observed resting on the slope at various heights above the roadway at the time of investigation. The established vegetation and apparently stable boulders suggest the slope is relatively stable. The brow of the slope is a natural near-vertical, relatively fresh, exposure of the glacial till deposits. This is the source of the small boulders found on the vegetated slope below. A few large boulders, greater than one foot diameter, were observed on the slope. There is a relatively deep ditch at the base of the slopes parallel to the roadway at both mileposts 241.28 and 241.3 that appeared to be incised naturally by flowing water (**Figure 7-9**). This ditch is serving as a catchment for boulders. Based on the site review it is apparent that milepost 241.3 lacks the smaller conifer trees that are now growing adjacent to the failure. A near-vertical exposure at the brow of milepost 241.28 appears the source for some of the local sediment. No sediment control measures were observed at either location at the time of investigation. The site at milepost 241.3 is approximately 100 feet wide by 80 feet high; the site at milepost 241.28 is approximately 200 feet wide by 40 feet high.

Figure 7-7. Milepost 241.3

Figure 7-8. Milepost 241.28

Figure 7-9. Naturally incised drainage ditch that serves as a catchment for small boulders between mileposts 241.28 and 241.3

7.3.6 Milepost 240.6

The site at milepost 240.6 consists of several feet of glacial till overlying weak igneous bedrock **(Figure 7-10**). There is evidence of seasonal springs in the form of shallow slope failures and minor earthflow features that have removed the thin layer of topsoil and vegetation. No existing erosion control features were observed at the time of our investigation. This site is approximately 1000 feet wide by 90 feet high.

Figure 7-10. Milepost 240.6

7.3.7 Milepost 239.7

Poor quality igneous bedrock and a possible shear zone are present at milepost 239.7 (**Figure 7-11**). Joints in the bedrock are discontinuous and in unfavorable orientations. The possible shear zone is the prominent sediment source at this location; the rest of the identified site presents minimal to no sediment source but presents a rockfall hazard. This site is approximately 500 feet wide by 80 feet high; the shear zone is approximately 100 feet wide.

Figure 7-11. Milepost 239.7. Possible shear zone in center of photo

7.3.8 Milepost 239.56

The site at milepost 239.56 is a steep slope of northeast-facing weathered igneous bedrock that is jointed perpendicular to the roadway (**Figure 7-12**). The minimal topsoil with grassy vegetation tends to be near the bottom, and less steep, parts of the slopes. Conifer trees are growing on the upper portion of the slope immediately northwest of the slope failure. The slope failure is a collapse feature that failed as a rockfall along joint planes. The resulting chute is perpendicular to the roadway and appears to direct water and sediment towards the roadway. Although no large rocks were found during this investigation, rocks at the surface made mobile during precipitation events or by freeze/thaw could become mobile and travel along this chute. No large rocks were observed at the base of the chute during this investigation, and grasses were growing on fine granular material at the base of the chute. This indicates that the failure occurred some time ago as the rocks have been removed and vegetation has been re-established. At the top of the chute, the topsoil and root zone of the trees has been undercut and is in danger of collapsing into the chute and possibly into the roadway. No erosion control measures were observed. The dimensions of this site are approximately 50 feet by 50 feet.

Figure 7-12. Milepost 239.56

7.3.9 CDOT Mitigated Area from the mid-1990s

The remaining locations are within the portion of roadway that CDOT focused erosion mitigation measures in the mid-1990s. This work included construction of an approximately three foot tall concrete wall and a ten to twelve foot wide concrete-lined drainage ditch between mileposts 239.4 and 238.05 “to help reduce undermining” (Price, 1996). Most of the slopes within this area consist entirely of glacial till deposits; there are occasional igneous bedrock outcrops on the slope below the glacial material. The glacial deposits contain boulders sometimes exceeding two meters (6 feet) in diameter (Price, 1996). The finer material is washed away with rain and snowmelt, exposing and removing support from the larger gravels and boulders which may then tumble towards the roadway.

7.3.10 Milepost 239.1

The fill side of the roadway at milepost 239.1 consists of alluvial and glacial till material (**Figure 7-13**). Sheetwash and surficial erosion has removed vegetation and prevented successful regrowth. The cutslope side of the roadway consists of glacial till and is performing well. Geocell matting is present along the brow. There is no curb at the base of the guardrail along this section of roadway. This site is approximately 800 feet wide and as much as high as 350 feet.

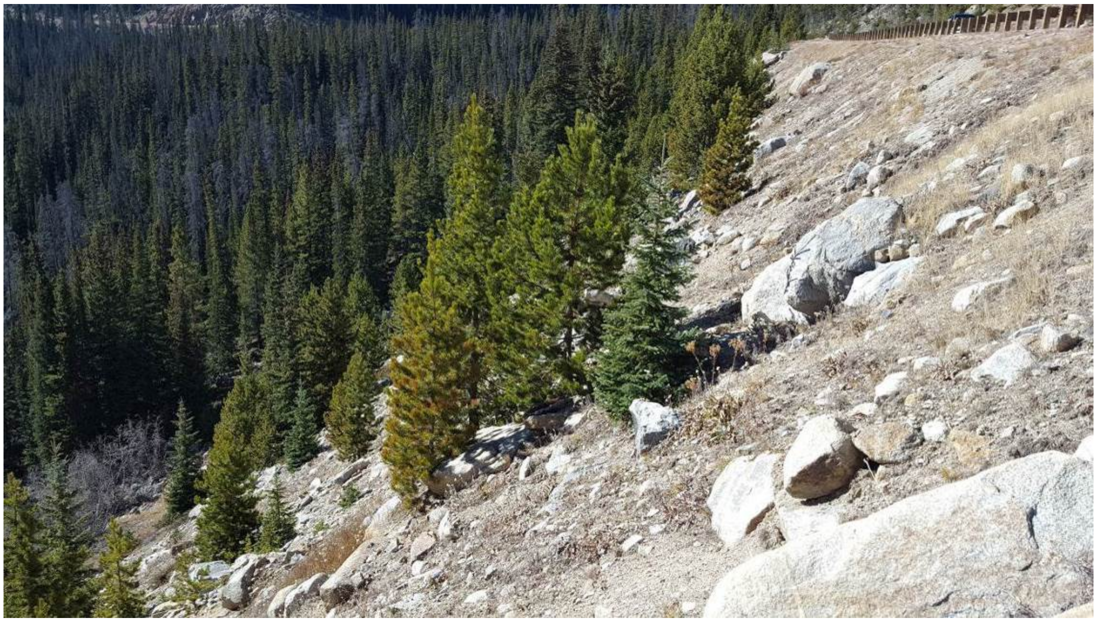


Figure 7-13. Fill side of roadway at milepost 239.1 affected by slopewash and surficial erosion

7.3.11 Milepost 238.7

The oversteepened slope at milepost 238.7 is comprised of glacial till deposits that include exposed boulders approximately 6 feet in diameter (**Figure 7-14**). The slope has a minimal layer of topsoil supporting tufts of grass and some wildflowers. A scarp at the top of the eroded section suggests the failure originated as an earthflow. Further erosion continues due to slopewash and seasonal spring blowouts. No vegetation was growing on this eroded section at the time of investigation. Much of the material removed from the slope has accumulated at the base of the slope and on the barrier wall (**Figure 7-15**). Some gravel and small boulders have fallen onto the concrete ditch, and at least one small boulder had reached the asphalt of the roadway at the time of investigation (**Figure 7-16**). No sediment control measures, aside from the wall and ditch, were observed at the time of investigation. The brows are partially covered with cellular and erosion control blankets. This site is approximately 800 feet wide by 100 feet high.

