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Rock Cut Blasting Aesthetics Best Management Practices Phase II

APPLIED RESEARCH & INNOVATION BRANCH

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16. Abstract

Rock excavations are necessary for construction of highways in transportation corridors that pass through Colorado's mountains. Scenery along these corridors is an asset worthy of preservation and rock slope excavations can negatively impact the visual appeal of the natural landscape. The visual impacts from rock excavations can be mitigated by use of Best Management Practices (BMP) that result in more natural appearing excavated slopes. To be effective, the BMPs must be incorporated into the rock excavation design and implemented during construction. A literature review was conducted to assess the current state of practice for mitigating the visual impacts from rock excavations along highways. Field investigations were performed to document conditions at selected existing rock excavations. This report provides a description of commonly used Rock Excavation BMPs, a compilation of the selected existing rock excavation sites within Colorado that represent effective use of the BMPs, and a construction specification that provides a means to implement BMPs and control their use during construction.

Commonly used BMPs consisting of blasting techniques and methods of landscape enhancement are presented as a "Toolbox" for use by planners, designers, and construction management staff. The compilation of representative excavation sites is presented as a searchable catalog of examples organized by Colorado highway corridor that includes notes on the design, construction and effectiveness of the BMPs used at each site. The specification was drafted in the standard format for CDOT Project Special Provisions and is intended to allow flexibility in the implementation of rock excavation BMPs as conditions are exposed during construction.

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Executive Summary

A collection and catalog of Best Management Practices (BMPs) for design and construction of safe and visually appealing rock cut slopes is needed to provide guidance to CDOT staff responsible for the safety and appearance of transportation corridors in Colorado's mountainous terrain. This research consisted of assembling a 'toolbox' of BMPs comprised of graphical representations and descriptions of rock excavation methods commonly used in highway construction. In addition, a catalog of 53 preselected existing rock cuts located throughout Colorado was compiled that includes photos, measurements, and construction documentation records.

Field data collection included: measurements at each selected site to assess the visual impacts of the cuts on motorists and nearby land users, descriptions of the geologic conditions exposed by the excavations, digital images of the cuts and the viewsheds affecting motorists, recording the visual evidence of excavation methods such as marks and blasting traces on the rock faces, and noting the presence of rockfall mitigation measures. A form was created by the research team to provide a common format for collection of the field data.

The toolbox of BMPs was assembled in a table form with diagrams and images of available methods to mitigate the visual impacts of rock excavation. The data collected in the field was compiled into a catalog table of rock cut examples organized by highway corridor. A report was prepared that documents the BMPs used effectively in each major mountainous corridor. The team prepared a Project Special Provision specification suitable for inclusion in rock excavation construction contracts that have safe and visually appealing rock cut slopes as a project goal.

The BMP toolbox provides designers with accepted practices that can be implemented by specification and for which costs can be estimated by engineers and contractors. The catalog describes BMPs previously used successfully in the rock types expected in each individual highway corridor.

The number of excavated rock slopes along the major highways in Colorado provided multiple examples of the most commonly used BMPs. Examples of innovative use of blasting techniques or landscape methods that resulted in naturally appearing excavations were rare. Defining a means to implement BMPs that may require adjustments to excavation methods, pay quantities,

and costs during construction was difficult in the design-bid-build framework traditional for highway construction.

CDOT planners, landscape architects, and engineers involved in design and construction can use this research document as a guide for achieving rock excavation project goals related to safety and mitigation of the visual impacts of rock excavations. Standardization of a process for selecting appropriate BMPs with input from CDOT Staff Branches and non-CDOT project stakeholders will require commitment from leaders in every CDOT region. Mitigating the visual impacts of new rock excavations may add to project costs. However, the benefits of maintaining the natural beauty of the state while creating safe and resilient transportation corridors can be a lasting benefit to the well-being of Colorado's residents and visitors.

Implementation

Implementation of the BMPs will require collaboration between Geotechnical, Environmental (Landscape Architects), and Roadway Design branches early in the planning and scoping of projects that include rock excavations. Stakeholders should be encouraged to participate in the selection of rock excavation BMPs.

The BMP toolbox and catalog are to be used to select excavation and landscaping methods that mitigate visual impacts and are appropriate to the geologic conditions in each corridor. Preparation of construction contracts that include specifications allowing modification and of rock excavation methods and adjustment of pay quantities will allow construction engineers to take advantage of opportunities to mitigate visual impact.

This research will help deliver projects that achieve goals of safety, resilience, and enhanced visual appeal of transportation corridors. These goals benefit CDOT and its customers, the travelling public, while demonstrating stewardship of the state's natural landscapes.

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INTRODUCTION

1.1 Background

Highway construction in the steep terrain prevalent in much of Colorado requires controlled removal of bedrock and use of accepted methods for design of rock excavations. Blasting for rock excavation often results in exposed rock slopes that, although safe and stable, are not visually pleasing to the travelling public and other stakeholders and may contrast sharply with adjacent natural rock features. The Colorado Department of Transportation (CDOT) Research Program is supporting research to improve rock excavation design and construction practices with the goal of providing guidance to designers and construction staff for rock excavations that are both safe and visually appealing. The goal of this research is to develop a catalog of rock excavation techniques, design methods, planning approaches and specifications to assist CDOT's efforts in maintaining the visual appeal of Colorado's mountain corridors and other highway rock cut areas.

Phase I of the research resulted in report CDOT-2018-07 "Rock Excavation Best Management Practice Phase I (Rock Cut Perimeter Blasting BMP)" prepared by the Advanced Explosives Processing Research Group (AXPRO), Colorado School of Mines and published in April 2018. The Phase 1 work provided a method and mathematical formula to calculate percent aesthetic enhancement (PAE) that is an objective measure for quantitatively assessing the degree of mitigation required to improve the aesthetics of undesirable features resulting from rock slope construction. Determination of PAE includes evaluation of a highway user's viewshed as they approach rock features or when the features are visible from a distance or by slow moving users of nearby facilities such as bicycle/pedestrian trails. The Phase I report also discussed how controlled blasting methods can be used during rock excavation to improve the appearance of the final cut slope. A short catalog of completed rock slopes and methods used to construct them was prepared. Guidelines were provided to assist blast designers with the selection of controlled blasting methods for construction of rock cuts that fit within the context of the project setting.

This report presents Phase 2 of the research. The project involves assembling an extensive catalog of existing rock excavation sites along highway corridors within the State that can be used as examples of rock excavation Best Management Practices (BMPs). Each entry in the catalog includes photos, descriptions of the geologic conditions, the visual impact based on the methodology presented in the Phase 1 Report, a discussion of the design and construction, and the exhibited BMPs for the site.

Scope of Phase 2 Research

The scope of the Phase 2 research includes a review of available relevant literature, field visits to document selected sites, collection of design and construction information, composing the catalog of example sites by highway corridor, and an assembly of a 'toolbox' of BMPs. The results of the research form the basis of a proposed strategy to implement rock excavation BMPs in design that can be carried into construction. A revised rock excavation specification was prepared to provide a method for including the BMPs in construction contracts. The BMPs for use in design and construction are presented in Appendix A.

The literature review focused on articles, reports and manuals that include discussions of rock excavation in highway construction. Topics ranged from general methods to improve the visual appeal of highway infrastructure to specific techniques for rock blasting. Sources included journal articles, research papers, design manuals and case studies.

Members of the research team visited selected sites along Colorado highway corridors where rock excavation is prevalent. The site visits were conducted to photograph rock slope conditions, obtain measurements to evaluate visual impact, record site geology, and observe conditions such as slope stability, safety, and appearance that demonstrate effective use of rock excavation BMPs. Information from site visits was recorded in the field on forms prepared specifically for this research project. Data from the field forms was transferred to an electronic spreadsheet format, creating a presentation that is clear and legible. The final field data forms are included in Appendix C of this report.

Design plans and construction records for projects that included the selected rock excavation sites were reviewed so that comments regarding design and construction could be included in the catalog. Sources for this information were the CDOT online library, consultant records, personal recollections of the research team and interviews with design and construction engineers. The assembled historic project information provides a comparison with our field observations and allows an assessment of the long-term effectiveness of the constructed BMPs.

Information collected during site visits and from project records has been provided in Appendix B as a catalog of rock excavations. The catalog is in the form of a table and summarizes the field data for each site, displays photographs, and includes comments on the degree of success for the BMPs used. Catalog entries are organized by highway corridor and are linked to the field sheet and additional photographs in Appendix C.

A general discussion of conditions that could influence the design and construction of rock excavations is provided for each corridor studied, including corridor location and use, geologic setting and general rockfall type and mitigation. Selected rock excavation sites that represent key conditions within a particular highway segment are discussed in detail. The detailed discussions give information on design considerations, excavation methods, techniques used to improve visual appearance, rockfall hazard mitigation, slope stabilization and post-excavation enhancements. An evaluation of the suitability and effectiveness of the BMPs used to reduce visual impacts is presented.

The report presents a proposed strategy for implementation of rock excavation BMPs in design and construction that relies on clear communication between stakeholders at defined steps in the project delivery process. Existing CDOT procedures in the Project Delivery Manual are used to define how stakeholder preferences can be considered when making BMP design decisions between project conception and final design. A rock excavation construction specification that states how BMPs can be selected or modified to address conditions that arise during construction, from contractor choices or aspects of site geology that are revealed during excavation, is critical to successful implementation. A draft of this specification is provided in Appendix D.

LITERATURE REVIEW

This section provides a literature review about the process of constructing aesthetic rock cuts as context sensitive solutions (CSS). Visual impact assessment is the first step in these designs. Blasting and machine excavation methods, rockfall mitigation, slope stabilization, vegetation, rock staining, rock face treatments, and slope rounding are used to achieve a context sensitive design.

Visual Impact Assessment

Colorado Department of Transportation (CDOT) and the Federal Highway Administration (FHWA) use visual impact assessments to develop landscape compatible mitigation design for roadways, which evaluates visual impacts as agreed on by all parties involved in a project (CDOT, 2019). In general, the process is based on the idea that visual impact can be determined. (US DOT, 2015) and that the impact is analyzed using landscape units in the project area. Aesthetic rock cuts include context sensitive solutions (CSS) for site-specific construction that includes safety and project site preservation by including site stakeholders in the implementation of the design and project development (AASHTO, 2004; Andrew 2011). R.A. Cummings (2002) describes the need for aesthetic criteria for cut slopes in protected areas and the need for communication between those outside the construction team and the road builders. Acceptable context sensitive design requires a consensus between groups with different ideas regarding the impact of cut slopes (Harber 2000). S. Moler (2002) details the history of a Montana highway that required cooperation between state and federal government agencies and two Native American tribes and the resulting acceptable design that increased safety while fitting the landscape. This project put forward the idea of the road as a "visitor" to the landscape that incorporates the respect and understanding of what makes an area unique. Departments of Transportation in Pennsylvania and New Jersey (2008) joined forces to promote CSS and introduce a balance between the "desire to go through a place with the desire to go to a place," recognizing that roadway design should support community character and change as necessary.

Flexibility during construction should be expected for a CSS design. In the United Kingdom, government regulations in national park areas require that "the highway should have as natural an appearance as possible." (Green, 2005) Difficult rock conditions in a steep narrow mountain

roadway in an environmentally sensitive national park in Wales required collaboration between engineers and contractors as needed for contract flexibility that allowed for changes during construction. An understanding of area slope geology is required for successful design (Andrew, 2011). Transport Scotland (Harber, 2000) stresses that good field investigation methods with an emphasis on expertise and experience are needed to assure sustainable rock slope design at satisfactory cost. Detailed examples of environmental impact for use in rock slope excavations with flow charts for various phases during design and construction of rock slopes are included in Harber's Rock Engineering Guides to Good Practice.

FHWA (US DOT, 2015) includes viewpoints of the foreground, middle ground and background with viewsheds that are static where adjacent to the roadway and dynamic on the roadway. Short and long range distance views of the slope should be included in CSS (Cummings, 2002). The Percent Aesthetic Enhancement (PAE) considers short- and long-range viewsheds, which require different designs (Petr, 2018).

Mitigation of visual impact includes avoidance, minimize impact, compensation and enhancement (US DOT 2015). Detailed suggestions for aesthetic design treatments for rock cuts are given in the US DOT FHWA Guidelines for the Visual Impact Assessment of Highway Projects. Designs should be as close to natural state as possible and include natural processes where possible (Harber, 2000). In France, to preserve landscapes, some roads have been placed in tunnels (Route One, 1998). Designs should meet the needs of the client, be sensitive to the environment and "deliver the required product in terms of buildability and performance." However, the possibility of uncontrollable instability is raised (Harber, 2000). CDOT Aesthetic Guide Index for Interstate 70 Mountain Corridors (2015) suggests that scarring of slopes, including half casts should be avoided or disguised and that the use of benching with vegetation can produce a visually compatible rock cut.

Blasting Methods

Rock excavation methods used to stabilize slopes include blasting, drilling, and ripping (Andrew, 2011). Blasting of rock cuts have been accomplished using the rudimentary methods found in mining techniques (Andrew 2011). These methods have been refined for use in CSS design. R.A. Cummings (2002) lists specific methods for slope excavation to construct CSS. Rock blasting elements are described extensively in a circular titled Explosives and Blasting Procedures Manual (Dick, 1987) provided by the Bureau of Mines and U.S. Department of Interior. More natural appearing cuts can be achieved by designing blast plans that can create ledges or shape slopes to match existing terrain (Andrew, 2011; Green, 2005). Complex rock strata can limit this approach (Green, 2005). In-depth details of blasting are described in Harber's Engineering Guide to Good Practices (2000). CDOT's Rock Cut Perimeter Blasting Best Management Practices Phase I (Petr, 2018) is a guide for blasting contractors and outlines the responsibilities of the contractor, types of blasting and the documentation and construction of an aesthetic blasted rock cut design. Blasting types covered in the guide include presplitting, smooth blasting, cushion blasting, contour blasting and horizontal drilling. FHWA (1989) provides guidelines in Rock Slopes: Design, Excavation, Stabilization for blasting design with benefits of various blasting methods including line blasting, cushion blasting, pre-shear blasting and buffer blasting. Controlled blasting is recommended to limit damage behind the rock face (Wyllie, 1996). Reshaping rock faces using blasting is discussed as design option for rockfall mitigation in Turner's Rockfall: Characterization and Control (2012). CDOT Aesthetic Guide Index for Interstate 70 Mountain Corridors (2015) recommends the use of scatter blasting and random rock drilling to expose natural fracture patterns in rock faces.

Machine Excavation Methods

Machine rock excavation methods include drilling. ripping, scaling, trimming, manual, and chemical. Specific methods for slope excavation, grading and sculpting to construct context sensitive designed rock cut slopes can be found in several publications including FHWA Context Sensitive Slope Design Solutions (Andrew 2011), Harber's 2000 Rock Engineering Guides to Good Practice, U.S. DOT/FHWA 1989 Rock Slopes: Design, Excavation, Stabilization, and Cummings 2002 Highway Cut Slopes in Rock. Stabilization methods include rock removal using resloping, trimming and scaling (Wyllie, 2004). Slope rounding, can be done using ripping, scaling and other excavation techniques. (Andrew 2011).

Rockfall Mitigation

When rock cut slopes cannot be stabilized, rockfall mitigation is required and could include mesh, barriers, and catchment areas (Andrew 2011). Pre-design considerations for rockfall mitigation include prediction of rockfall behavior using a simulation program, such as Colorado Rockfall Simulation Program (Andrew 1992). In Missouri, a rockfall hazard rating system measures both risk and consequence of rockfall on state highways (Maerz, 2004). This system requires a video library of all rock cuts with technology to extract measurements within 10% accuracy and pairs information regarding the history of rock slopes with the slope features to accumulate successful context sensitive designs and identify failed slope plans. Details of rock cut features on video can be measured using a digital imaging program and objects in view for scale (Maerz, 2003). Documentation of rockfall events and road maintenance has been historically limited and ways to work around this are provided in Rockfall: Characterization and Control (Turner, 2012), a comprehensive textbook that provides information regarding rockfall mechanics and an understanding of the mitigation process for rockfall including the element of aesthetics considerations that involve preservation of the rockface for aesthetic, scenic, historic and environmental reasons. CDOT Aesthetic Guide Index for Interstate 70 Mountain Corridors (2015) recognizes that rockfall mitigation may require vertical cuts for safety. In addition, they recommend considering impacts to wildlife when designing rockfall mitigation.

Wire mesh and cable net can be designed for CSS using colorizing, limiting mesh coverage to areas of lower visibility, using patterns in mesh coverage, and increasing mesh contact (Muhunthan, 2005; CDOT, 2015). Use of vegetation for cover must be chosen to minimize damage to mesh that can occur with large shrubs and trees. Muhunthan's Analysis and Design of Wire Mesh systems (2005) provides detailed examples of mesh and cable designs, with loading test data and suggested maintenance included. Mesh should follow the existing contours of rock cuts (CDOT, 2015). Rockfall mitigation may require a catchment area/ditch as a protective measure (Wyllie, 1996), and the Oregon Department of Transportation Rockfall Catchment Area Design Guide (Pierson, 2001) provides a good basis for rock cut catchment design including user-friendly charts and recommendations for site-specific rock rolling for design. Additional protective measures include rock sheds and tunnels (Wyllie, 1996).

Slope Stabilization

Rock slope stabilization methods include slope geometry modification, reinforcement using internal and/or external stabilization, and drainage installation (Andrew, 2011). Methods to reshape slopes include scaling and trimming of rock, unloading excavation, resloping of rock face and reinforcement methods, which include the installation of bolts, cables, dowels, buttresses and retaining walls (US DOT/FHWA, 1989; Wyllie, 1996). Polyurethane resin (PUR) injection, or 'rock gluing', is a process in which polyurethane material is injected into a fractured rock mass to limit the gaps in these fractures and help stabilize potential rock mass failures (Arndt, 2008).

Accurate record keeping of rock fall areas and stabilization projects is important to determine long-term effectiveness of designs (Wyllie, 1996). In Chapter 18-Stabilization of Rock Slopes by D.C. Wyllie (1996) a flow chart and subsequent detailed sections are provided with recommended procedures for a stabilization project that includes inventory of stability conditions, analyzing rockfall hazards, stabilization planning, decision analysis for optimum design, preparation on contract documents, and construction services. Rock quality and topography should be accounted for when sculpting for natural appearance (CDOT, 2015).

Vegetation

As part of the landscape, vegetation can be a valuable aesthetic tool in creating and hiding views of the rock cut. The rock cut project involves an inventory and assessment; completing a visual inventory, contrasting the proposed project with the landscape, evaluating visual impacts, developing a graphic visualization of the impacts, and cumulatively evaluating the impacts of the project. (CDOT, 2019) Using landscape design as a "valued enhancement" and a way to "integrate a roadway into the surrounding environment," Pennsylvania DOT (2008) expands the importance of landscape design in the role of the project. Applying one design over an entire highway may create a problem as vegetation, geology and other characteristics may change within the corridor. An FHWA project in Montana visualized large and diverse spaces as large outdoor rooms with separate landscapes combined into design segments that responded to the land using native materials and plants whenever possible (Moler, 2002). The Rock Engineering Guides to Good Practice (Harber, 2000) cites "Cost Effective Landscape: Learning from Nature" that recommends the Bottom Dead

Centre design approach or “reduced degree of artificiality” to create designs as close to natural state as possible and to include natural processes where possible. An example of mature vegetation planted in benched cuts following construction can be found along Interstate 70 (CDOT, 2015) near on Vail Pass near MP 185.7. Rock excavation may have a detrimental effect on existing vegetation. Vegetation may take a generation to rejuvenate. Pre-planning and care should be taken to limit disturbance to surrounding vegetation. Where possible shrubs, and smaller trees can be relocated. Rock excavation may also affect vegetation. Care should be taken to limit these effects. (Wyllie, 2004).

Vegetation can naturalize the visual aspect of a rock slope design and provide erosion and sediment control. Ground Bioengineering Techniques for Slope Protection and Erosion Control, together with a companion book, Water Bioengineering Techniques, shows how soils, plants and their ecology can be used to protect and stabilize natural and formed slopes along transportation routes and locations adjacent to industrial and housing areas, and leisure facilities (Schiechtl, 1996). The maximum use of vegetation in erosion and sediment control is often referred to as "green engineering" and produces many long-term benefits, including improved visual aesthetics, increased infiltration, reduced stormwater runoff, increased air quality and habitat.

Vegetation and rolled erosion control products (RECPs), also known as soil retention blankets (SRBs), can provide optimal green erosion control solutions, so long as the SRBs are properly designed and installed, and the vegetation is properly selected. (Sprague, 1999). SRBs can help temporarily stabilize soil and promote the establishment of vegetation on slopes that are too steep for traditional seeding and mulching (CDOT Standard Specifications for Road and Bridge Construction, 2019). This makes SRBs useful for mitigation of vegetation loss around rock excavations. CDOT Aesthetic Guide Index for Interstate 70 Mountain Corridors (2015) advises including soil pockets in rock ledges for revegetation. Caution is noted in choosing vegetation for slope aesthetics and erosion control because large shrubs and trees can damage rock mesh (Muhunthan, 2005) and rockfall can be caused by tree root growth wedging apart rocks (Wyllie, 2004, Relic, 2018) or by root penetration of rocks accelerating chemical weathering (Relic, 2018). Trees can provide rockfall protection more effectively if located outside the source area for rockfall (Relic, 2018).

Staining

Context Sensitive Rock Slope Design Solutions from FHWA (Andrew, 2011) discusses rock staining of fresh rock faces as an effective and cost-efficient way to reduce visual contrast for both short and long views. Nevada DOT (2009) also includes staining of exposed rock cuts as an aesthetic design alternative to blend cuts into the landscape. Environmental concerns require that appropriate stains be used. Staining has also been used to blend retaining walls and existing older concrete walls to match with surroundings, including natural bedrock outcrops (Szalankiewicz,, 2016). CDOT Aesthetic Guide Index for Interstate 70 Mountain Corridors (2015) directs are treated to match the pre-blast rock face with one or more of the following: rock staining, soil-coloring, and accelerated-weathering treatments. Rock protection material, such as mesh and cable components have been colorized to create a more natural color to match existing rock slopes (Muhunthan, 2005).

Face Treatments

Context Sensitive Rock Slope Design Solutions from FHWA (Andrew, 2011) discusses shotcrete as a face treatment to cover rock bolts and erodible rocks. Shotcreted faces should have a natural appearance and can be colored and sculpted to match the surrounding rock (Wyllie 2004). Other detailed descriptions for options using shotcrete can be found in Chapter 13 of the textbook, Rockfall: Characterization and Control (Turner, 2012).

Slope Rounding

Rock cuts generally have an unnatural appearance. The Nevada Department of Transportation adopted guidelines for aesthetic alternatives (NevDOT, 2009) that include reshaping of slopes using slope rounding at the top and toe of rock cuts. In addition, rounding of the slopes can reduce future instability. Harber (2000) notes that slope design considerations can include slope shaping. CDOT has adopted a standard detail for slope rounding at the tops of cuts based on the steepness of the slope (CDOT Standard Detail D-203-3).

Slope Warping

Warping is the gradual change in the slope at the ends of a rock cut to match the slope of the surrounding terrain. This technique is often employed during construction as the excavation exposes natural features and structure that can become the limits of excavation. Andrew (2011) affirms that slope warping, like rounding, can smooth the rock cut transition to the adjacent topography and can be achieved using blasting/ripping, scaling and other excavation techniques. Harber (2000) notes that the slope angle designed for the cut is generally based on safety considerations and changing the design slope angle to accomplish warping may reduce global stability or increase rockfall hazard.

Conclusion

No comprehensive resource for rock excavation with best management practices for aesthetic design was found during this literary review. This research has been undertaken to provide a catalog of rock excavation techniques, design methods, planning approaches and specifications that designers and construction staff can use for rock excavations that achieve the goals of safety and stability while employing context sensitive solutions to mitigate the visual impacts of rock excavations in highway corridors. A valuable part of the best management practices involves the use of rock excavation and revegetation techniques that blend with the surrounding environment. Key to successful large scale landscaping at rock excavation sites is understanding the geologic conditions that have shaped the adjacent natural slopes over time and mimicking those effects with controlled blasting, mechanized excavation, and properly planned revegetation.

CORRIDOR DESCRIPTIONS

Interstate 70 Corridor

Interstate 70 is the primary east/west transportation route across Colorado. The route is essential for private and commercial freight traffic between the midwestern and western states and traverses virtually every geologic setting to be found in the State. Construction has required rock excavations along the route from the Utah State Line to the western edge of the Denver metropolitan area. Significant rock excavation and tunnel construction has occurred from the De Beque Canyon area,

through Glenwood Canyon, at the Continental Divide, and through the mountain ranges west of Denver. Continuing improvements to safety and capacity will include rock excavation and geohazard mitigation along this crowded and scenic corridor.

Rock excavations along Interstate 70 from the Utah state line at MP 0 to approximately MP 104 near New Castle generally encounter the flat-lying, interlayered sedimentary rock including sandstone, shale, claystone, siltstone, mudstone and conglomerate of Jurassic age (older) through Tertiary age (younger) rock formations of the northeastern Colorado Plateau. The interstate follows the Colorado River Valley from the Utah state line to MP 133. The Colorado Rocky Mountain physiographic province starts at approximately MP 104 and continues to the western edge of the Denver metropolitan area at about MP 259. At MP 104 to MP 117 east of Glenwood Springs, exposures of tilted and faulted Paleozoic age sedimentary rocks include sandstone, shale, claystone, mudstone, siltstone, conglomerate, and limestone. Between MP 117 and MP 133 at Dotsero the steep walls of Glenwood Canyon are carved in faulted Paleozoic sedimentary rock layers over Precambrian metamorphic and igneous rock. At MP 133, the interstate follows the Eagle River to MP 171, north of Minturn, through Paleozoic sedimentary rocks that include evaporite salt layers with gypsum, siltstone, shale, sandstone and conglomerate. Landslide deposits occur in this area, including at Wolcott (MP 159) and at Dowd Junction (MP 169-171). The interstate traverses various ranges in the Colorado Rocky Mountains from MP 171 to MP 259 and two major mountain passes, Vail Pass and Eisenhower/Johnson tunnels, at elevations up to approximately 11,200 feet. Rock excavations, including several tunnels, expose Paleozoic (older) and Mesozoic (younger) sedimentary rock layers and a variety of Precambrian metamorphic and igneous rock types. The rocks in this area have been faulted, folded and tilted during the episodes of mountain building forces, which also formed the Colorado Mineral Belt that crosses Interstate 70 between MP 221 near Silver Plume and MP 248 east of Idaho Springs. Many areas in the mountain region have been glaciated and glacial deposits may contain boulders of more than 10 feet diameter. The interstate continues east from MP 259 to the Kansas state line (MP 449.5) across the Tertiary age sedimentary rocks of the hilly Colorado Piedmont and across the plains of eastern Colorado, with infrequent rock exposures.

I-70 Rabbit Valley, EB MP 4

The rock excavation east of the Rabbit Valley exit along I-70 was constructed during the original Interstate program in the 1970's. The cut was constructed in a massive sandstone bedrock unit using the standard presplit and production drilling methods common at the time. A unique aspect of these cuts is the drilling pattern that was used to develop the blast. The presplit line and corresponding production holes were laid out to create a zigzag final rock face. The pattern did help break up the appearance of the cut and help hide some of the half-casts left from the presplit drilling. This also left a varying ditch width along the base of the cut. The eastbound side of the cut is shown in Figure 1.

Figure 1. I-70 MP 4, EB, Rabbit Valley

I-70 De Beque Canyon, MP 49 to 58 and SH 65 MP 55 to 61

Rock excavations in the flat-lying, interbedded shale and sandstone of the De Beque Canyon area are well represented by the cuts along SH 65, a few miles southeast of I-70. On the north flank of Grand Mesa, SH 65 follows Plateau Creek in a canyon that cuts through sedimentary bedrock units

composed of sandstone, siltstone and shale. The highway was widened and several of the curves were smoothed in the 1970's which required multiple rock cuts and embankment fill. Two of the cut slopes have been evaluated in the catalog to highlight techniques that were used to develop the rock excavation. The sites are shown in Figures 2 and 3.

The first area is located near Milepost 55. In this cut slope, two different blast techniques were used excavate the rock. The intent of using two different drilling and blasting techniques was to evaluate the appearance and performance of the methods. The right half or upstream portion of the cut was drilled and shot using a traditional presplit and production blast pattern. Because the rock is primarily massive sandstone, the remnants of the presplit drill holes are still very visible along the slope face. The left half or downstream portion of the cut utilized cushion blasting for the excavation. It is obvious that the left half has an appearance that more closely resembles the natural setting. The left half does appear to have some slight blast damage on the fringe of the cut where it transitions into the drainage intercept but in general has not experienced an increase in rockfall due to the blasting method used for this specific rock type.