Figure 7-14. Milepost 238.7

Figure 7-15. Accumulation of slopewash material at milepost 238.7

Figure 7-16. Small boulders that have fallen onto the concrete ditch and asphalt roadway at milepost 238.7

7.3.12 Milepost 238.65

At 238.65, the fill side of the roadway consisting of alluvial and glacial till material is affected by sheetwash and surficial erosion (**Figure 7-17**). Much of the vegetation has been removed or covered with soil resulting in extensive rill erosion. There is no curb beneath the guardrail along this section of the road. This site is approximately 1000 feet wide and as high as 350 feet.

Figure 7-17. Milepost 238.65

7.3.13 Milepost 238.4

The oversteepened slope at milepost 238.4 is comprised of glacial till deposits. There are several apparent failures on the slope due to slopewash and seasonal spring blowouts. Rocks and sediment have accumulated near the bottom of the slope and on the barrier wall beneath the larger eroded section. Water has ponded at the base of the slope immediately behind the wall and was actively flowing over the wall at the time of investigation. Lush, yellow-green vegetation, including willows, growing in and near the ponded water indicate that springs are perennially active. Water has been flowing over the wall long enough for algae to grow on the wall. The slopewash failure is significantly higher than the springs and therefore should not be affected by the lower perennial spring water. The largest eroded area on the slope appeared very similar at the time of site visit to the Google Street View images dated October 2012. The smaller of the two most prominent eroded areas as seen in **Figure 7-18** is much less noticeable in the Google Street View images and appears to have grown significantly between the Google image date of October 2012 and the time of our investigation. This site is approximately 1200 feet wide and 100 feet high.

Figure 7-18. Milepost 238.4

7.3.14 Milepost 238.2

At milepost 238.2 is an east-northeast-facing oversteepened slope of glacial till deposits and some poorly exposed, highly weathered outcrops of igneous bedrock on the lower portion of the slope (**Figure 7-19**). The thin layer of topsoil appears to support of variety of grasses. Large boulders, greater than 3 feet diameter, were exposed on the slope at the time of our site visit. These slopes had experienced seasonal seeps and spring blowouts and significant slopewash. One large boulder had apparently recently become loosened and slid down to rest near the barrier wall. Pieces of concrete have been removed from the top of the barrier wall, apparently due to damage from falling boulders. The brow of the slopes have been covered with erosion control and cellular blankets. The slopes are partially covered with snow in the Google Street View images dated October 2012, but the blowout and erosion in the center of the site appears to be smaller than at the time of site visit and appears as a scarp with minimal erosion below. The blowout and erosion on the western portion of the slope is not apparent in the Street View images but boulders and tufts of grass dot the slope indicating that most or all of the slopewash occurred between October 2012 and the time of investigation. This site is approximately 450 feet wide and 100 feet high.

Figure 7-19. Spring blowouts (shallow localized slope failures) and slopewash at milepost 238.2

7.3.15 Milepost 237.9

The slope at milepost 237.9, between switchbacks, is an east-facing oversteepened slope (**Figure 7-20** and **Figure 7-21**). The slope consists of glacial till and weathered igneous bedrock. The upper portion of the slope is covered with a thin layer of topsoil supporting grasses. The lower portion of the slope is igneous bedrock outcrop that supports some tufts of grass and small bushes on ledges. The middle section of this slope is covered by light-colored draped mesh. An erosion control blanket was in place covering a portion of the upper slope during the site visit. The blanket itself was covering what appears to be an earthflow feature or small rockfall of strongly weathered igneous rock. Slopewash has eroded the height of the slope between the blanket to the barrier wall and sediment up to small boulder size has accumulated on the barrier wall. No rocks greater than gravel size were found in the ditch at the time of investigation. The erosion control blanket is visible in the Google Street View images dated October 2012 but the only apparent erosion associated with the blanket seems to be minor slopewash immediately below the blankets. The earthflow and significant slopewash are therefore more recent phenomena, three years old or younger at the time of investigation. The north and south currently unmeshed portions of this slope are referred to as sites A and B, respectively. Site 237.9 A is approximately 50 feet by 50 feet and site 237.9 B is approximately 300 feet wide by 60 feet high.

Figure 7-20. The upper slope at milepost 237.9, as viewed from the lower switchback

Figure 7-21. Accumulation of sediment on the knee wall and the lower portion of the slope at milepost 237.9

7.3.16 Milepost 237.6

The east-facing slope at milepost 237.6 is oversteepened and consists of glacial till deposits (**Figure 7-22**). The till includes material of various sizes up to large boulders, possibly greater than 6 feet in diameter. In the segment delineated as 237.6 A, a thin layer of topsoil supports grasses and sparse conifer trees and bushes (**Figure 7-23)**. A green synthetic erosion control mat has been used to reduce erosion along the slope transition from native slope to cut slope. A perennial stream flows in the southern drainage, referred to as 237.6 B (**Figure 7-24**), and was active at the time of both site visits. Above the knee wall at the southern drainage is a collection of boulders, some of which were placed for erosion control and some that have rolled down the slope. Erosion control blankets have been placed on the brow of the slope and atop the ridge between the drainages. The barrier wall has been damaged by falling rock beneath both drainages and has been patched in some places. In the segment delineated as 237.6 C there are two drainage channels present, one of which has been filled with local material (**Figure 7-25**). At the base of this filled channel Type 4 barrier and fencing has been installed on top of the knee wall and is heavily damaged from falling boulders. The condition of the slope appears very similar in the Google Street View images dated October 2012 to the condition at the time of our investigation. The Street View images show two tree trunks on the northern failure that appear to have been removed by the time of our first site visit. A young conifer tree growing in the middle of the northern failure at the time of our site visit is not apparent in the Street View images, indicating that the slope has been stable enough to support some vegetation regrowth within the last several years. Site 237.6 A is approximately 200 feet wide by 50 feet high; site 237.6 B is approximately 35 feet wide by 50 feet high; site 237.6 C is approximately 25 feet wide by 80 feet high.