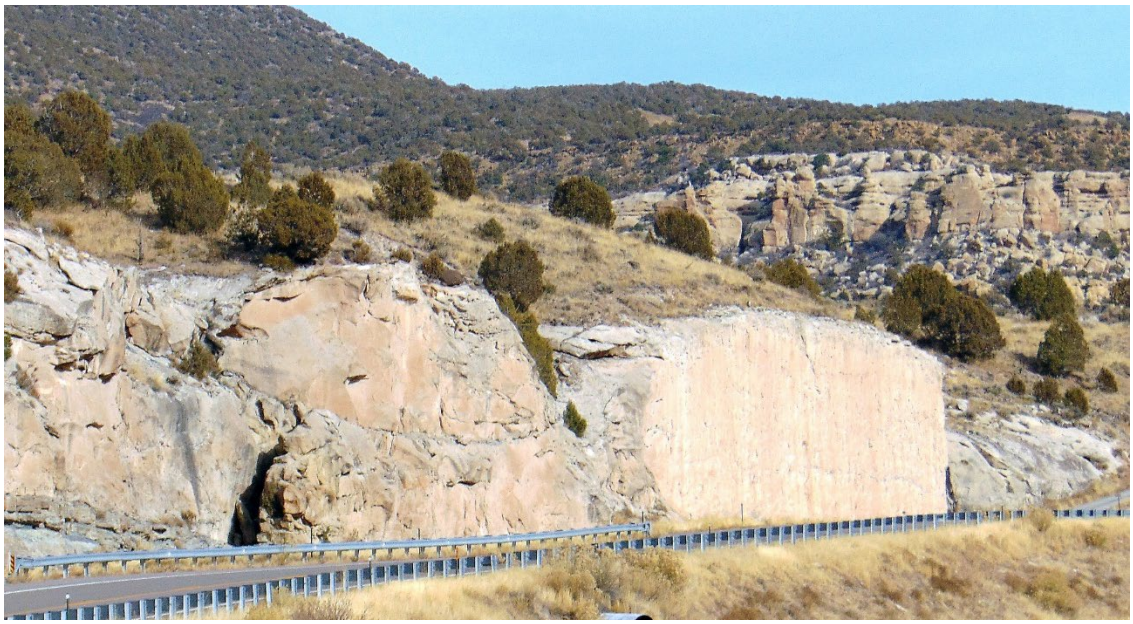


Figure 2. SH 65 MP 55

The other example location along SH 65 is located near Milepost 60. This cut is excavated through several different materials and rock types. The top of the cut is capped with a cemented alluvial deposit composed of rounded cobble sized rocks over layers of interbedded sandstone and shale. A presplit line is still visible in the more resistive sandstone layers.

The slope angle was varied throughout the cut according to the type of rock and other materials that were encountered in the excavation. The more massive sandstone layers were cut at a near vertical slope whereas the softer shale and soil layers were laid back to a more gradual angle. The slope angles that were used simulate the surrounding topography and slopes that are present in De Beque Canyon formed as a result of natural erosional processes.

Figure 3. SH 65 MP 60

I-70 Glenwood Canyon, MP 124 to MP 128

Glenwood Canyon was the final constructed link of I-70 through Colorado. During design and construction, care was taken to incorporate the highway improvements into the fragile canyon environment while preserving as much of the natural terrain and vegetation as possible. In the planning stages, a citizen's advisory group greatly influenced the design of a project that would "tread lightly" in the canyon. State-of-the-art techniques were used for rock excavation and exposed rock cuts were stained to match their original colors. Rock cuts in this area included sliver cuts with minimal excavation and precision blasting operations that removed multiple small volumes near the Reverse Curve Tunnel. Loose and blasted material was removed to the natural fractures to develop a more natural appearing rock slope. Strategically placed rock bolts were used for rock slope stabilization. Rockfall mitigation was achieved with extensive scaling, timber-faced walls and flexible barriers. Figure 4 shows how natural fractures and joints near MM 124 were used to control the limits of this sliver cut. Rock bolts that anchor larger blocks are visible.

Figure 4. I-70 Glenwood Canyon MP 124

I-70 Vail Pass, MP 184 to 186

One of the most iconic projects in the State of Colorado, the I-70 Vail Pass project, represents some of the most successful approaches to introducing natural elements into the rock excavation. The blast pattern for most of the rock cuts used a presplit line along the final face with production drill holes used to remove most of the rock mass. The presplit line is visible in some of the more massive rock units. The excavation was stepped using the more resistive rock as the vertical features and the softer seams were sloped at a more gradual angle. As with most horizontally bedded sedimentary rock, a series of naturally occurring vertical fractures are present through the rock formation. An excavator was used to remove some of the rock back to the vertical fractures providing a more natural appearing rock face. Most of the cuts were benched and planting shelves and pockets were created and revegetated with willow and conifer trees, and native grasses. The width of the ditches was varied based on the natural topography and the faces adjacent to the drainage channels were heavily rounded to mimic the project setting. Figure 5 shows an example of this excavation method.

Figure 5. I-70 Vail Pass MP 184

I-70 Tenmile Canyon, MP 200

The rock cut near Milepost 200 was completed during the original construction of I-70 through Tenmile Canyon. Much of the excavation was achieved using conventional presplit to control overbreak and production blasting. Drill traces or half-casts are still visible throughout the near-vertical portions of the rock face. A predominate and naturally occurring fracture (joint) that slopes at roughly 45 degrees was also used to control over-break from the production blasting. The rusty brown natural staining of the infilled joint was exposed and is still visible on the slope. As shown in Figure 6, the benches in the slope were cut to break up the slope face and develop planting zones for evergreens, brush, and grasses.

Figure 6. I 70 Ten Mile Canyon MP 200

I-70 Veterans Memorial Tunnels, MP 242

The rock cuts at the east and west portals of the Veteran's Memorial Tunnels were constructed during the widening project for the westbound tunnel. The bedrock that was encountered in the rock cuts consisted of metamorphic rock with occasional granite intrusions. The primary rock structures (natural fractures in the rock mass) were dipping away from the highway into the slope face. To

control overbreak and blast damage to the final rock face, most of the rock was blasted using conventional presplitting and production drilling techniques. Because the cut was excavated in a very steep natural slope, horizontal drilling and blasting was used to develop access to the top of the cut for conventional drilling equipment. The blast holes were drilled parallel to the roadway alignment in a fan shaped pattern. As a result of the horizontal drilling, some blast damage did occur to the slope face and many of the blasts led to an uncontrolled quantity of material falling from the slope during the shots. Expanded slope rounding was used to remove the overshot material and highly weathered rock at the top of the cut to blend the final cut face into the natural rock slope. Draped wire mesh was installed to control rockfall because the ditch width was reduced for road widening in the steep canyon setting. Figure 7 shows the site.

Figure 7. I-70 MP 242, Veterans Memorial Tunnels

SH 119 Corridor

This mountainous corridor provides a connection between Interstate 70 and several small mountain communities located in the interior of the Front Range. With the advent of low stakes casino gambling in Colorado, the towns of Black Hawk and Central City became major destinations for

visitors. The development spurred construction along the route to improve safety and mobility. Daily commuter traffic also increased as urban residents discovered the attractiveness of mountain living while continuing their employment in the Denver metropolitan area.

State Highway 119 (SH 119) follows North Clear Creek from MP 0, at the intersection with US Highway 6, to MP 9.5. The highway traverses the Front Range of the Rocky Mountains in Precambrian age intrusive igneous granite and metamorphic rock continuing north and east and exiting the mountains at Boulder, MP 41. Numerous rock cuts are present in this area where rocks have been faulted, folded and tilted during episodes of mountain building forces, SH 119 continues north and east concurrent with several other highways and streets on Cretaceous age shale, claystone, and sandstone in the hilly Colorado Piedmont to its terminus at MP 63.7 and intersection with Interstate 25.

SH 119 Black Hawk, MP 6

SH 119 through the Town of Black Hawk has been widened from two lanes to four through a series of projects dating back to 2005. The widening project near Milepost 6 was developed to extend the 4-lane section further down the canyon and straighten some of the tight curves. The rock slopes were cut at compound angles where the less resistive material was laidback at 1:1 slopes and the harder more restive slope were steepened to mimic the natural rock slopes. Additional slope rounding was conducted at the drainage intercepts to achieve a more naturally appearing slope and to reduce the rate of erosion along the drainage channels. Figures 8, 9 and 10 show the cuts near Blackhawk.

The majority of the rock cut was blasted using a presplit and production drill pattern due to the poor quality of the rock and prevalent adverse rock structure. The ditch width varied along the rock cut to accommodate the hydraulic requirements and to break-up the appearance of the newly excavated rock face. A brown colored draped wire mesh was applied over the rock face to control rockfall in areas where the ditch width was narrowed for road widening.

Figure 8. SH 119 MP 6 Catchment Ditch

Figure 9. SH MP 6 Draped Mesh

Figure 10. SH MP 6 Half Casts

US Highway 34 Corridor

This two-lane highway connects the Front Range town of Loveland to the east entrance for Rocky Mountain National Park at Estes Park. The route passes through the Big Thompson River Canyon, where intense summer storms at higher elevations have generated severe flooding, both historically and in the recent past.

Realignment, widening and repair of flood damage have required rock excavation in the canyon west of Loveland. Bedrock in the corridor consists mainly of interbedded schist and gneiss that can be highly foliated with zones of granitic intrusions, creating weaker planes and natural fractures.

US Highway 34, MP 77.5 and 78.3

The recently excavated rock cut at approximate MP 77.5, about 15 miles west of Loveland, used presplit blasting and cushion blasting. A rockslide during construction exposed a natural foliation

plane that became the face of the cut. The foliation plane is visible in Figure 11. Additional rock excavation was needed to remove unstable materials following the rockslide and the result was on overrun in plan quantities. Use of advanced bedrock mapping techniques, seismic surveys and subsurface exploration at the top of the cut may have provided sufficient geologic information during the design phase to accurately predict the occurrence of the natural failure zone. The designers could have used this knowledge to plan the excavation and save costs. At other locations along the route, the joint patterns in the foliated rock were favorable to excavation and tended to obscure the half casts from presplit blasting.

Figure 11. US 34 MP 77.5

Rockfall mitigation along US 34 west of Loveland consists of rock anchors to stabilize large blocks and draped mesh to contain smaller fragments generated by weathering of foliated features. Dark colors used for anchor end hardware and draped mesh reduce the visibility of the mitigation measures as seen at MP 78.3. Figure 12 shows draped mesh on a highly foliated slope.

Figure 12. US 34 MP 78.3

SH 82 Corridor

State Highway 82 follows the Roaring Fork River from Glenwood Springs to Aspen and across the high mountains to Twin Lakes near Leadville. The highway is used by daily commuter traffic and is the only route from the east to the popular tourist destinations in the Aspen area during the winter when Independence Pass is closed. Construction in the corridor over the last few decades has improved mobility and safety. Much of the construction has required rock excavation, particularly at Snowmass Canyon, Shale Bluffs, and Independence Pass.

Between MP 0 and east of MP 30 between Old Snowmass and Woody Creek, the road travels on surficial deposits of alluvium and glacial outwash overlying Paleozoic age sedimentary rock of sandstone, shale, conglomerate, gypsum, and evaporite/salt deposits of primarily the Pennsylvanian-Permian age Maroon Formation and the Pennsylvanian age Eagle Valley Evaporite. Exposures of these prominent red and tan rocks are adjacent to the highway and present geohazards including rockfall and collapse associated with sinkholes. Southeast of MP 30, in an area of faulted and

fractured rock known as the Castle Creek Fault Zone, rock types along the highway change to Mesozoic age sedimentary rocks of limestone, mudstone, claystone, shale and sandstone. Cliffs of Cretaceous age Mancos Shale have presented rockfall hazards at Shale Bluffs near MP 35.5. Surficial deposits of alluvium and glacial outwash are present between MP 36 and MP 40 in Aspen.

SH 82 Snowmass Canyon, MP 29

The Snowmass Canyon Project between Basalt and Aspen was the final phase of the widening program of SH 82. There were several rock cuts that were developed to allow for the added roadway width in the steep canyon setting. All of the cuts were drilled and blasted using a cushion blasting pattern. The rock cut near Milepost 29 was required for the construction of a bridge structure for the eastbound lanes. The blast pattern for this cut was adjusted and offset at the bottom of each lift to create benches similar to the natural terrain. An excavator was used to remove the soil and highly weathered overburden material and to remove excess loose material from the high wall as the cut was brought down. The cut slope was designed to allow falling rock to pass between the rock face and bridge, and the catchment area at the base of the cut was designed to control rock fall for the westbound lanes.

In some areas at the top of the cut, extensive soil deposits and weathered bedrock cap the more resistive sandstone layers. The soil was derived from the debris flows and the natural weathering process from the canyon bedrock. Due to the steep terrain, these deposits could not be laid back to an acceptable slope angle. A shotcrete-faced soil nail wall was used to stabilize the unconsolidated deposits. To contain the loose material, the facing was tapered onto the newly excavated rock face and anchored using rock bolts and soil nails. The shotcrete was colored reddish-brown to match the natural outcrops using an integral concrete pigment and then stained to simulate the natural weathering, such as limonite and iron oxide patina. The stained shotcrete is visible in the upper left corner of Figure 13 below.

Figure 13. SH 82 MP 29

SH 133 Corridor

State Highway 133 follows the North Fork of the Gunnison Valley from Hotchkiss, through the agricultural region around Paonia and into the West Elk Mountain range near Somerset. North of the coal mining district around Somerset, the road passes west of Paonia Reservoir and gradually climbs to McClure Pass. The highway follows the Crystal River from the north side of the pass to Carbondale where it intersects SH 82. The route allows access to the coal mines and farms along the North Fork of the Gunnison and heavy haul trucks supplement the railroad to move coal down the valley. SH 133 also allows recreational traffic to connect between Carbondale and the Black Canyon of the Gunnison.

Above Somerset the highway travels through Cretaceous age sedimentary rock of shale, coal, and sandstone of primarily Mancos Shale and cliffs of the Mesaverde Formation that are prone to

rockfall hazard. The West Fork of Muddy Creek enters the Paonia reservoir at approximately MP 27 and the highway follows the East and West Forks of Muddy Creek to MP 36 through claystone, mudstone, sandstone, and conglomerate of the landslide-prone Tertiary age Wasatch Formation. Landslide deposits are adjacent to the highway between MP 28 and MP 33 and near MPs 36 and 39. The highway ascends to McClure Pass, elevation 8,755 feet, through Wasatch Formation from MP 36-43.5 with overlying glacial gravel deposits from MP 38 to MP 43.5. The winding descent of SH 133 from MP 43.5 to MP 49 is in sandstone, shale and coal cliffs of primarily the Mesaverde Formation in an area of past rockfall mitigation. The highway continues north following the Crystal River valley between MP 46 and the terminus at MP 68.8. Between MP 49 and MP 62 sedimentary rock adjacent to the highway includes sandstone, siltstone, conglomerate, and gypsum with igneous intrusive granitic rock at MP 56. At MP 62 the highway is on gravel deposits to the intersection with State Highway 82 at MP 68.8, Carbondale.

SH 133 Paonia Reservoir, MP 24

There are several rock cuts along the SH 133 corridor near Paonia Reservoir. Most of these cuts experience frequent rockfall due to the geologic setting and cut slope configurations. These cuts were excavated through massive sandstone units that are interbedded with weak shale and claystone seams. Weak shale seams are visible in Figure 14 below. The rockfall occurs as the softer seams weather and undermine the sandstone causing large blocks to calve from the rock face. A rockfall mitigation project was developed for one of the more active sites at the rock cut near the dam at the reservoir. The major project elements included removing the unstable rock features, control of the rockfall using draped wire mesh and rock bolts, and stabilization of the soft shale seam along the base of the cut.

Line drilling and smooth wall blasting techniques were used to reestablish the cut face and remove material that had become undercut from the erosion of the softer shale and claystone seams. Because there was little material to buffer the shot, blast mats were used to control the blasts and protect the surrounding facilities. Blast mats could not be used in some of the shots due to access limitations and some of the shots resulted in excess flyrock.

The soft shale seam along the base of the cut was stabilized using a shotcrete faced soil nail wall. The shotcrete was stained a color similar to that of the surrounding sandstone units. The shotcrete was also tapered onto the resistive sandstone layers to help minimize soil loss behind the facing.

Figure 14. SH 133 MP 24

US 24/285 Corridor

US Highway 24 and US Highway 285 join south of Buena Vista near MP 213 continuing concurrently using mile numbers for US Hwy 24 east to MP 226.5 to Antero Junction, 12 miles west of Hartsel where the highways split. The route carries a moderate volume of recreational and freight traffic with recreational traffic increasing dramatically in the summer months. This highway is an important connection between the Arkansas River Valley and the Front Range metropolitan areas. Passing lanes were constructed in 2017 by excavating through the igneous rocks to widen the roadway.

The highway is in the south edge of the Mosquito Range of the Rocky Mountains. Rock excavations along the highway between MP 213 and MP 221 expose Precambrian age intrusive igneous granite and extrusive igneous ash flow tuff from Tertiary age San Juan Mountains volcanic activity. From MP 221 to MP 226.5 are Paleozoic age sedimentary rocks that include limestone, gypsum, siltstone and shale. Some northwest-southeast trending faults cross the highway between MP 215 and MP 220. The highway crosses Trout Creek Pass, elevation 9,346 feet, at about MP 225.5.

US 24/285 Trout Creek Pass, MP 217

The US24/285 project was designed to add climbing lanes and smooth some of the curves along the south side of Trout Creek Pass west of Johnson's Village near Buena Vista. Rockfall was known to emanate from many of the existing rock slopes along the highway. Bedrock is composed of granitic rock (intrusive igneous) with varying degrees of weathering and random rock structure much of which is oriented in an unfavorable direction.

The plans and special provisions (specifications) for the project required that the final appearance of the rock cuts resemble the natural occurring rock exposures found throughout the area. The contractor utilized a cushion blasting drilling and loading pattern to achieve the rock slope configuration. Ripping with an excavator was also used to remove the less resistive material and round the cut slopes to transition into the natural slopes. An area where ripping was used is shown below in Figure 15. In many areas, the excavator also pulled portions of the rock at the face back to the existing fractures resulting in a more stable and natural appearing slope. Other rock slope integration methods were used to achieve the final face including varying the slope angle based on the hardness of the rock and rock structure, expanding the drainage intercepts, and varying the ditch width along the alignment.

Rock bolts and draped wire mesh were used in the taller rock cuts to control rockfall where the catchment area at the base of the cut was narrowed for road widening. Portions of the draped wire were likely not required but the support anchors for the mesh system were drilled and installed prior to the rock excavation and it was felt that most of the labor for the contract item had already been completed.

Figure 15. US 24/285 MP 217

US 160 Corridor

US Highway 160 is one of the principal east/west routes across southern Colorado and connects Western Slope communities to Interstate 25. The corridor is heavily used by daily commuters, recreational visitors and commercial freight. Much of the route is narrow, two-lane road winding through terrain that varies from broad river valleys to high mountain passes. The more remarkable rock excavations are on the east and west sides of Wolf Creek Pass. Geohazards include snow avalanche, rockfall and landslides.

US Highway 160 enters Colorado approximately 0.5 mile east of the Four Corners Monument at MP 0 and continues north and east in Cretaceous age shale, mudstone, coal and sandstone, primarily of the Mancos Shale and the Mesaverde Group. The highway follows the western and northern edges of Mesa Verde on the east edge of the Colorado Plateau and enters the San Juan Mountain Range of the Rocky Mountains at MP 73, just east of Hesperus. Between MP 86 and MP 116 the Cretaceous to Tertiary age Animas Formation exposed in road cuts consists of interlayered sandstone, shale, and conglomerate, including abundant volcanic and arkosic detritus without clearly defined bedding. The road crosses major deposits of alluvium in this area, particularly between MP 91 and MP 94 and in the area of MP 101.

Between Bayfield and Piedra, from MP 116 to MP 153, rock excavations expose sedimentary rocks of primarily the Mancos Shale and the Mesaverde Group. Near MP 129 a northwest-southeast trending fault separates the Mesaverde Group to the west from the Mancos Shale to the east. US Hwy 160 crosses the San Juan River and several north to south flowing tributaries of the San Juan River between MP 0 and MP 144 at Pagosa Springs. Alluvial deposits at MP 135-136 follow another northwest-southeast trending fault.

As elevation increases to above 7,500 feet, the highway crosses glacial deposits and alluvium between MP 153 and MP 158 with a landslide between MP 158 and MP 159. The highway is on intrusive rocks, including various sequences of ash-flow tuff related to volcanism of the central San Juan Mountain calderas from MP 159 to MP 185 at South Fork. Several rock cuts are located at Wolf Creek Pass, elevation 10,857 feet. US Hwy 160 continues to the north and east and follows the Pass Creek drainage between MP 170 to about MP 175, where Pass Creek joins the South Fork Rio Grande River. Southwest of the confluence of Trout Creek and the South Fork Rio Grande near MP 185 are several large road cuts along US Hwy 160. The South Fork Rio Grande enters the Rio Grande River at South Fork, MP 186, and US Hwy 160 follows the Rio Grande drainage east to MP 233 at Alamosa. From Monte Vista to Alamosa US Hwy 160 and US Highway 285 overlap.

Between South Fork and east of Del Norte at MP 206, the road exits the San Juan Mountains and enters the San Luis Valley on alluvial deposits east to MP 259 near Fort Garland at the west edge of the Sangre de Cristo Mountains. The highway traverses the mountains from MP 259 to about MP 286 northwest of La Veta, on folded and faulted sedimentary rock, including siltstone, sandstone and conglomerate of mainly the Santa Fe and Sangre de Cristo Formations, mixed intrusive rocks related to volcanism, and undifferentiated Precambrian rocks. La Veta Pass at an elevation of 9,413 feet is at about MP 278.5.

From MP 286 east to MP 410, US Hwy 160 is on relatively flat-lying Cretaceous to Tertiary age sedimentary rocks including limestone, shale, sandstone and conglomerate. Between MP 410 and the Kansas state line at MP 497, the road crosses the Comanche National Grassland and the rock type is predominately loose to well-cemented gravel of the Tertiary age Ogallala Formation.

US 160 Wolf Creek Pass – East MP 174 to 184

Several projects have been completed along the east side of Wolf Creek Pass that have required significant rock excavation. One of the more notable projects runs adjacent to and across the highway from, the Fun Valley Campground just west of South Fork. Several methods were used to introduce excavation and stabilization techniques into the project to blend the improvements into the surrounding setting included rock blasting, slope rounding, slope protection, and retaining walls.

Many of the cuts exceeded 100 feet in height which would typically require widened catchment ditches to collect rockfall. Given the nature of the steep terrain in the slopes above the cuts, widened ditches would have led to even taller and more massive rock cuts. A small technical group composed of representatives from CDOT Region 5, CDOT Geotechnical, CDOT Landscape Architects, the United States Forest Service, and the design Architectural and Engineering (A&E) team was formed to determine the best approach to developing the rock excavation. This group determined that the ditches would be kept at a minimal width and still able to accommodate the roadside drainage and serve as rockfall catchments. Brown colored draped wire mesh was applied in the upper portion of the cut and extended down the face to 20 feet above the base of the cut to

control rockfall and minimize impacts to the viewshed. All of the rock cuts were stained with a color reactive treatment to mimic the natural limonite staining that is common to the area. The rock staining that was used reacts to the mineral composition of the rock and exposure to sunlight to provide a more weathered and aged appearance.

The bedrock in the area is composed of extrusive volcanic rhyolite derived from the numerous, large pyroclastic flows and lahars that emanated from the volcanic region around Creede. The process of deposition of this material resulted in massive bedrock with a horizontal bedding type pattern and near vertical fractures perpendicular to the bedding planes. The approach to blasting was also determined largely on the potential impacts to the viewshed. The rock excavation consisted of three primary methods of blasting: presplitting in the upper portions of the cuts; cushion blasting in the lower portions of the cuts; and a cushion blasting technique that utilized the naturally occurring near vertical fractures to control overbreak. The presplitting did result in visible half-casts and an attempt was made to remove the drill traces from the final rock face using a hand-held pneumatic bush hammer. A test section of the hammering method and rock staining was implemented to evaluate the final appearance. It was determined that the rock stain was too dark in the areas of the hammering as compared to the overall face and that it did not improve the appearance over leaving the drill traces. Figure 16 shows stain being applied and Figure 17 shows the stained rock face several years later.

Figure 16. US 160 MP 183

Figure 17. US 160 MP 184

The rock cut located east of Fun Valley at approximately MP 184.2 utilized cushion blasting techniques where the blast pattern was laid out using the natural vertical fractures. This process created a stable cut with a more natural appearance. Portions of the cut were still removed using presplitting, but where the natural fractures allowed, the rock material was removed back to the near vertical joint. The contrast between cushion blasting and presplitting is evident in Figure 18.

Figure 18. US 160 MP 184

US 550 Corridor

The US 550 Corridor extends north from the New Mexico State Line to Montrose. The highway is essential for transportation to and from Durango, the mountain towns of Silverton, Ouray and Ridgeway, and cities on the Western Slope. The route carries freight and recreational traffic across high mountain passes and through narrow, winding canyons. Rock excavation has been required for safety improvements and realignment between the state line and Durango, and from Coal Bank Pass near Mile Marker (MM) 50 to Ridgway near MM 106. The highway bench from approximately MM 53 to MM 93 is very narrow and nearly every improvement requires rock excavation.

Rock excavations from the state line to MM 7 expose interlayered sandstone and shale of the Nacimiento Formation. The Animas Formation is exposed in cuts near Durango and it consists of interlayered sandstone, shale, and conglomerate with abundant volcanic and arkosic detritus without clearly defined bedding. Between MM 50 and Ouray the rock excavations along US 550 are in sedimentary rock, mainly the Hermosa and Molas Formations, mixed intrusive rocks related to volcanism that formed the Silverton Caldera, and undifferentiated Precambrian rocks in the

Uncompahgre Gorge. North of Ouray the corridor follows the broad Uncompahgre River valley and minimal rock excavation has occurred until Ridgway, where a large excavation has exposed interlayered sandstone and shale of the Morrison Formation.

Mechanisms of rock slope instability along the US 550 corridor include undercutting and toppling in the sandstone/shale formations, in-place weathering and erosion (slaking) in the Animas Formation and wedge failure or raveling in the jointed intrusive rocks of the high mountain passes. Rockfall mitigation measures along the corridor include protective grading, rock reinforcement, draped mesh and cable net.

US 550 MM 2.0 to 2.5 – NM State Line North

The site near MM 2 is typical of excavations in the sedimentary sandstone/shale formations. The site was excavated in 1999 and 2000 to allow widening the highway to four lanes and to mitigate a rockfall hazard zone. Cushion blasting techniques were specified to avoid visible half-casts. The shale layer underlying the massive sandstone was covered after excavation with a fill slope to reduce erosion that could undercut and destabilize the sandstone. The sandstone exposed in the cut generally matches the surrounding natural cliffs visible in the distance as shown in Figure 19. Excavating to follow the curvature of the highway and rounding at the top of the slope were employed to improve the natural appearance. The duration of visibility is greatest when approaching from the south.

Figure 19. US 550 MP 2

US 550 MM 91 – Bear Creek Bridge

This cut through very hard, thinly laminated schist was excavated in 2009 and 2010 to widen the highway during construction of the new Bear Creek Bridge. The Project Special Provision for rock excavation was written as a 'method' specification that closely controlled the contractor's drilling and blasting operations. The tight control on rock excavation was needed due to the limited space for construction and the environmentally sensitive surroundings. Although the specification required final exposed face of permanent rock slopes to follow natural rock mass features, the closely spaced jointing and hard nature of the rock required pre-splitting to conform to the strict excavation limits. As a result, some half-casts were created. Raveling since construction has reduced the visibility of half-casts and draped mesh rockfall containment further obscures the signs of construction. The final slope face closely resembles the natural rock surface visible in Figure 20 on the sides of Bear Creek Gorge. Posted speed limits in this segment are low and the slope is highly visible for more than one minute when approaching Bear Creek Bridge from the south. Stationary visitors to the nearby Bear Creek Overlook also see the cut slope and how it contrasts with the natural surroundings. The light colored draped rockfall mesh is visible in the Figure.

Figure 20. US 160 MP 91

US 550 MM 106 – North of Ridgeway

Rock excavation at this site was performed in 2015 primarily as a rockfall mitigation measure and to improve site distance on a sharp curve. The bedrock geology consists of alternating layers of sandstone, claystone and shale. Presplitting was employed during production while trim blasting was used to construct a pioneer road to the top of the cut. The design called for rock reinforcement and shotcrete facing in the claystone layer at the bottom of the cut to prevent erosion that could undercut the overlying sandstone and create a rockfall hazard. Draped rockfall mesh was installed over the upper portion of the excavated face to contain rockfall from raveling of weak layers and weathered sandstone. Visible half-casts were not prohibited in the Rock Excavation project Special Provision and are apparent in the lower part of the slope face above the shotcrete treatment. The extent of half-casts made have been reduced if angle drilling and cushion blasting had been used, but the non-homogeneous rock made precise drilling and controlled blasting difficult. The outer two-inch thick layer of the shotcrete was integrally pigmented and textured to improve the appearance. The rock slope is visible for about one minute by motorists approaching from the south and is also visible from the west by users of a multi-modal trail for access to the nearby Ridgway State Park. The textured shotcrete and less visible draped mesh are shown in Figure 21.

Figure 21. US 160 MP 106

IMPLEMENTATION

Use of BMPs to mitigate the visual impacts from highway rock excavations is best considered early in the project delivery process. Maintaining the scenic beauty along Colorado's highways should be an important rock excavation project goal. Acknowledgement of this goal provides a justification for budget allocation and design effort to implement BMPs where rock excavations are necessary.

Begin the process of rock excavation design during project scoping. An in-office review of available satellite imagery and videos of the corridor can give an initial impression of the natural surroundings and potential visual impacts of the rock excavation. A site visit is recommended to observe the setting and gather information needed for design. The site visit can be included in the Design Scoping Review (DSR) agenda or can be a separate visit to focus on the proposed rock excavations. Coordinate with the Environmental Branch and the Landscape Architect to be sure the following are documented during the visit:

- Photograph the area of the proposed rock excavation, nearby natural rock features and existing excavations.
- On existing alignments, travel both directions to assess the potential visual impact of the proposed excavation. Use the methodology discussed in the Phase 1 research (viewshed, travel time, short and long range views, etc.). Obtain video and measurements to support observations.
- On new alignments, observe and document the appearance of nearby natural rock slopes.
- Consult with the Geotechnical Engineer to identify the rock formation types and document obvious characteristics such as drainage channels, weathering, talus deposits, rock structure, and potential rockfall hazards. Refer to the Catalog in Appendix B for expected conditions at the project location.
- Observe and document any nearby public properties, recreational facilities, non-State highways, Federal Lands, Tribal Lands, and others where users could view the proposed cut. Representatives of these entities may be considered stakeholders in the project.