Figure 7-22. Milepost 237.6 showing (A) the glacial till slope (left), (B) active drainage channel with collection of boulders on knee wall (center), and (C) former drainage filled with till and alluvium (right, above damaged Type 4 barrier and fencing)

Figure 7-23. Milepost 237.6 A, slope of glacial till with erosion blanket at brow

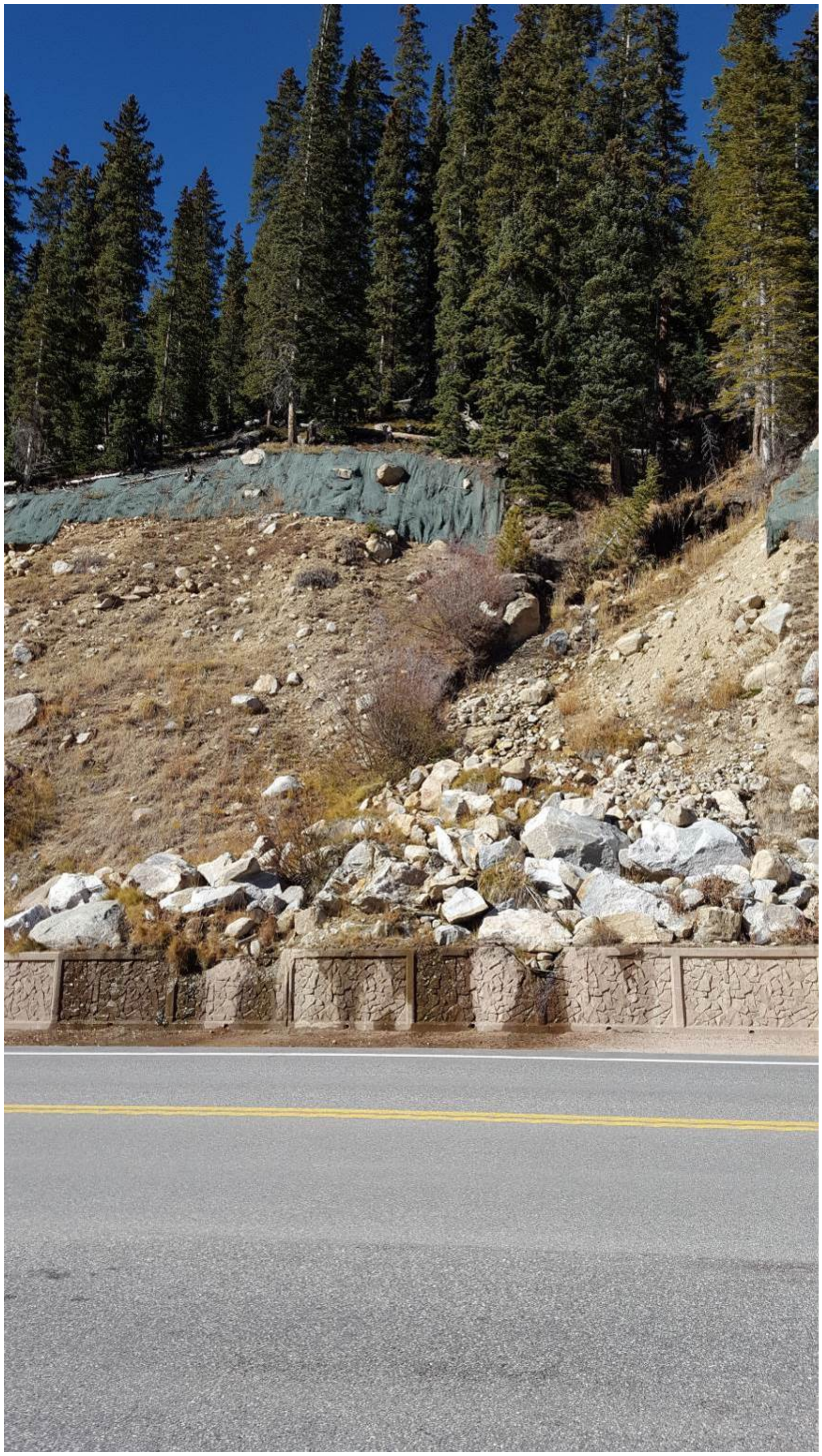


Figure 7-24. Milepost 237.6 B, perennial stream drainage with collection of boulders above knee wall. Some boulders were placed for erosion control while others rolled from the slope above

Figure 7-25. Milepost 237.6 C, drainage channel which was partially stabilized with boulders and fill during the mid-90's slope stabilization projects. Type 4 barrier and fencing placed on top of knee wall for erosion and rockfall control has been heavily damaged

7.3.17 Mileposts 237.38 and 237.35

The east-facing oversteepened slopes at mileposts 237.38 and 237.35 consist of highly weathered igneous bedrock overlain by glacial till (**Figure 7-26** and **Figure 7-27**). The brows of the slopes were covered with erosion control blankets at the time of investigation. Much of the igneous bedrock has weathered to grus, though the weathering of the outcrop appears to be forming some boulder-sized fragments. Seasonal spring blowouts and failures in the weak bedrock occur due to saturation of the overlying glacial material. Seasonal blowouts and slopewash appear to be the main erosion processes on these slopes. Sediment and small boulders have accumulated at the base of the slope and on top of the barrier wall. The barrier wall had some existing damage apparent during our site visit. There was very little sediment and rocks found in the concrete ditch at the time of investigation. In the Google Street View images dated October 2012, there are some rocks and sediment in the ditch below the slope at milepost 237.35 and abundant rocks and sediment in the ditch below the slope at milepost 237.38. The condition of the slopes in the Street View images is very similar to the conditions seen on our site visit. There appeared to be slightly more vegetation growing near the base of the slope at 237.38 at the time of investigation than in October 2012. The combined width of both sites is approximately 250 feet and the heights of both sites vary between approximately 70 and 100 feet.

Figure 7-26. Milepost 237.38

Figure 7-27. Milepost 237.38 (right) and milepost 237.35 (left)

7.3.18 Milepost 237.2

At milepost 237.2, a portion of the slope is not covered by draped mesh, though the adjacent slopes are covered by mesh. There are erosion control blankets on the brow, however. This slope consists of weathered, poor quality bedrock (**Figure 7-28**). This site is approximately 100 feet wide and 75 feet high.

Figure 7-28. Milepost 237.2

7.4 Evaluation of Erosion Potential

The conditions at the thirteen sites of interest along US 40 at Berthoud Pass have some potential to affect roadway travel. All of the oversteepened slopes could create hazardous conditions along the roadway during or after heavy rainfall or rapid snowmelt runoff. Sites based in igneous bedrock, could potentially deliver rocks into the travel lanes, but in general will contribute little sediment. Sites based in glacial till deposits appear to have the greatest potential for rocks and sediment to reach the roadway and/or flow towards the watershed. The greater hazard posed by these oversteepened slopes in glacial material has been previously noted by CDOT (Andrew, 1994). All of these glacial sites are within the zone of erosion control mitigation projects carried out by CDOT in the mid-1990s, and some of these sites appear to have the most currently active and significant spring blowouts and slopewash occurrences as seen when comparing the historical images from Google Street View to those taken during our site visits. The differences seen between these images, especially at milepost 238.2, is possibly due to excessive rainfall during September 2013 which caused widespread flooding and mass wasting events in north-central Colorado. The potential for sediment and large rocks to reach the roadway is high at milepost 237.6, and the existing erosion control structures in place suggest that the travel lanes have been repeatedly impacted at this location. The wide concrete ditch along the knee wall at most discussed locations acts as a catchment zone and buffers the roadway from some falling rocks. Most of the fallen material seen during our site visit and in Street View images appears to have landed in the ditch.

7.5 Sediment Control and Mitigation Options

7.5.1 Slope Rounding

Slope rounding, which consists of rounding the top of the slope brow can be an effective method to reduce erosion rates. Steep brows in unconsolidated material are prone to erosion and slopewash. These areas can generate rockfall from underlying materials and generally are undercut creating the potential for larger scale slope instability. In addition, brows with sharp changes in grade, such as those with sub-horizontal tops or ledges above steep slopes, tend to erode or fail more rapidly than gently curved brows. According to the CDOT Erosion Control and Stormwater Quality Guide, Chapter 5, rounding can be considered when existing slopes are steeper than 2H:1V at the top, and rounding typically occurs over a distance of 20 feet (**Figure 7-29**). Revegetation is necessary after rounding to further reduce erosion rates, especially as a result of heavy rains or rapid snowmelt.

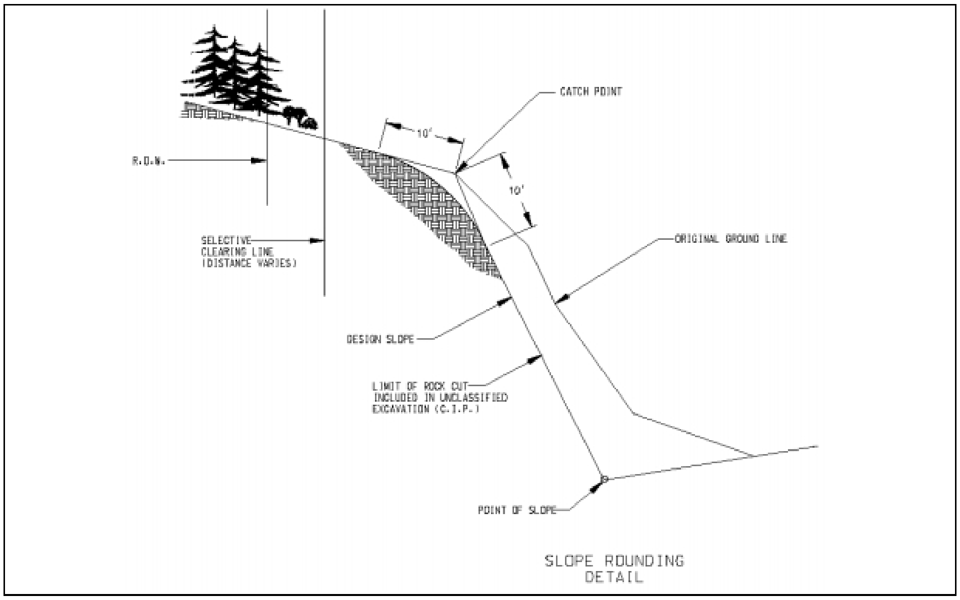


Figure 7-29. Depiction of slope rounding from CDOT's Erosion Control and Stormwater Quality Guide

7.5.2 Revegetation

Multiple applications of seed have proven effective in establishing sufficient vegetation cover as described in "Evaluation of Slope Stabilization Methods (US 40 Berthoud Pass)." This report describes CDOT's three-stage soil preparation method involving seed, fertilizer, tackifier, and mulch. Once established, the vegetation reduces erosion and blends the disturbed slope into the surrounding natural landscape (**Figure 7-30**).

Figure 7-30. Photograph of revegetated slope (after rounding) from CDOT's Landscape Architecture Manual

7.5.3 Scaling

Scaling of steep rock cuts and colluvial slopes can be useful to remove loose material, mostly large cobbles and boulders that are unstable and prone to rolling down the slope. However, in some instances, scaling can cause further undermining or destabilization of the slope. Select scaling should be observed by an individual familiar with scaling operations. **Figure 7-31** depicts manual scaling of a rock slope.

Figure 7-31. Manual scaling of a rock slope using scale bars

7.5.4 Draped Mesh

Draped mesh systems are typically used to reduce rockfall and offer slope protection to reduce erosion. Draped mesh adds a degree of confinement to the loose materials on the slope surface and can reduce erosion of surficial materials. Draped mesh allows rock to migrate under the system and be deposited in a catchment ditch that may need routine cleaning to remove fallen material. Shoulders and ditches beneath these slopes will need periodic cleaning to remove the sediment. Draped mesh is typically anchored about 10 feet back from the top of the brow of a slope. Draped mesh is preferred over pinned mesh on steep, rocky slopes because of the tendency of pinned mesh to accumulate sediment at anchor points and create future maintenance issues. An example of draped mesh is shown in **Figure 7-32**.

Figure 7-32. Example of draped mesh

7.5.5 Pinned Mesh

Pinned mesh is a common method used to stabilize soil and rock slopes with a pattern of anchors installed to further confine surficial materials beneath wire mesh (**Figure 7-33**). Pinned mesh has been successfully used to reduce erosion and increase stability or soil and rock cuts. Pinned mesh systems that are installed on steeper slopes may require periodic maintenance and cleaning if accumulation of materials begins to create bulging of the system. This typically does not occur on slopes less than 45 degrees. Additional anchors on a tighter pattern and/or longer anchors can be installed to further stabilize the slope. These systems typically require design to provide the best product.

Figure 7-33. Example of pinned mesh

7.5.6 Erosion Mats

Erosion mats (**Figure 7-34**) are polypropylene mesh with smaller cells than other wire mesh products. Erosion mats can be placed under draped or pinned mesh or woven in the mesh to enhance the containment of rocks and smaller material.

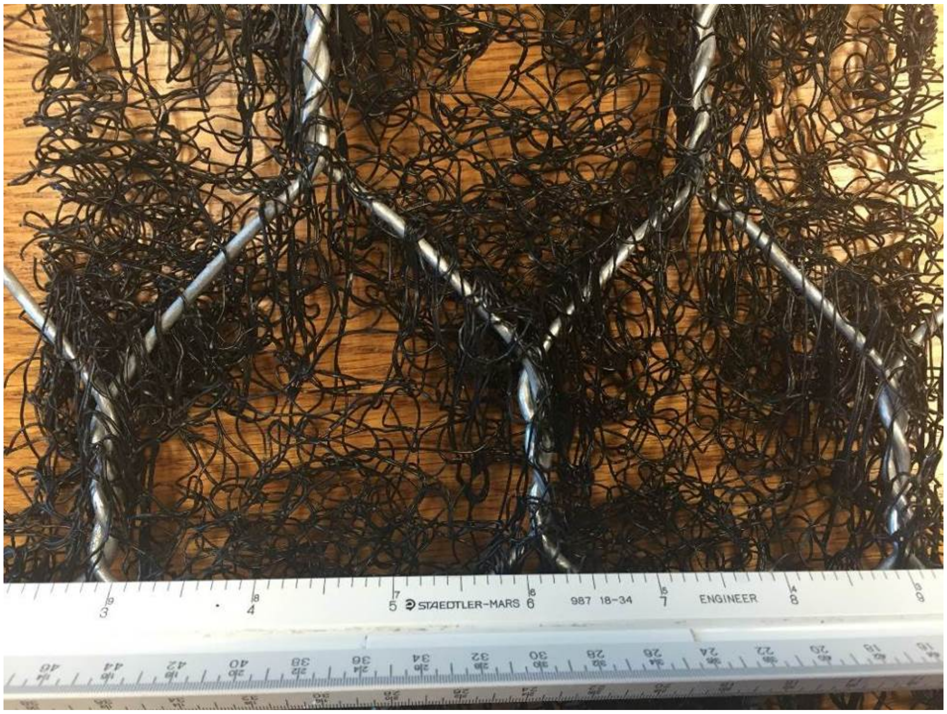


Figure 7-34. Example of polypropylene erosion mat woven with mesh

7.5.7 Drainage Rundown Structure and Rock Inlays

A drainage rundown structure in the form of an inlaid terraced rockery involves over-excavating the base of the slope, inlaying or keying-in boulders for slope stability, and stacking boulders on top of the inlay to a prescribed height within a drainage channel. A grout or flow-fill can be used to reduce infiltration between boulders. An example of an inlaid terraced rockery is shown in **Figure 7-35**.