The preliminary design of the new alignment or roadway widening will dictate the horizontal extent and minimum limits of rock excavation for the project. Site geology and geotechnical engineering considerations will indicate the maximum allowable rock slope grades. Aerial survey techniques

such as Lidar and photogrammetry can be used to help define the practical limits of rock excavation at locations where terrain makes traditional on the ground survey methods difficult. Right-of-Way and environmental constraints are often controlling factors in determining the cut limits.

After the minimum and maximum allowable extents of the rock excavation have been determined, the design should focus on mitigating the adverse effects of the excavation. Consider slope stability, geohazards such as rockfall, seepage and erosion when mitigating for visual impact. Consult with the geotechnical engineer, CDOT Geohazards Group, CDOT Environmental Branch, and Landscape Architect to select mitigation methods from the BMP tables in Appendix C that are suitable for the site. Stakeholders such as Federal agencies, tribal governments, local municipalities, adjacent landowners, and other stakeholders may have specific restrictions or desires regarding the final appearance of the cut.

Minimizing the volume of rock excavation generally reduces project costs. However, removing more rock is often a better solution to achieve the desired mitigation goals. A Value Engineering Analysis (VEA) of the proposed BMPs is recommended to aid in the selection for the final design. The VEA participants should include CDOT Geotechnical, Geohazards, and Environmental branches. Input from other stakeholders should also be considered.

A Project Special Provision (PSP) is recommended to communicate the design intent and construction requirements for implementing the rock excavation BMPs. General notes, environmental notes, and details on plan sheets clarify the design and indicate specific site locations for construction of various elements of the design. The PSP specifies the scope of the work, contractor qualifications, materials, blasting and excavation methods, and method of measurement and payment for the rock excavation. Appendix D provides a draft PSP that can be edited by the designer so that specific rock excavation BMPs are included in the contract. The PSP indicates the stages of construction when input from the CDOT Staff branches is required to ensure that the BMPs are being constructed as designed or can be successfully modified to conform to geologic conditions exposed during excavation.

Prior to beginning the excavation, the Contractor's submittal should be reviewed and approved by the Construction Project Manager/Project Engineer, Resident Engineer, and representatives of the appropriate staff branches. The submittals critical for rock excavation and BMP implementation include a general excavation plan, production blasting plan, and BMP specific blasting plans. The plans should consist of schematic drawings, narratives, and schedules that adequately describe the proposed excavation sequences. Deviations from the approved plans during construction should be avoided without review by the design team. Changes that appear to accelerate construction can create conditions that undermine the effectiveness of visual impact or geohazard mitigation designs. Examples include construction of inappropriate pioneer roads to access blasting benches that result in unstable slopes or visual impacts that cannot be corrected, and pre-installation of rockfall mitigation elements before an evaluation of the actual rockfall hazard from the completed cut, leading to unnecessary costs and increased visual impact.

REFERENCES

AASHTO, American Association of State Highway and Transportation Officials, 2004, A Guide for Achieving Flexibility in Highway Design, https://store.transportation.org › Common › DownloadContentFiles accessed December 2, 2019.

Andrew, R.D., Bartingale, R., and Hume, H. 2011, Context Sensitive Rock Slope Design Solutions, Federal Highway Administration (FHWA) Federal Lands Highway Division (FLHD) Publication No. FHWA-CFL/TD-11-002, 122 p.

Andrew, R.D., 1992, Selection of Rockfall Mitigation Techniques based on Colorado Rockfall Simulation Program, Transportation Research Record 1343, pp 20-22.

Arndt, B., Demarco, M., Andrew, R., 2008, Polyurethane Resign (PUR) Injection for Rock Mass Stabilization, Federal Highway Administration (FHWA) Federal Lands Highway Division (FLHD) Publication No. FHWA-CFL/TD-08-004.

Colorado Department of Transportation, 2019, CDOT Visual Impact Assessment Guidelines, CDOT Visual Resources Program.

Colorado Department of Transportation, 2015, CDOT I-70 Mountain Corridor Aesthetics Guidance, I-70 Mountain Corridor Context Sensitive Solutions accessed on January 20, 2021 at: https://www.codot.gov/projects/contextsensitivesolutions/design/i-70-mountain-corridor-aesthetics-guidance

Cummings, R.A., 2002, Highway Cut Slopes in Rock: Specialized Excavation and Enhancement Techniques, 53rd Highway Geology Symposium, San Luis Obispo, CA, 20 p.

Dick, R.A., Fletcher, L.R., D'Andrea, D.V., 1987, Explosives and Blasting Procedures Manual, U.S. Department of the Interior, Bureau of Mines Information Circular 8925.

Green, R.G., and Hawkins, A.B., 2005, Rock cut on the A5 at Glyn Bends, North Wales, UK, Bulletin of Engineering Geology and the Environment. 64. 95-109. 10.1007/s10064-004-0272-3.

Harber, A.J., Nettleton, I.M., Matheson, G.D., McMillan, P., and Butler, A.J., 2000, Rock Engineering Guides to Good Practice: Road Rock Slope Excavation, Transport Research Laboratory published project report PPR556, Transport Scotland and the Highways Agency, 124 p.

Maerz, N. H., Youssef, A., and Lauer, R., 2004. MORFH RS: A rockcut rating system for Missouri highways. 55th Highway Geology Symposium, Kansas City, Missouri, Sep. 7-10, 2004, pp 406-424.

Maerz, N. H., Youssef, A., and Xiang, Q., 2003. Digital Imaging for Screening and Making Measurement of Features on Highway Rock Cuts. Transportation Research Board, 82th Annual Meeting, January 12-16, 2003, Washington, D.C.

Moler, S., 2002. A Hallmark of Context-Sensitive Design, Federal Highway Administration Research and Technology, Washington, D.C., Public Roads Volume 65, No. 6, May/June 2002.

Muhunthan, B. et al, 2005. Analysis and Design of Wire Mesh/Cable Net Slope Protection, Washington State Transportation Commission and Federal Highway Administration, Washington State Department of Transportation Research/Reports, Publication number WA-RD 612.1.

Nevada Department of Transportation, 2009, Aesthetic Alternatives for NDOT Design Standards, Design Workshop CH2MHill and Hoverstein Associates, https://www.nevadadot.com/home/showdocument?id=1543, accessed July 27, 2020.

PennDOT & NJDOT, New Jersey and Pennsylvania Departments of Transportation, 2008, Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities, https://www.dvrpc.org/reports/08030A.pdf, accessed March 19, 2020.

Petr, V., Lozana, E., Nieczkoski, E., 2018, Rock Cut Perimeter Blasting Best Management Practices Phase I, Colorado Department of Transportation (CDOT), Advanced Explosives Processing Research Group (AEPRG) Colorado School of Mines, CDOT Report 2018-07.

Pierson, L.A., Gullixson, C.F., and Chassie, R.G., 2001, Rockfall Catchment Area Design Guide, Final Report SPR-3(032), Metric Edition, Oregon Department of Transportation-Research Group and Federal Highway Administration, Washington, D.C.

Relic, I., Scheidl, C., Lauss, E., Perzl, F., Kofler, A., and Kleemayr, K., 2018, The state of the art in rockfall protection forests-Alpine space project 462 - RockTheAlps, WP T2-Activity A.T2.1, Deliverable D.T2.1.1, V 1.0, TORRID toolbox, Interreg Alpine Space Rock the Alps, European Union, European Regional Development Fund, pp.

Route One Publishing Limited, 1998, French A84 on Track, World Highways/Routes du Monde, Volume: 7,Issue Number: 3,Publisher: Route One Publishing Limited, Surrey, England, ISSN: 0964-4598, pp. 97-98

Schiechtl, H.M., Stern, R., 1996, Ground Bioengineering Techniques for Slope Protection and Erosion Control, Blackwell Scientific Publications Limited, Oxford, England, 146 pages.

Sprague, C.J., 1999, Green Engineering: Design Principles And Applications Using Rolled Erosion Control Products. Part Two, Civil Engineering News, Incorporated, Kennesaw, Georgia, ISSN: 1051-9629, Volume 11, Issue Number 2, pp 76-78, 80-81

.

Szalankiewicz, S., et al, 2016. Geotechnical Aspects of an Off-line Walkway Addition to the Route 28 Project, 67th Highway Geology Symposium Proceedings, July 11-14, 2016, Colorado Springs, Colorado, pp. 453-470.

Turner, A.K., Schuster, R.L., editors, 2012, Rockfall: Characterization and Control, Transportation Research Board Miscellaneous Publication, National Academy of Sciences. Textbook. p. 68, pp. 445-455, pp. 478-489, pp. 496-511, pp. 530-542.

U.S. Department of Transportation, 2015. Guidelines for the Visual Impact Assessment of Highway Projects, Federal Highway Administration Report No. FHWA-HEP-15-029, Washington, D.C.

U.S. Department of Transportation, Federal Highway Administration, 1989, Rock Slopes: Design, Excavation, Stabilization, Federal Highway Administration Report No. FHWA-TS-89-045, McLean, Virginia

Wyllie, D.C., and Mah, C.W., 2004, Rock Slope Engineering, Civil and mining, Chapters 11 and 12, Spon Press, 270 Madison Avenue, New York, NY 10016, 4th Edition.

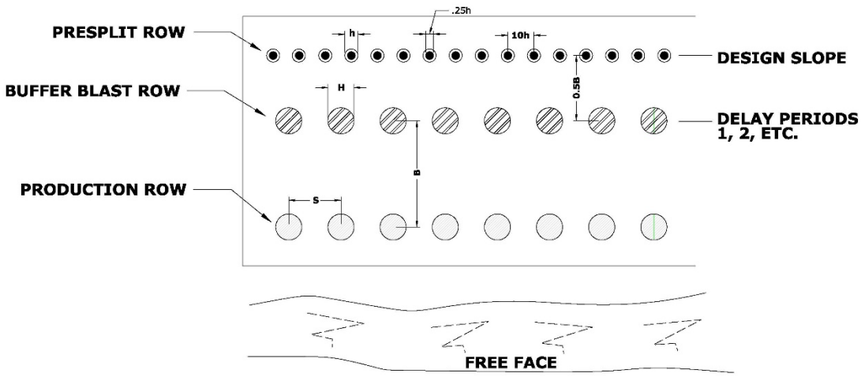
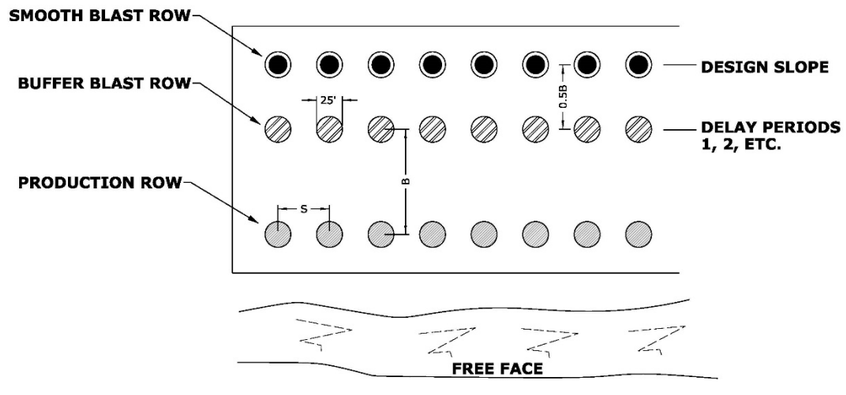
Wyllie, D.C., and Norrish, N. I., 1996, Landslides: Investigation and Mitigation, Chapter 18-Stabilization of Rock Slopes, Transportation Research Board Issue Number 247, pp. 474-504.

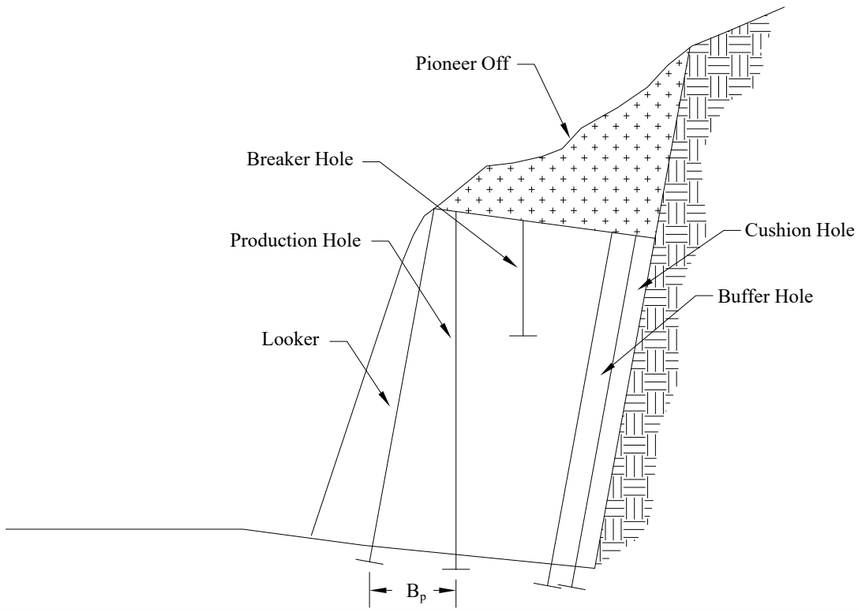
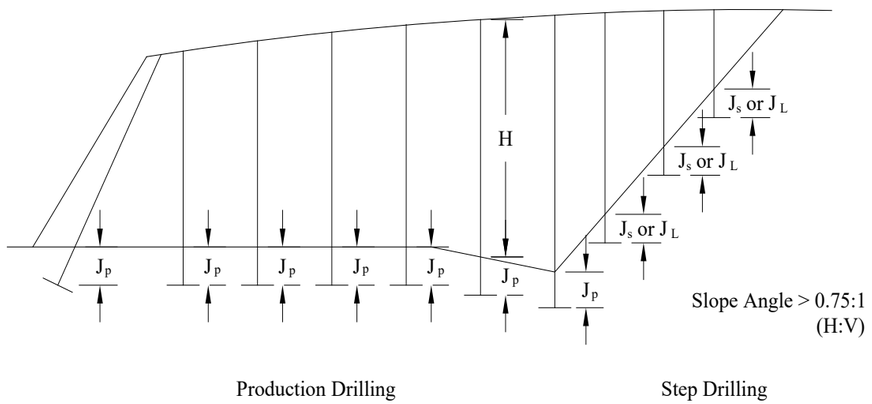
Appendices