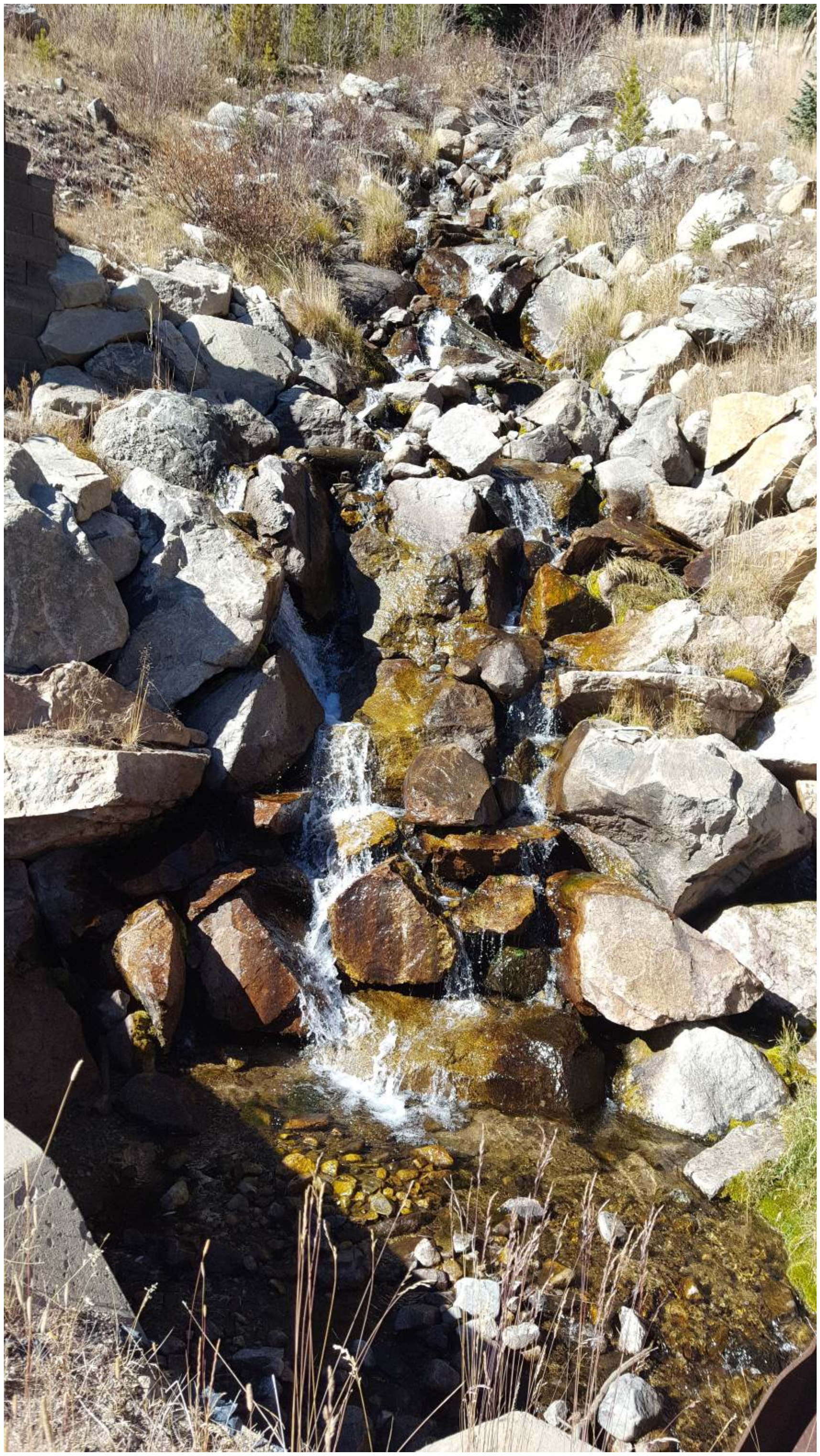


Figure 7-35. Example of an inlaid terraced rockery rundown feature at a tributary of Hoop Creek

7.5.8 Concentrating Runoff Flow (Addition of Curb to Fill Side of Roadway)

Concentrating runoff involves collecting and channeling water into a certain direction or path. This can create new problems if the directed pathway is not stable or reinforced. It is necessary to evaluate the slope that the concentrated flow will follow and install a culvert, structured channel, terraced rockery, or other appropriate solution to prevent incision.

7.5.9 Replacement of Geocell with Enkamat or Similar Product

The Geocell mats that were placed in the 1990s are torn, stretched, and not performing well. In select areas, it may be beneficial to replace (or cover) the Geocell mats with new Enkamats or similar product which perform better. An example of existing Geocell and Enkamat products on Berthoud Pass is shown in **Figure 7-36**.

Figure 7-36. Poorly-performing Geocell mats (left and center) and better-performing Enkamat (right)

7.6 Suggested Slope Treatments

Prior to selecting the preferred mitigation option or options for a site, each site should be surveyed to provide site geometry information for design of appropriate mitigation, quantities, and for bidding.

In general, most igneous bedrock cutslopes can first be scaled, then sediment and debris removed from ditches at the base of the slope, and finally the slope can be covered with draped mesh. These slopes are often too rocky, with almost no soil cover, for reseeding. Reseeding efforts can be successful in select areas of weathered bedrock cutslopes.

Cutslopes of glacial material can be scaled to remove large boulders, if exposed, after review of the scaling effort by a qualified individual. Rounding of oversteepened brow sections can also be performed during scaling. Next, a reseeding effort can be pursued followed by installation of a mesh and erosion mat system.

Table 7.1, **Table 7.2**, and **Table 7.3** provide approximate cost estimates for select mitigation measures.

Table 7.1. Estimated Costs for Draped Wire Mesh with Polypropylene Erosion Mat (See Figure 7-32)

Item	Low	High
Wire Mesh	$3.00 SF	$6.00 SF
Erosion Mat	$1.50 SF	$3.00 SF
Mesh Anchor*	$0.97 SF	$1.53 SF
Est. Total Cost	$5.50 SF	$10.50 SF

*Assumed 12 feet anchor spacing and 30 feet of mesh extending down slope

Table 7.2. Estimated Costs for Pinned Wire Mesh with Polypropylene Erosion Mat (See Figure 7-33)

Item	Low	High
Wire Mesh	$3.00 SF	$6.00 SF
Erosion Mat	$1.50 SF	$3.00 SF
Anchor*	$7.50 SF	$14.00 SF
Est. Total Cost	$12.00 SF	$23.00 SF

*Assume 10' x 10' anchor spacing

Table 7.3. Estimated Costs of Scaling (See Figure 7-31)

Item	Cost per Crew Hour	Scaling Time needed at each site per Crew	Removal of Material, per cubic yard	Estimated amount of material to be removed at each scaling site
Scaling	$250-$300	20-40 hours	$35-$50	30-60 cubic yards

Table 7.4 presents a summary of site conditions, dimensions, mitigation options, and costs.