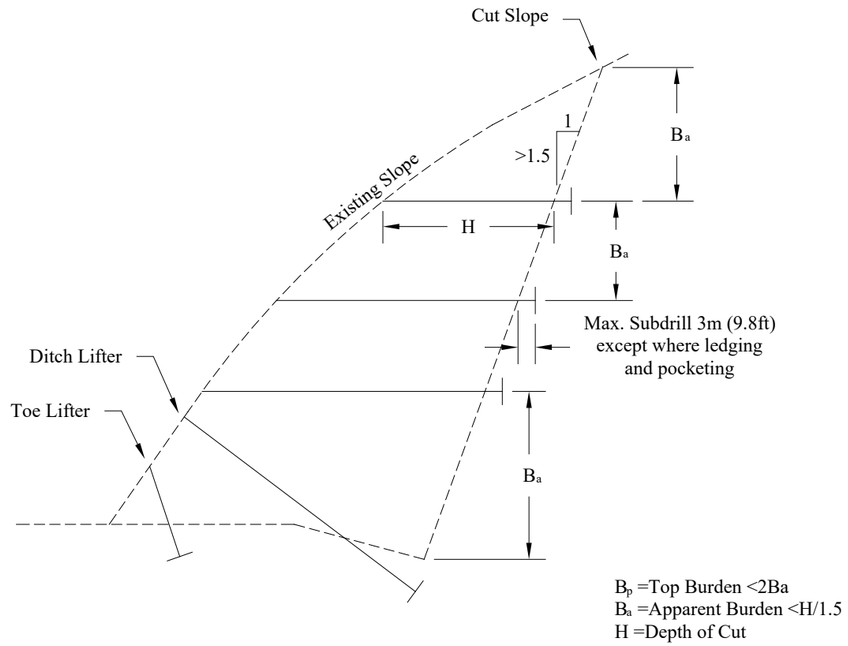
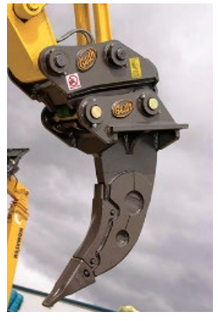
List of Appendices

APPENDIX A – ROCK EXCAVATION BMP TOOLBOX

Summary of Typical Drilling and Blasting Methods used in Highway Construction

PROCEDURE		DESCRIPTION	BEDROCK TYPES	ADVANTAGES	LIMITATIONS
Presplit Blasting		Presplit holes are blasted before production blasts. Procedure uses small diameter holes at close spacing and lightly loaded with distributed charges. Typically required in rock with adverse rock structure.	Generally, the preferred method to develop stable rock cuts in fractured rock with adverse rock structure. Applicable to all bedrock types.	Protects the final cut by producing a fracture plane along the final slope face that fractures from production blasts cannot pass. Can produce steeper cuts with less maintenance issues. Performs well in hard competent rock.	The small diameter borings limit the blasting depth to 15 m (50 ft). Borehole traces are present for entire length of boring. Does not perform well in highly weathered, weak rock.
Smooth Blasting		Similar to Presplit Blasting except that the row of closely spaced drill holes are generally larger, loaded with decoupled charges (charges with a smaller diameter than the drill hole) and fired simultaneously with or just after the main blast to produce an excavation contour without fracturing or damaging the rock behind or adjacent to the blasted face.	Typically used in formations composed of massive sandstone units or extrusive igneous (volcanic) bedrock where vertical joints are present to control overbreak from the blasting.	Produces a cosmetically appealing, stable perimeter. Can be done on slopes years after initial construction. Drill hole traces are less apparent than presplitting. Performs best in hard, competent rock.	The small boring diameter limits blasting depth to 15 m (50 ft). Borehole traces are present for much of the boring length. Does not protect the slope from damage caused by production blasting. Does not perform well in highly fractured, weak rock.

PROCEDURE		DESCRIPTION	BEDROCK TYPES	ADVANTAGES	LIMITATIONS
Cushion Blasting		Cushion blasting is done after production blasts. Larger drill holes are used with small diameter, lightly loaded distributed blasting loads. Space around the explosive is filled with crushed rock to cushion the explosive force.	Typically used in formations composed of massive sandstone units, igneous (intrusive and extrusive/volcanic) rock or metamorphic rock where near vertical joints are present to control overbreak from the blasting.	Reduces the amount of radial fracturing around the borehole and also reduces borehole traces. The large diameter holes allow blasting depths up to 30 m (100ft). Produces a ragged final slope face. Performs well in all rock types.	Radial fractures are more abundant than presplit and smooth blasting. Slope face is more prone to raveling. A catchment area is recommended at slope base. More demanding on the driller. Borehole traces still apparent in hard, competent rock.
Step Drilling		Larger diameter drill holes drilled vertically and used as production blasting, although spaced closer and loaded lighter to minimize radial fractures. Slope face is formed along base of blast holes that are drilled to different depths.	Best suited for bedrock units where the base of the blast holes coincides with geologic structure to form the final slope face. Bedrock units include bedded sedimentary rock, and fractured igneous and metamorphic rock with the appropriate joint structure, generally with bedding and joint planes parallel to the roadway.	If properly designed the final slope face shows minimal signs of blasting. Best used in moderately to highly fractured rock or bedded sedimentary bedrock units.	Can produce extensive damage to slope or inadequate base fracturing if not designed properly. Should only be used with experienced driller and blasting engineer. Only applicable for slopes between 0.7:1 and 1:1 (H:V). Does not perform well in hard competent rock.

PROCEDURE		DESCRIPTION	BEDROCK TYPES	ADVANTAGES	LIMITATIONS
Horizontal Drilling		Larger diameter, closely spaced, lightly loaded horizontal borings used for production style blasting in massive rock to eliminate drill holes or in areas of poor access.	Can be used in all bedrock types but not very effective in weathered bedrock.	Eliminates bore hole traces when drilled perpendicular to the slope face. Good in massive rock where traces are not acceptable. Allows for development of the pioneering access to the top of the excavation in steep terrain.	Demanding on the driller and explosives engineer. Can produce extensive radial fractures or inadequate base fracturing if not loaded properly. Requires complicated loading and timing procedures, and special stemming procedures.
Ripping	 	Uses a tractor or hydraulic excavator with an attached tooth or teeth that is lowered into the rock and dragged to break up material for excavation.	Limited to weathered and/or highly fractured bedrock. Can be used in a limited basis (although inefficiently) in more resistive bedrock units.	Much cheaper and safer than blasting. Can be done in close proximity to development without disturbance. Is effective on a variety of angled cuts and an excavator can be used after ripping for slope sculpting.	The tooth of the ripper can leave scars on the rock surface. The tractor cannot be used on steep slopes because of risk of overturning. Ripping is limited to relatively low density rocks.

Overview of Rock Slope Integration Methods

PROCEDURE	EXAMPLE	DESCRIPTION	BEST ROCK TYPES /ADVANTAGES	APPLICABLE DRILLING AND BLASTING METHODS	LIMITATIONS/ DISADVANTAGES
Major Slope Warping		Rounds the ends of the cut to smooth the transition between the rock cut and the natural terrain.	Can be used on any rock type. Best used to mimic and transition into existing ridge and valley systems.	Cushion blasting methods are more commonly used to achieve the transitions from the cut slope to the surrounding terrain. Step drilling methods can also be used if the geologic structure allows.	Flatter portions of the slope will be more exposed to weathering and erosional processes. Requires blasting procedures capable of angled borings. Slope ends are visible to motorists for a longer time.
Expanded Slope Rounding		Rounds the crest of the cut slope to smooth the transition to the natural terrain.	Can be done on any rock type. Best on slopes that are capped with a weathered layer and/or soil. The crest is often an area of increased weathering and blasting damage, removing it reduces rockfall hazard.	This is typically achieved using ripping methods. Where more resistant rock is present at the top of the slope in steep terrain, horizontal drilling may be required.	Areas of thick colluvial cover, including large gravel and boulders, requires heavy soil excavation techniques and possible access problems.

PROCEDURE	EXAMPLE	DESCRIPTION	BEST ROCK TYPES /ADVANTAGES	APPLICABLE DRILLING AND BLASTING METHODS	LIMITATIONS/ DISADVANTAGES
Drainage Intercepts		Specifically designed to transition topographical low areas to high areas by gradually decreasing the slope angle transitioning to the low area.	Can be used in any rock type. Combining with expanded slope rounding and major slope warping can improve the appearance of the slope in relation to the surrounding area.	Cushion blasting methods are more commonly used to achieve the transitions from the cut slope to the drainage areas. Step drilling methods can also be used if the geologic structure allows.	Blasting procedure must be capable of different angles of borings. Rockfall launching features may result if the transition section is rough. Slope ends are visible to motorists for a longer time.
Ditch Width Variation		Provides slope variation longitudinally along the slope and often extends throughout the slope height. Works well in areas of long monotonous cuts.	Can be used on any rock type. Ditch width variations can be used to hide drill hole traces. Effective in reproducing natural undulations in the slope.	All drilling and blasting methods can be used to develop the variations in the ditch width.	May be difficult in moderately to highly fractured rock because of kinematics. Blasting procedure must be capable of variable angled borings. Can create rockfall launching features.

PROCEDURE	EXAMPLE	DESCRIPTION	BEST ROCK TYPES /ADVANTAGES	APPLICABLE DRILLING AND BLASTING METHODS	LIMITATIONS/ DISADVANTAGES
Slope Angle Variation		Varies the slope angle laterally along the slope to accentuate prominent geological features or differences in weathering rates.	Design changes with rock type. Layered rocks result in a stair step pattern while massive rock is dependent on intrusions, joint patterns, and competency variations. Very effective in sculpting the rock.	Cushion blasting methods are more commonly used to achieve the variations within the cut slope. Step drilling methods can also be used if the geologic structure allows. Ripping methods are commonly used in zones of less resistive rock.	Very dependent on geological features and rock structure. Rockfall prone areas can cause problems due to launching features. Ditches typically need to be widened to retain fallen rock. Often increases time of construction.
Rock Staining		Stain is applied to the rock surface to help blend the freshly cut slope color to the natural weathered rock color.	Best used on massive rock formations or where joints are widely spaced. Can be used for any rock type. Creates the appearance of weathered rock and reduces the visual impact of fresh rock faces.	Applicable to all drilling and blasting methods.	Must test several stains to find the correct color that fits the natural conditions. Slope should be thoroughly scaled and can be power washed to remove loose material.

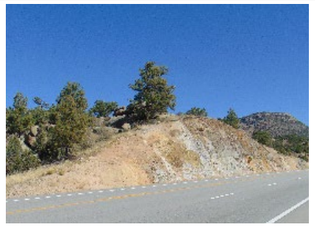
PROCEDURE	EXAMPLE	DESCRIPTION	BEST ROCK TYPES /ADVANTAGES	APPLICABLE DRILLING AND BLASTING METHODS	LIMITATIONS/ DISADVANTAGES
Shotcrete		Shotcrete can vary in appearance from very rough—in its natural, “as-shot” (unfinished) condition—to moderately rough in the "rodded" condition, to as smooth as cast-in-place concrete (with appropriate finishing). Architectural shotcrete (or sculpted shotcrete) can produce a wide range of finished surfaces.	In most instances, structural shotcrete is applied to rock slopes to protect a surface which, left untreated, would erode or to provide structural support for unfavorable orientations or degree of fracturing.	Applicable to all excavation methods. Care should be taken to develop the raw slope face prior to the application of the shotcrete.	Can look artificial if not properly sculpted to represent the adjacent rock outcroppings. Shotcrete that is used to cover soft erodible material needs to be transitioned to unweathered and sound bedrock to avoid erosion and undermining. Rock staining can be applied to shotcrete but amount of product needs to be carefully considered since cementitious materials absorb stain at a higher rate than many types of bedrock.
Rockery		A rockery is a retaining or protection structure that consists of stacked rocks without mortar, concrete, or steel reinforcement. Although the rocks are stacked in an “interlocking” pattern, there are no mechanical connections made between the individual rocks. Rather, these structures rely on the weight, size, shape, and interface friction of the rock elements to provide overall stability.	Maintains the appearance of historic retaining features. Dimensions of the stones used in the construction of the system is based on the material behind the rockery. Generally, the rock sizes can be reduced when used for erosion protection at the toe of slope in more resistive material and bedrock.	Applicable to all excavation methods. Care is required to excavate the slope face to the appropriate dimensions and configuration.	There are no established design guidelines for rockery design. Many agencies only allow a maximum height of 12 feet when used to protect soil slopes. The performance of the rockery is highly contingent on the quality of construction which includes the skill of the equipment operators and the placement of the stones.

PROCEDURE	EXAMPLE	DESCRIPTION	BEST ROCK TYPES /ADVANTAGES	APPLICABLE DRILLING AND BLASTING METHODS	LIMITATIONS/ DISADVANTAGES
Benching in Sedimentary Rock		Sedimentary rock formations can offer a layered structure of hard and soft zones that allows excavation of shelves or benches where native vegetation types can be planted.	Best used in layered rock formations, typical of sedimentary deposits. As the plantings mature, their roots can promote natural weathering processes and the long term result can be a man-made cut indistinguishable from natural features.	Cushion blasting and step drilling can be used to shape benches that follow naturally occurring layers. Ripping is often possible depending on the rock type. Where excavation by ripping is practical, blasting can often be avoided.	Steps and broad benches suitable for vegetation result in flatter slopes and require more ROW than steep cuts. In arid climates, long term irrigation should be included in the work to establish vegetation. Not suitable where thick, massive, rock layers prohibit the natural formation of benches.
Planting Pockets		Depressions or shelves are excavated in massive formations with no defined layering. These pockets are filled with soil to provide for growth of native vegetation that will eventually obscure the cut and blend with the surroundings.	The planting pocket technique can be used in most rock types that are not highly fractured and jointed. Provides locations for individual plants or groups of plants that can soften the appearance of cuts in hard metamorphic or intrusive rock where the natural weathering process is slow.	Presplit blasting to control overbreak during production blasting. Identification of major joint patterns during the design phase can help plan where pockets can be created by following natural fractures.	Requires adequate ROW for flatter slope. A well designed blasting plan coupled with a well identified rock structure are necessary to achieve both adequate planting zones and a stable rock face. Costs of landscape maintenance should be considered in design.

APPENDIX B – ROCK SLOPE CATALOG

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 70						
Interstate 70, eastbound, north side, MP 3.9, 1.9 miles east of Rabbit Valley and 22 miles west of Grand Junction REGION 3 I70ebn		Sedimentary rock-massive sandstone interbedded with mudstone; fluvial features including lenticular bedding; dipping approximately 3 degrees toward NW.	Height: 15 to 20 ft Length: 815 ft 85 degree SE facing slope	Eastbound 12 seconds; Westbound not seen; static view from Rabbit Valley Road trail south of I-70 may have view of top of cut	The cut was constructed in a massive sandstone bedrock unit using the standard presplit and production drilling methods. The presplit line and corresponding production holes were laid out to create a zigzag final rock face.	The variation of distance of the final face of the cut from the travelled way contributes to a more natural appearance, similar to naturally weathered sandstone formations. Presplit blasting methods were needed to excavate the rock face to the desired pattern. Half-casts from presplit holes remain visible.
Interstate 70, eastbound, south side, MP 3.9, 1.9 miles east of Rabbit Valley and 22 miles west of Grand Junction REGION 3 I70ebs		Sedimentary rock-massive sandstone interbedded with mudstone; fluvial features including lenticular bedding; dipping approximately 3 degrees toward NW.	Height: 15 to 20 ft Length: 415 ft 85 degree NW facing slope	Eastbound 12 seconds; Westbound not seen; Old Spanish National Historic Trail that intersects cut east/west; static view possible from trail north of I-70	The cut was constructed in a massive sandstone bedrock unit using the standard presplit and production drilling methods. The presplit line and corresponding production holes were laid out to create a zigzag final rock face.	The variation of distance of the final face of the cut from the travelled way contributes to a more natural appearance, similar to naturally weathered sandstone formations. Presplit blasting methods were needed to excavate the rock face to the desired pattern. Half-casts from presplit holes remain visible.
Interstate 70, westbound, northwest side, MP 124.7, Glenwood Canyon, 8.7 miles east of Glenwood Springs REGION 3 I701247		Biotite granite and granodiorite	Height: 100-120 ft Length: 350 ft 80 to 85 degrees ESE facing slope	Westbound 18 seconds Eastbound 21 seconds; Static view from recreational users of Colorado River south of cut and users of paved pat on south/east side and under I-70.	Sliver cuts using cushion blasting techniques. Cut to the existing fractures to develop a more natural appearing rock slope. Rock bolts initially designed for a 6'x6' pattern were modified in the field to be placed at select spot locations where continuous and unfavorable discontinuities created unstable slope conditions. Blast holes and holes from the rock bolts were drilled from a basket suspended from a crane.	The timber faced mechanically stabilized earth (MSE) wall structure located below the oversteepened talus section was installed to mitigate rockfall. Extensive scaling and rock bolts installed at selected locations were used to minimize rockfall potential.
Interstate 70, eastbound, west side, MP 127.2, Glenwood Canyon, 11.2 miles east of Glenwood Springs REGION 3 I701272		Sedimentary rock, massive sandstone, and conglomerate; dipping approximately 8 degrees toward 090 degrees	Height: 60 ft Length: 510 ft 80 to 85 degrees SE facing slope	Eastbound 18 seconds Westbound in tunnel; Static view from recreational users of Colorado River south of cut and users of paved pat on south/east side and under I-70.	The rock excavations in this area were removed using cushion blasting. Most of the cuts were blasted using precision blasting techniques due to the proximity to the Reverse Curve Tunnel. These methods included small shots, frequent delays in the blast layout, and smaller drill holes with lighter powder loads.	The eastbound alignment of I-70 was pulled in tight to the rockface to reduce the impacts to the Colorado River and facilitate the construction of the adjacent recreational trail. The concrete barrier was cast directly to the rockface because the slip forms used for the installation of the barrier would not fit against the rock slope. A flexible rockfall barrier was located on top of the rock cut at the Reverse Curve Tunnel since a rockfall catchment could not be constructed along the inside of the eastbound lanes.
Interstate 70, eastbound, west side, MP 183.9, West Vail Pass REGION 3 I701839		Sedimentary rock-layered; sandstone, shale, and conglomerate; dipping approximately10 degrees toward 230 degrees	Height: 35 to 40 ft Length: 618 ft 35 to 75 degrees northeast facing slope	Eastbound 45 seconds Westbound 34 seconds; Static view from bike path/trail northeast of and across highway from cut.	Minimal blasting was required on this and similar rock cuts in the area. Most of the excavation was performed by ripping with an excavator. The excavation was stepped using the more resistive rock as the vertical features and the softer seams were sloped at a more gradual angle.	Planting pockets and shelves were established in the cut face to create slopes that mimicked the surrounding area and allow for trees and other vegetation to become reestablished

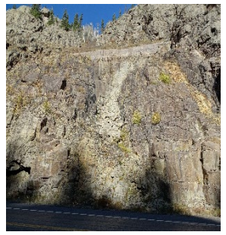
Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 70						
Interstate 70, westbound, east side, MP 185.5-186.5, West Vail Pass REGION 3 I701855		Sedimentary rock-layered; sandstone, mudstone, and conglomerate; dipping approximately 4 to 14 degrees toward 120 to 210 degrees	Height: 25 to 125 ft Length: 3,800 ft 40 to 85 degrees west to northwest facing slopes	Westbound 53 seconds; Eastbound 57 seconds; Static view from bike path/trail west of and across highway from cut.	The blast pattern for most of the rock cuts used a presplit line along the final face with production drill holes used to remove most of the rock mass. The excavation was stepped using the more resistive rock as the vertical features and the softer seams were sloped at a more gradual angle. As with most horizontally bedded sedimentary rock, a series of naturally occurring vertical fractures is present through the rock formation. An excavator was used to remove some of the rock back to the vertical fractures providing a more natural appearing rock face.	Designing the excavation to expose horizontal layers of softer seams provides benches that mimic natural weathering and erosion. The flatter portions of the slopes give vegetative cover an opportunity to establish. The presplit line is visible in some of the more massive rock units.
Interstate 70, westbound, north side, MP 200 near Frisco REGION 3 I70200		Metamorphic rock; Gneiss with mafic (dark) minerals; wedge blocks are inclined toward road tilted at 30 to 40 degrees	Height: 80 to 100 ft Length: 610 ft 50 to 85 degrees southeast facing slope	Westbound 53 seconds; Eastbound 57 seconds; Static view from bike path/trail west of and across highway from cut.	Much of the excavation was achieved using conventional presplit to control overbreak during production blasting. A predominate and naturally occurring fracture (joint) that slopes at roughly 45 degrees was also used to control over-break from the production blasting. The benches in the slope were cut to break up the slope face and develop planting zones for evergreens, brush, and grasses.	Whereas sedimentary rock formations can consist of hard and soft layers that allow benching during excavation, this hard metamorphic rock has no natural layering and bench creation required a well-designed blasting plan. Drill traces or half-casts are still visible throughout the near-vertical portions of the rock face.
Interstate 70, westbound, north side, MP 242.2, West Portal, Veterans Memorial Tunnels, Idaho Springs REGION 1 I70242wp		Metamorphic rock; Gneiss with feldspar, interlayered dark/light minerals, some biotite; some foliation layers tilt toward road	Height: 40 ft Length: 300 ft 43 to 79 degrees SE facing slope	Westbound 6 seconds; Eastbound 23 seconds; Static view from bike path/trail and building south of cut.	Because the excavation occurred in a very steep natural slope with ROW constraints, horizontal drilling and blasting was used to develop access to the top of the slope and a working bench for conventional drilling equipment. The blast holes were drilled parallel to the roadway alignment in a fan shaped pattern. To control overbreak and blast damage to the final rock face, the rock was blasted using conventional presplitting and production drilling techniques once an adequate working bench could be established. Expanded slope rounding was used to remove the overshot material and highly weathered rock at the top of the cut to blend the final cut face into the natural rock slope.	Horizontal drilling and blasting can be difficult to control. Some blast damage occurred to the slope face during development of the access route and many of the blasts led to an uncontrolled quantity of material falling from the slope during the shots. Mitigation of the post construction rockfall hazard was required. This included slope rounding to blend the final cut face into the natural rock slope and draped wire mesh to control rockfall because the catchment ditch width was reduced.
Interstate 70, westbound, north side, MP 242.2, East Portal, Veterans Memorial Tunnels, Idaho Springs REGION 1 I70242ep		Metamorphic rock; Gneiss with feldspar, interlayered dark/light minerals, some biotite	Height: 100 to 125 ft Length: 600 ft 70 degrees south-southeast facing slope	Westbound 20 seconds; Eastbound 9 seconds; Static view from bike path/trail south of and across highway from cut.	Because the excavation occurred in a very steep natural slope with ROW constraints, horizontal drilling and blasting was used to develop access to the top of the slope and a working bench for conventional drilling equipment. The blast holes for the access benches were drilled parallel to the roadway alignment in a fan shaped pattern. To control overbreak and blast damage to the final rock face, the lower half of the cut was blasted using conventional presplitting and production drilling techniques once an adequate working bench could be established. Expanded slope rounding was used to remove the overshot material and highly weathered rock at the top of the cut to blend the final cut face into the natural rock slope.	Horizontal drilling and blasting can be difficult to control. Some blast damage occurred to the slope face during development of the access route and many of the blasts led to an uncontrolled quantity of material falling from the slope during the shots. Mitigation of the post construction rockfall hazard was required. This included slope rounding to blend the final cut face into the natural rock slope and draped wire mesh to control rockfall because the catchment ditch width was reduced

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 24						
US Highway 24/285, westbound, north side, MP 217.4 to 217.6, 7.1 miles east of Buena Vista REGION 5 us242852174		Granodiorite porphyry and granite; spheroidally weathered outcrops;	Height: 10 to 25 ft Length: 370 ft 50 degree south facing slope	Westbound 17 seconds; Eastbound 6 seconds; no static views noted	The contractor utilized a cushion blasting drilling and loading pattern to achieve the rock slope configuration. Ripping using an excavator was also used to remove the less resistive material and round the cut slopes to transition into the natural slopes. In many areas, the excavator also pulled portions of the rock at the face back to the existing fractures resulting in a more stable and natural appearing slope. Scaling, rock dowels and draped wire mesh rockfall mitigation.	Post-excavation re-evaluation of the rockfall potential may have shown that wire mesh was unnecessary. Mesh anchors were installed in advance of excavation due to easier access to the top of the slope. The early installation of anchors contributed to the decision to install mesh that is unsightly and possibly unnecessary.
US Highway 24/285, westbound, north side, MP 217.6 to 217.8, 7.3 miles east of Buena Vista REGION 5 us242852176		Granodiorite porphyry and granite; spheroidally weathered outcrops;	Height: 5 to 25 ft Length: 300 ft 65 degree southeast facing slope	Westbound 33 seconds; Eastbound 16 seconds; static view from driveway intersection south side of road	Controlled blasting using pre-split blasting and cushion blasting techniques. Excavation of weathered zones in decomposed granite by machine. Scaling, rock dowels and draped wire mesh rockfall mitigation	Post-excavation re-evaluation of the rockfall potential may have shown that wire mesh was unnecessary. Mesh anchors were installed in advance of excavation due to easier access to the top of the slope. The early installation of anchors contributed to the decision to install mesh that is unsightly and possibly unnecessary.
US Highway 24/285, westbound, north side, MP 217.8 to 217.9, 7.3 miles east of Buena Vista REGION 5 us242852178		Granodiorite with foliated biotite gneiss xenoliths/inclusion, spheroidally weathered outcrops	Height: 20 to 30 ft Length: 215 ft 65-70 degree southeast facing slope	Westbound 33 seconds; Eastbound 16 seconds; static view from driveway intersection south side of road	Controlled blasting using pre-split blasting and cushion blasting techniques. Excavation of weathered zones in decomposed granite by machine. Scaling and rock dowels for rockfall mitigation.	Machine tooth marks in decomposed granite will become less visible as the excavated face weathers.
US Highway 24/285, westbound, north side, MP 217.9 to 218.1, 7.4 miles east of Buena Vista REGION 5 us242852179		Granodiorite with foliated biotite gneiss xenoliths/inclusion, spheroidally weathered outcrops	Height: 10 to 25 ft Length: 640 ft 65-70 degree southeast facing slope	Westbound 20 seconds; Eastbound 33 seconds; static view from driveway that intersects road northeast of cut	Controlled blasting using pre-split blasting and cushion blasting techniques. Excavation of weathered zones in decomposed granite by machine. Scaling, rock dowels and draped wire mesh rockfall mitigation.	Post-excavation rockfall evaluation may have shown that draped mesh was not needed on this low cut.
US Highway 24/285, westbound, north side, MP 218.1 to 218.3, 7.5 miles east of Buena Vista REGION 5 us242852181		Granodiorite with foliated biotite gneiss xenoliths/inclusion, spheroidally weathered outcrops	Height: 35 to 40 ft Length: 650 ft 65-70 degree southeast facing slope	Westbound 44 seconds; Eastbound 20 seconds; static view from pullout SE side of road across from cut, SE end	Controlled blasting using pre-split blasting and cushion blasting techniques. Scaling, rock dowels and draped wire mesh rockfall mitigation.	Rock excavation to limits shown on the plans left a narrow ridge of highly fractured and jointed bedrock near the east end of the project, south side. This ridge was deemed unstable and additional blasting was required to remove the hazard.

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 24						
US Highway 24, westbound, north side, MP 283.8, 1.2 miles southwest of Woodland Park; cut faces frontage CR 231/CR 25 REGION 2 us242838		Granite with shotcrete facing, fault in area of cut	Height: 25 to 40 ft Length: 306 ft 85 degree southeast to southwest facing slope, wall curves	Westbound 10 to 14 seconds; Eastbound 32 to 58 seconds; static view from house to south and bicycle lanes	Controlled blasting using pre-split blasting and cushion blasting techniques. Use of sculpted shotcrete to improve appearance, stabilize the excavated face, and hide visible signs of blasting. Reestablished vegetation on the flatter slopes at the ends of the cut.	This site is a good example of the use of sculpted and stained or pigmented shotcrete to create a visual effect of a natural rock slope. The sculpting consists of a semi-random pattern of deeply incised "joints". Advance planning and cooperation between the designer, geologist, landscape architect, and contractor were required for success.
US Highway 24, westbound, north side, MP 298.4, Manitou Springs REGION 2 us242984		Sedimentary rock-layered shale, sandstone, conglomerate, with boulder size clasts; dipping approximately 9 to 12 degrees toward southeast.	Height: 30 to 40 ft Length: 793 ft 65 degree south facing slope	Westbound 38 seconds; Eastbound 23 seconds; static view from private residences south of cut	Controlled blasting using conventional presplitting techniques. Some of the half-casts (drilling traces) are still visible but many have eroded due to the soft nature of the bedrock materials.	The cut slope is a source of rockfall caused by the different rates of erosion between the harder sandstone and conglomerate layers versus the softer claystone and siltstone units. Presplitting methods have helped control the rockfall following the original construction.
US Highway 34						
US Highway 34, westbound, north side, MP 77.4 to 77.6, 15 miles west of Loveland REGION 4 us34775		Granite, tonalite (granitoid) and mica schist and gneiss	Height: 75 to 150+ ft Length: 1120 ft 45 to 75 degree southwest facing slope, wall curves	Westbound 30 seconds; Eastbound 35 seconds; static view from houses and a pullout to south	Presplit blasting for excavation to the cut line and cushion blasting to follow existing joints and fractures, where possible. Following a rockslide during construction, the western portion of the cut was laid back to follow foliation planes. The east portion of the cut is benched to give more natural appearance. Rockfall mitigation includes draped mesh on upper and lower benches and rock bolts. Both mesh and exposed portions of the bolts were colored dark brown.	The slope grade breaks within the cut provide a more natural appearance. This example shows how rock bolts are used to stabilize large blocks. Maintenance of upper draped mesh may be required as debris accumulates on the bench. ROW acquisitions allowed for an adequate rockfall catchment ditch and allowed the draped mesh to terminate 20+ feet above the roadway, lessening the visual impact of the mesh.
US Highway 34, westbound, north side, MP 78.3 to 78.4, 14.2 miles west of Loveland REGION 4 us34783		Gneiss, schist, some garnetiferous, possible metaconglomerate	Height: 40 to 60 ft Length: 240 ft 50 degree southwest facing slope	Westbound 16 seconds; Eastbound 14 seconds; static view from houses on south and west end above road, and fishing activity	The north face of a slot cut for roadway realignment. Presplit blasting along the final face with production blasting. Due to the dominant joint and foliation in the rock structure, half-casts from the presplitting are not prevalent. Due to favorable jointing and adequate rockfall catchment, the planned rockfall mesh was eliminated during construction. Rock bolts used to stabilize large blocks and colored dark brown to blend in with the rock face.	Prominent jointing within the rock mass provided preferred planes for the rock slope to break back to, even with presplitting techniques. These natural joints provide an irregular pattern to the face.
US Highway 34, eastbound, south side, MP 78.3 to 78.4, 14.2 miles west of Loveland REGION 4 us34783s		Gneiss, schist, some garnetiferous, possible metaconglomerate	Height: 70 to 80 ft Length: 300 ft 50 degree north facing slope	Eastbound 8 seconds; Westbound 11 seconds; static view from house on west end, north side above road, and fishing activity	The south face of a slot cut for roadway realignment. Presplit blasting along the final face with production blasting. Due to the dominant joint and foliation in the rock structure, half-casts from the presplitting are not prevalent. Rockfall mitigation includes draped mesh and rock bolts. Both mesh and exposed portions of the bolts were colored dark brown.	ROW acquisitions allowed for an adequate rockfall catchment ditch and allowed the draped mesh to terminate 20+ feet above the roadway, lessening the visual impact of the mesh