Table 7.4. Summary of Site Conditions, Dimensions, Mitigation Options, and Costs

Milepost	Description	Approximate Length (ft)	Approximate Height (ft)	Approximate Area (SF)	Mitigation Option	Estimated Unit Cost**	Estimated Cost	Notes
242.35 A	Existing drainage channel with shallow bedrock overlain by glacial till and alluvium	300	20	6000	Draped mesh and revegetate	$8.50	$51,000	No rockfall hazard
242.35 B	Less-resistant rock slope, possible joint or fault	50	50	2500	Draped mesh and revegetate	$8.50	$21,250	Little to no rockfall hazard
242.1	Minor raveling at brow, some erosion at bottom of slope	450	75	33750	Revegetation	**		No instability observed
241.95	Active seeps in poor quality bedrock, pocket of oversteepened glacial till	600	30 (brow and top of slope only)	18000	Round and mesh brow only	$50.17	$903,000	
241.75	Shallow, poor quality bedrock. Numerous seeps, springs during runoff season	330	50	16500	Round brow, draped mesh, revegetate	$15.70	$259,050	Affected by drainage from overlying switchback. Minimal rockfall hazard, ≤ 6 in
241.48	Weathered and jointed bedrock, fault	100	70	7000	Scale, draped mesh	$13.64	$95,500	
241.3	Glacial till with seasonal spring blowouts, oversteepened brow	100	80	8000	Round brow, draped mesh, revegetate	$14.13	$113,000	
241.28	Glacial till and alluvium, oversteepened brow	200	40	8000	Round brow, draped mesh, revegetate	$17.50	$140,000	
240.6	Several feet of glacial till overlying weak bedrock, seasonal springs with few blowouts	1000	20 (brow and top of slope only)	20000	Minor brow rounding, revegetation	$18.00	$360,000	Minor rockfall hazard, 6 in to 2 ft
239.7	Weathered, poor quality bedrock, possible shear zone. Discontinuous joints; unfavorable joint orientations.	100/500*	80	8000/40000	Fix worst sedimentation area only: minor slope rounding, erosion blanket at brow†	$5.63	$45,000	Site presents a moderate rockfall hazard. Most of the hazard is rockfall (≤ 3 ft), not sedimentation
239.56	Poor quality bedrock with minor drainage failure	50	50	2500	Minor brow rounding, scaling, draped mesh, and revegetate	$17.50	$43,750	
239.1	Fill consisting of alluvial and glacial till material. Sheetwash and surficial erosion below on fill side of roadway. Cutslope performing well.	800	≤ 350	280000	Control surface drainage, add curb on fill side, concentrate runoff, revegetate	800 Linear feet of Concrete Curb, plus Structured Drainage Rundown (Costs included in Section 5 of SCAP)		Very minimal rockfall hazard on cutslope, could possibly revegetate and/or replace 600 ft of geocell with Enkamat
238.7	Glacial till with seasonal spring blowouts	800	100	80000	Draped mesh and revegetate (no slope rounding)	$8.50	$680,000	Site presents a moderate rockfall hazard
238.65	Fill consisting of alluvial and glacial till material. Sheetwash and surficial erosion below on fill side of roadway.	1000	≤ 350	350000	Control surface drainage, add curb on fill side, concentrate runoff, revegetate	1000 Linear feet of Concrete Curb plus Structured Drainage Rundown (Costs included in Section 5 of SCAP)		
238.4	Glacial till with seasonal spring blowouts; year-round springs with willow growth near knee wall	1200	100	120000	Draped mesh and revegetate (no slope rounding)	$8.50	$1,020,000	

Milepost	Description	Approximate Length (ft)	Approximate Height (ft)	Approximate Area (SF)	Mitigation Option	Estimated Unit Cost**	Estimated Cost	Notes
238.2	Glacial till with seasonal seeps and spring blowouts	450	100	45000	Draped mesh and revegetate (no slope rounding)	$8.50	$382,500	Site presents a moderate rockfall hazard
237.9 A	Shallow, poor quality bedrock between switchbacks	50	60	3000	Draped mesh and revegetate (no slope rounding)	$8.50	$25,500	Sites present a moderate rockfall hazard
237.9 B	Shallow, poor quality bedrock between switchbacks	300	60	18000	Draped mesh and revegetate (no slope rounding)	$8.50	$153,000	
237.6 A	Glacial till slope	200	50	10000	Draped mesh and revegetate	$8.50	$85,000	Sites present a moderate rockfall hazard
237.6 B	Perennial creek in glacial till, slope failures present. Accumulation of boulders at bottom (some fill boulders, some rockfall)	35	50	1750	Terraced rockery rundown feature (6-10 ft high) with inlay, leave existing boulders	$50.00	$17,500	
237.6 C	Old drainage channel, filled with glacial till and alluvium. Damaged Type 4 barrier and fencing at bottom.	25	80	2000	Terraced rockery rundown feature (10 ft high) with inlay, revegetate	$50.00	$100,000	
237.35-237.38	Weathered, poor quality bedrock overlain by glacial till. Some seasonal spring blowouts and failures in weak rock because of saturation of the overlying till.	250	70-100	17500-25000	Draped mesh	$8.50	$148,750-$212,500	Site at 237.38 presents a moderate rockfall hazard, ≤ 12 in
237.2	Weathered, poor quality bedrock. Surrounding slopes are already meshed.	100	75	7500	Draped mesh	$8.50	$63,750	
Revegetation as noted	Revegetation for Sites as noted above – approximately 20 acres total			20 Acres	Revegetation	$10,000/acre	$200,000	
Subtotal Construction	**Total of Costs above (higher cost used when range is shown)**						**$4,971,000**	
Traffic Control						5%	$248,550	
Contingency						20%	$994,200	
Preliminary Engineering						10%	$497,100	
Final and Const. Engineering						22.5%	$1,118,475	
Total Cost (planning level)							**$7,829,325**	

Most sites present a low rockfall hazard; if not stated in notes, then rockfall hazard is low

*Worst sedimentation area is 100 ft wide, entire slope is 500 ft wide

**Revegetation include as line item above. Costs of scaling and rounding vary due to height and accessibility of slope.

† Fix entire slope: 2-3 days rock scaling, minor slope rounding, 1000 linear ft of rock bolts, mesh, cleaning & grubbing

8.0 SCAP IMPLEMENTATION SCENARIOS

With funding limitations, it will likely be very challenging to fully implement the comprehensive set of sediment control BMPs and slope stabilization treatments identified in **Sections 5/6** and **Section 7**, respectively. It is anticipated that the measures identified in this SCAP will most likely be implemented over time in a series of implementation steps or scenarios. This will begin with continuation of the traction sand management and sediment control practices that CDOT has currently in place. As funding and resources become available, these measures can be supplemented by a series of actions complementing and building on previous actions. A summary of potential implementation scenarios is presented below, ranging from continuation of current practices (Scenario 1) to full implementation (Scenario 4).

8.1 Implementation Scenario 1: Continue Current Maintenance and Sediment Control Practices

Scenario 1 entails continuation of the maintenance practices CDOT has developed and refined over time, and also the sediment collection CDOT has implemented with stakeholders with the Fraser River settling pond. Under Scenario 1, CDOT would continue current practices as follows:

- Continue current traction sand application, ditch cleaning, and sweeping practices
- Continue sediment capture and annual sediment removal at Fraser River diversion settling pond
- Remove accumulated sediment from existing benches and other areas, as appropriate and feasible when highway projects, such as guardrail replacement, are undertaken on adjacent highway segments
- Continue annual record keeping of traction sand application and recovery

The roadway would continue to be maintained at present levels under Scenario 1. Winter maintenance practices including snow removal and traction sand application would continue as needed to maintain safe travel conditions. Cleanup of traction sand, accumulated rock and debris, and sweeping would be undertaken as time and resources allow.

Sediment would be removed from the Fraser River diversion settling pond each year, as well as from existing sediment basins. This material would be transported to the approved disposal site. If project-specific funding allows, sediment would also be removed from guardrail, benches, and other areas when possible.

Winter maintenance material use tracking would continue, including sand and salt, and liquid deicers. Sand cleanup amounts would also be documented.

Under Scenario 1, an effort to seek additional funding for sediment maintenance activities would be undertaken by CDOT, working with stakeholder agencies, with the goal of initiating Implementation Scenario 2. CDOT would also identify projects that are needed to maintain highway safety and/or slope stability and would undertake these as separate projects, as appropriate.

8.2 Implementation Scenario 2: Enhanced Maintenance and Sediment Control Practices

Building on CDOT existing actions, Scenario 2 entails enhancing CDOT current practices through increased drainage system maintenance, repairs and some improvements, as well as removal from accessible roadside location of sediment that has accumulated over a number of years. Scenario 2 would provide greater sediment control and a reduction of the release of sediment to the environment relative to Scenario 1.

As funding becomes available, CDOT would proceed with Scenario 2, which would include:

- Continue existing Scenario 1 activities
- Inspect drainage system and clean/repair existing drainage, sediment collection, and clean water bypass facilities
- Remove accumulated sediment from roadside areas and drainage inlets, where practicable, to reduce sediment available for transport
- Remove shoulder sediment accumulations and repair drainage structures downstream of the Fraser Diversion from MP 234.3 to 232.9
- Consider drainage system improvements, such as additional clean water bypass, tributary channel stabilization in cut slope areas, and slope rundowns in high priority locations, where these can be easily implemented to reduce erosion and sediment transport
- Develop annual maintenance plan and schedule for enhanced sediment control activities

In addition to current sediment control efforts in Scenario 1, the existing drainage inlets and cross drain pipes would be inspected, cleaned, and replaced as needed. This would reduce drainage and erosion problems that have developed over time from plugged inlets and culvert drains. As a particular focus, roadway drains downstream of the Fraser Diversion between MP 234.3 and 232.9 would be cleaned to remove accumulated sediment. The drainage system in this area would be maintained to reduce sediment transport to the Fraser River between the Fraser Diversion and Winter Park.

Clean water bypass would be established and maintained where possible to prevent clean spring and tributary water from becoming contaminated with sediment and roadway runoff. In particular, CDOT would install sediment controls at the Berthoud Ditch crossing and at major tributary crossings. CDOT would maintain channel erosion control measures at cut slope tributary crossings, as well as provide rundowns and channel armoring at tributary outfalls to reduce fill slope erosion.

Detailed design would be completed prior to implementation. CDOT would develop an annual sediment control maintenance plan and schedule for enhanced maintenance measures and activities.

For planning purposes, costs for implementation of Scenario 2 could range from $1,000,000 to $2,000,000, depending on how many clean water bypass facilities and other drainage improvements are established. This cost would be refined during detailed design.

8.3 Implementation Scenario 3 – Sediment Reduction through Targeted Drainage Improvements, Sediment Collection BMPs and Slope Erosion Controls

Building on the enhanced maintenance and sediment control practices in Scenario 2, Scenario 3 would be initiated if additional funding can be obtained. Scenario 3 would include the design and installation of targeted sediment reduction and control actions, which would further reduce the release of sediment into the environment relative to Scenario 2.

Scenario 3 would include:

- Implement targeted erosion control actions, such as revegetation, knee wall repair/ maintenance and other slope stability measures to reduce erosion and sediment generation from oversteepened cut and fill slopes
- Install additional clean water bypass facilities to separate clean tributary and spring water from roadway runoff to improve receiving stream water quality
- Repair and stabilize major tributary channel erosion in cut slope areas to reduce sediment transport
- Install pipe rundown drains in areas with high slope erosion
- Re-route drainage to existing sediment collection basins, where feasible, to enhance sediment capture
- Install drainage and sediment control measures at major tributary crossings and high priority locations including Berthoud Pass Ditch, Horseshoe Bend Fen, Current Creek, Second Creek, First Creek, Fraser River, Parsenn Creek, Mary Jane, and Unnamed tributaries

In addition to the enhanced maintenance sediment control efforts in Scenario 2, Scenario 3 would develop and implement drainage collection and treatment BMPs and slope erosion controls in key locations. This may include slope revegetation, knee wall repair or replacement, and other slope stability and maintenance measures to improve traffic safety and reduce sediment derived from slope erosion.

Install clean water bypass facilities at springs and tributaries to prevent sediment from entering waterways. This will reduce contamination of clean tributary water and improve receiving stream water quality. Clean water bypass facilities will need to be designed and integrated with existing drainage infrastructure.

Repair and stabilize major tributary crossings to eliminate channel erosion in cut and fill slope areas. This may include installation of channel riprap, pipe rundowns, and other measures to reduce channel erosion and sediment transport.

Remove sediment accumulated around guardrail and other deposits near the roadway to reduce the potential for off-site sediment transport.

Implement targeted SCAP recommendations at existing sediment basins to enhance sediment collection and treatment. These include basins at MP 238 and 237, and the control berm at MP 238.6-238.7. Modifications to or the addition of cross-drain culverts may be required to route more sediment runoff into these treatment structures.

Implement targeted SCAP recommendations at major tributary streams and priority water crossings to reduce sediment transport directly to streams. Priority locations include Berthoud Pass Ditch, Horseshoe Bend Fen area, Current Creek parking area, Second Creek parking area, First Creek parking area, and stream crossings at Fraser River, Parsenn Creek, Mary Jane road, and Unnamed tributary. Protection of these priority waters will reduce sediment loading and improve water quality in the Fraser River.

Costs for implementation of Scenario 3 could vary depending on the actions undertaken. An estimated cost ranging from $3,000,000 to $6,000,000 can be used for planning purposes. The actions to be undertaken under this scenario could be selected based on the funding available, with priority given to actions providing the greatest likely sediment reduction benefit and/or contributing to other objectives such as safety. By targeting the highest priority locations, substantial sediment reductions could be achieved. Costs would be refined during detailed design.

8.4 Implementation Scenario 4 – Full SCAP Implementation of Permanent Sediment Collection/Treatment BMPs, Drainage and Erosion Controls, and Slope Stabilization Measures

Scenario 4 would entail implementation of the full range of measures identified in this SCAP. This scenario would provide the greatest level of sediment reduction relative to the other scenarios, but the cost would be relatively high as would on-going maintenance costs.

Given funding limitations, full implementation may not be possible in the near future. One possibility would be that some or all of these actions are deferred to be considered and implemented in conjunction with major roadway reconstruction when that is required at some future date.

Scenario 4 would include the following:

- Provide comprehensive sediment control through continuation of practices identified in the steps above, plus the implementation and maintenance of a system of permanent sediment collection/treatment BMPs identified in this **Section 5** and **Section 6**. This system would likely be implemented in phases, with monitoring to gauge system effectiveness and focus subsequent phases.
- Implement slope stability projects to mitigate rockfall hazard and slope failure areas identified in **Section 7**.

Implementation of the all of the identified sediment collection/treatment BMPs and slope stabilization actions would take several years and considerable design, construction, and maintenance resources.

As noted, current funding limitations make it uncertain when or if CDOT will have resources to implement Scenario 4.

A planning level estimate for engineering and construction cost for the comprehensive system of sediment control BMPs is approximately $12.5 million, as described in **Section 5**. Once implemented, annual maintenance costs are estimated to be $150,000 to $200,000 per year, as described in **Section 6**.

In addition, a planning level estimate for full implementation of the slope stabilization measures identified in **Section 7** is approximately $7.8 million.

9.0 REFERENCES

Andrew, R. (1994, May). Colorado Rockfall Hazard Rating System, Colorado Department of Transportation, Report No. CTI-CDOT-2-94.

Banovich, M., and W. Outcalt (2002, July). Evaluation of Slope Stabilization Methods (US-40 Berthoud Pass), Colorado Department of Transportation, Report No. CDOT-DTD-R-2002-10.

CAIC (1950-2005). Colorado Avalanche Information Center, Dale Atkins, Berthoud Pass Monthly Snowfall Data.

CDOT (2002). Sediment Control Action Plan – Straight Creek I-70 Corridor; Black Gore Creek I-70 Corridor, Colorado Department of Transportation, Region 1. Prepared by Clear Creek Consultants and J.F. Sato & Associates May 2002.

CDOT (2002). Erosion Control and Stormwater Quality Guide. Available online at: http://ntl.bts.gov/lib/24000/24300/24336/swqGuide.pdf.

CDOT (2005). Colorado Department of Transportation. East Side Berthoud Pass US Highway 40 BMP Maintenance Manual – Revision 1, Prepared by the Colorado Department of Transportation and Clear Creek Consultants/J.F. Sato & Associates. February 2005.

CDOT (2007). Horseshoe Bend Sediment Control Plan, US Highway 40 Berthoud Pass East, Mile 243.5 TO 243.8, Prepared for Colorado Department of Transportation Region 1, Prepared by Clear Creek Consultants, Inc. June 2007.

CDOT (2010). Colorado Department of Transportation. Data Summary Report 2008-2009, Hoop Creek Water Quality and Highway BMP Monitoring, US Highway 40 Berthoud Pass East. Prepared by Clear Creek Consultants in cooperation with J.F. Sato & Associates. December 2010.

CDOT (2011). Colorado Department of Transportation/Grand County, 2011, Memorandum of Understanding between CDOT Region 1 and Grand County, unpublished document, 11p.

CDOT (2013). Colorado Department of Transportation, Interstate 70 Clear Creek Corridor Sediment Control Action Plan, Prepared by Clear Creek Consultants Inc., Matrix Design Group, and H&K Associates, October 2013.

CDOT (2015). Data Summary Report, Interstate 70 Mountain Corridor Storm Event/Snowmelt Water Quality Monitoring 2000-2013, Prepared for Colorado Department of Transportation, Prepared by Clear Creek Consultants, Inc. March 2015.

CDPHE (2004). Colorado Department of Public Health and Environment, 2004, Source Water Assessment Report – Surface Water Sources and Groundwater Sources Under the Direct Influence of Surface Waters: CDPHE unpublished report, 20p.

CDPHE (2000). Total Maximum Daily Load Assessment, Straight Creek, Summit County. Water Quality Control Division. Colorado Department of Public Health and Environment.

CDPHE (2014). Guidance for Implementation of Colorado's Narrative Sediment Standard Regulation #31, Section 31.11(1)(a)(i), Policy 98-1 November 2014.

CDPHE (2015). Colorado Department of Public Health and Environment, Water Quality Control Commission, 5 CCR 1002-33, Classifications and Numeric Standards for Upper Colorado River Basin and North Platte River (Planning Region 12) and 5 CCR 1002-38, Regulation No. 38, Classifications and Numeric Standards for South Platte River Basin.

CDPHE (2016). Colorado Department of Public Health and Environment, Water Quality Control Commission, 5 CCR 1002-93, Regulation #93, Colorado's Section 303(D) List of Impaired Waters and Monitoring and Evaluation List.

Christine L. Hirsch, M.R. (2010). Range-Wide Status of Colorado River Cutthroat Trout (*Oncohynchus clarkii pleuriticus*): 2010.

Colorado Climate Center (2015). http://ccc.atmos.colostate.edu/cgi-bin/mlydb.pl

D&M/JFSA (1997). J.F. Sato and Associates/Dames & Moore. Berthoud Pass East Environmental Assessment Project #FR 040-3(16), prepared for Colorado Department of Transportation Region 1 and U.S. Forest Service, November 1997.

D&M (1999). Dames & Moore. Hydrologic Monitoring Results and Recommendations, Horseshoe Bend Fen – Baseline Conditions. Letter Report to the Colorado Department of Transportation, 1999

DWB (2011). Denver Board of Water Commissioners, 2011, Fraser River Nonpoint Source Pollution Control Inter Governmental Agreement (IGA): unpublished document, 20p.

Ewert, J. (2016). Fish Survey and Management Information. Retrieved from Colorado Parks and Wildlife: https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/FraserRiver.pdf

Hugley, Andy (CDOT), verbal communication

Ivan, J. (2012). Putative Canadian Lynx (*Lynx canadensis*) Movement across Hwy 40 near Berthoud Pass, Colorado. Fort Collins, Colorado: Colorado Parks and Wildlife.

Lori E. Apodaca, J.B. (1999). Fraser River Watershed, Colorado–Assessment of Available Water-Quantity and Water-Quality Data Through Water Year 1997. Denver, CO.

McGrath, M.D. (1934). The Real Pioneers of Colorado: The Denver Museum (magazine), vol. 5, p. 47.

Price, D. (1996, March). Evaluation of Slope Stabilization Methods (US-40 Berthoud Pass), Colorado Department of Transportation, Construction Report.

Russel, C., P. Santi, and J. Higgins (2008, September). Modifications and Statistical Analysis of the Colorado Rockfall Hazard Rating System, Colorado Department of Transportation, Report No. CDOT-2008-7.

Theobald, P. (1963). Geologic map of the Berthoud Pass quadrangle, Clear Creek and Grand Counties, Colorado, U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-443.

USFS (1997). Forest Plan Final Environmental Impact Statement. Retrieved from USDA Forest Service Arapaho & Roosevelt National Forests and Pawnee National Grasslands: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_058043.pdf

USGS (2015). http://waterdata.usgs.gov/co/nwis/uv?site_no=09024000

USFS (2012). Clear Creek Ranger District Geographic Area: Berthoud Pass Geographic Area. Retrieved from USDA Forest Service Arapaho and Roosevelt National Forest and Pawnee Grasslands Forest Plan: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_058066.pdf

USFS. (2012, October). Sulphur Ranger District Geographic Area: Winter Park Geographic Area. Retrieved from USDA Forest Service Arapaho and Roosevelt National Forests and Pawnee Grasslands: https://fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5418694.pdf

USFS (2007). Laurie, G. (2007). TMDL Monitoring Results 1992 to 2006, Straight Creek, CO. White River National Forest, Silverthorne, CO.