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 34						
US Highway 34, eastbound, south side, MP 78.4 to 78.6, 14 miles west of Loveland REGION 4 us34785		Gneiss, schist, some garnetiferous, possible metaconglomerate	Height: 35 to 40 ft Length: 650 ft 70 degree southwest facing slope	Westbound 14 seconds; Eastbound 17 seconds; static view from fishing access west of and below cut	Presplit blasting along the final face with production blasting. Half-casts from the presplitting were mitigated with rock staining. Rockfall mitigation includes dark brown draped mesh and rock bolts. Rock bolts used to stabilize large blocks are colored dark brown to blend with the rock face.	ROW acquisitions allowed for an adequate rockfall catchment ditch and allowed the draped mesh to terminate 20+ feet above the roadway, lessening the visual impact of the mesh. Rock staining following excavation provided a weathered look to the rock and masked the presence of the half-casts.
US Highway 36						
US Highway 36, westbound, north side, MP 7.8 to 7.9, 8.1 miles southeast of Estes Park REGION 4 us3678		Granite with schist foliations	Height: 75 ft Length: 490 ft 76 degree southwest facing slope	Westbound 9 seconds; Eastbound 10 seconds; No static view noted	Presplit and production blasting, machine excavation (ripping). Unstable blocks along adverse jointing were removed by machine. Rockfall mitigation included rock bolts to stabilize blocks.	The adverse joint pattern made excavation within planned limits difficult. Loose blocks were removed where possible or stabilized with bolts. The result is a natural appearing cut, but with risks of instability and rockfall.
US Highway 36, westbound, north side, MP 10.9 to 11.5, 11.2 miles southeast of Estes Park REGION 4 us36109		Granite with schist foliations	Height: 15 to 40 ft Length: 3150 ft 80 to 85 degree south to west facing slope, cut has curves	Westbound 72 seconds; Eastbound 61 seconds; static view from house and pullout on west end	Presplit blasting left half-casts in the massive granite. Production blasting removed half-casts where natural fractures guided post-blast excavation.	Natural rock features were left undisturbed between areas where excavation was required.
US Highway 40						
US Highway 40, eastbound, north side, MP 244.5, 12.7 miles south of Winter Park REGION 1 us402445		Granite and gneiss	Height: 140 ft Length: 476 ft 50 to 75 degree southwest facing slope	Eastbound 12+8 seconds-2 views; Westbound 18 seconds; static view from bicyclists	Most of the rock cut at this location was removed using cushion blasting and production blasting techniques. An excavator was used to remove loose material at the slope face and pull some of the rock back to the natural seams within the bedrock mass.	The slope was heavily rounded to provide an older eroded appearance similar to the surrounding topography. Meetings were held with the CDOT Landscape Architects, Geotechnical Staff, Construction Staff and USFS to help develop the approach during construction.
US Highway 40, westbound, north side, MP 248.8, 17.1 miles south of Winter Park REGION 1 us402488		Granite with gneiss and migmatite	Height: 50 ft Length: 315 ft 45 degree south-southeast facing slope	Westbound 23 seconds; Eastbound 11 seconds; static view from intersection of US Hwy 40 and CR 202 NNE to cut	Most of the rock cut at this location was removed using cushion blasting and production blasting techniques. An excavator was used to remove loose material at the slope face and pull some of the rock back to the natural seams within the bedrock mass.	The slope was heavily rounded to provide an older eroded appearance similar to the surrounding topography. Meetings were held with the CDOT Landscape Architects, Geotechnical Staff, Construction Staff and USFS to help develop the approach during construction.

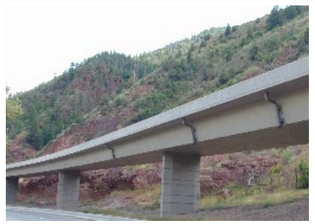
Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 50						
US Highway 50, westbound, east side, MP 56, 15 miles northwest of Delta REGION 3 us5056		Sedimentary rock-layered shale, sandstone, and carboniferous deposits (coal), with gypsum; dipping approximately 8 degrees toward southwest.	Height: 60 ft Length: 700 ft 75 degree south-southwest to southwest facing slope on curve	Westbound 14 seconds; Eastbound 12 seconds; static view from nearby trails, hikers, cyclists	Ripping was used to excavate soft bedrock layers. Limited cushion blasting followed by machine scaling was used in harder layers.	Difficult blasting conditions due to variable bedrock consistency. Alternating hard and soft rock layers continue to generate small size rockfall events. Draped mesh at this site is effective at reducing rockfall hazard.
US Highway 50, westbound, north side, MP 194.2, east of runaway truck ramp, 5.1 miles west of Monarch Pass, 23 miles west of Poncha Springs, and 37 miles east of Gunnison REGION 5 us50192e		Granite with metamorphic rock; porphyritic gneissic granite intruded by finer grained granite, some with biotite (mica); colluvial cover (gravels, loose material) above cut	Height: 30 to 40 ft Length: 315 ft 65 to 70 degree southeast facing slope	Westbound 7 seconds; Eastbound 18 seconds; No static view areas noted	The rock excavation was completed using cushion and production blasting methods. The final face was sculpted using an excavator by pulling portions of the rock face back to the natural rock fractures and joint structure.	Benches were introduced in the rock slope to provide a more naturally appearing cut. Where possible, portions of the top of cut were rounded to reduce rockfall at the brow and provide an eroded appearance.
US Highway 50, westbound, north side, MP 194.2, above runaway truck ramp, 5.1 miles west of Monarch Pass, 23 miles west of Poncha Springs, and 37 miles east of Gunnison REGION 5 us50192		Granite with metamorphic rock; porphyritic gneissic granite intruded by finer grained granite, some with biotite (mica); colluvial cover (gravels, loose material) above cut	Height: 60 ft Length: 540 ft 50 to 75 degree southeast facing slope	Westbound 13 seconds; Eastbound 32 seconds; No static view areas noted	The rock excavation was completed using cushion and production blasting methods. The final face was sculpted using an excavator by pulling portions of the rock face back to the natural rock structure.	Benches were introduced in the rock slope to provide a more naturally appearing cut slope. Where possible, portions of the top of cut were rounded to reduce rockfall at the brow and provide an eroded appearance.
US Highway 50, westbound, north side, MP 258.0, 20 miles west of Canon City REGION 2 us50258		Migmatitic Gneiss, layered gneisses	Height: 60 ft Length: 820 ft 45 to 60 degree northwest facing slope	Eastbound 14 seconds; Westbound 13 seconds; Static views from Pinnacle Rock parking area opposite cut and recreational users of Arkansas River	Rock cuts in this area were excavated using cushion blasting techniques. Loose and blasted material was removed to the natural fractures to develop a more natural appearing rock slope. Rock bolts were installed in areas where continuous and unfavorable discontinuities created unstable slope conditions. Some of the rock bolts were installed to a depth of 35 feet and consisted of 150 grade, #10 threadbar.	The timber structure at the south end of the cut that has the appearance of a pyramid is a timber-faced soil nail wall built as part of the rock slope and widening project. It was constructed to protect an archaeological site which is the remnants of a small stone fort. The fort was one of several areas that men were stationed during the Railroad War between the Denver & Rio Grande Railroad and Atchison, Topeka, and Santa Fe Railway in the late 1800's.
US Highway 50, westbound, north side, MP 259.7, 18.3 miles west of Canon City REGION 2 us502597		Migmatitic Gneiss, layered gneisses	Height: 60 ft Length: 1009, includes 470 ft of slope at east end, then estimated 200 ft of cut continues to east 85 to 100 (overhang) degree northeast facing slope	Eastbound 19 seconds; Westbound 19 seconds; Static view Salt Lick overlook at W end of cut; Five Points Campground at E end of cut; recreational users of Arkansas River	The rock excavations in this area were removed using cushion blasting in the harder rock and ripping in the softer material. Pockets of cobbles and soil material were removed and cleaned back to bedrock to eliminate the areas of oversteepened loose material.	Slope angles were steepened in the more resistant rock and then laid back at a shallower angle in the softer material. This technique was used to develop a more natural appearing slope and to address potential long-term stability and erosion.

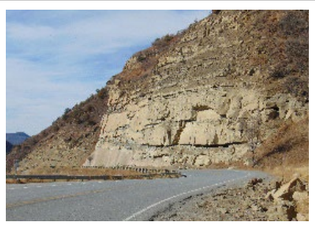
Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 160						
US Highway 160, westbound, north side, MP 79.2, 4.3 miles west of Durango REGION 5 us160791		Sedimentary rock-layered shale, sandstone, and siltstone; massive sandstone above cut; areas of shale undercutting sandstone ledges; erosional debris fans at base of cut; dipping approximately 5 to 10 degrees toward north and northwest.	Height: 60 to 90 ft Length: 1,200 ft 45 to 90 degree south-southeast to south-southwest facing slope on curve	Westbound 17 seconds; Eastbound 24 seconds; static view from nearby residential south of cut; driveway intersects US 160 across from cut	Ripping was used to re-cut the rock face during a roadway and ditch widening project that improved rockfall catchment.	Limited ROW access to the top of the cut prohibited laying back the face to create a more stable and visually appealing slope. Minor rockfall continues to be a maintenance concern.
US 160 eastbound, east side, MP 174.0-174.5, 12 miles southwest of South Fork and 30 miles northeast of Pagosa Springs REGION 5 us160174		Tertiary age ash flow, quartz latite tuff	Height: 80 to 100 ft Length: 2,890, includes 1,055 feet of tunnel, 80 to 90 degrees west to southwest facing slopes	Eastbound 62 seconds; Westbound 57 seconds; Static view possibly from fishing along Pass Creek, west side of US 160 and rock cut.	The rock excavation primarily consisted of presplitting blasting techniques with limited cushion blasting that utilized the naturally occurring, near vertical fractures to control overbreak. The presplitting did result in visible half-casts. Shotcrete was applied in select areas where the cut slope intersected portions of oversteepened glacial till. The shotcrete was anchored using soil nails and rock bolts. The final slope face was covered with brown colored draped wire mesh.	Seepage from behind shotcrete in glacial till areas has eroded the slope at the toe of the shotcrete east of the tunnel. The shotcrete near the west portal is a good example of sculpting and staining to mimic surrounding natural formations. Dark coloring of draped wire mesh helps to reduce the visibility of the rockfall mitigation.
US 160 westbound, north side, MP 180.2-181.2, 7 miles southwest of South Fork and 37 miles northeast of Pagosa Springs REGION 5 us1601802		Tertiary age ash flow, quartz latite tuff	Height: 40 to 50 ft Length: 5,230 and 750 feet of road cut on Forest Service Road 433 that parallels above US 160; Up to 620 feet of soil/gravel slopes included, 70 to 90 degrees southeast facing slopes	Westbound 77 seconds; Eastbound 74 seconds; Static view at each of cut from private resorts on east side of US 160 and for campers, cyclists, fishing along South Fork Rio Grande River.	The rock excavation consisted of three primary methods of blasting: presplitting in the upper portions of the cuts; cushion blasting in the lower portions of the cuts; and a cushion blasting technique that utilized the naturally occurring near vertical fractures to control overbreak. The presplitting did result in visible half-casts and an attempt was made to remove the drill traces from the final rock face using a hand-held pneumatic bush hammer.	A small technical group formed to determine the best approach to developing the rock excavation determined that the ditches would be kept at a minimal width and still able to accommodate the roadside drainage and fallen rock. Brown colored draped wire mesh was applied in the upper portion of the cut and extended down the face to 20 feet above the base of the cut to control rockfall and minimize impacts to the viewshed. All of the rock cuts were stained with a color reactive treatment to mimic the natural limonite staining that is common to the area.
US Highway 285						
US Highway 285, westbound, north side, MP 231, 5 miles southwest of Conifer REGION 1 us285231		Migmatitic biotite gneiss, metamorphic layering (foliation) with granitic gneiss lenses	Height: 70 to 90 ft Length: 1,160 ft 68 to 73 degree southeast facing slope	Westbound 20 seconds; Eastbound 56 seconds; static view from house and industrial buildings south and west of cut and from intersection for Elk Creek Road with stop sign; exit ramps have slow moving traffic	The rock excavation utilized primarily pre-split rock blasting techniques. The slope was also rounded using an excavator to reduce the potential for the brow of the cut to erode in the less resistive bedrock and overlying soils. Draped wire mesh was applied to the final rock face to further reduce the potential rockfall hazards.	Pre-splitting coupled with draped wire mesh was used on this cut due to the zones of unfavorable rock structure present in the formation and the concern over long-term rockfall potential.

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 285						
US Highway 285, westbound, north side, MP 233, 2.9 miles southwest of Conifer REGION 1 us285233		Granite, foliated with inclusions of biotite schist; some spheroidally weathered granite in outcrop adjacent to cut	Height: 35 ft Length: 700 ft 55 to 60 degree southeast facing slope	Westbound 20 seconds; Eastbound 28 seconds; Static view possible from houses southeast of cut; private driveway intersects US 285 at east end of cut	Cushion blasting techniques were used to excavate the rock cuts in this area. Spot rock bolts were installed to stabilize individual rock blocks.	Steps in the slope follow natural rock fractures. The steps promoted revegetation and reduced the rockfall hazard from this relatively low cut. ROW limits were sufficient to provide an adequate catchment ditch and flatter slope angle.
US Highway 285, westbound, northwest side adjacent to Old Highway 285, MP 240.5, 5.0 miles northeast of Conifer REGION 1 us2852405		Granite, foliated, may have gneiss inclusions; some spheroidally weathered granite in outcrop adjacent to cut; grus (eroded granite debris) at bottom of slope	Height: 40 ft Length: 420 ft 63 to 75 degree east-southeast facing slope	From US 285, Westbound 22 seconds; Eastbound 10 seconds; Static view from Old Highway 285; slow speed on deceleration/ acceleration lanes on US 285; private driveway SSE southeast of US 285	Cushion blasting techniques were used to excavate the rock cuts in this area. Some blast damage did occur in this cut during construction. Heavy rock scaling using an excavator was used to develop the final slope configuration. Spot rock bolts were installed to stabilize individual rock blocks.	The variations and blocky nature of the cut face contribute to a more natural appearance. However, the numerous rock bolts, required for slope stability and rockfall hazard mitigation detract from the overall visual appeal.
US Highway 285, westbound, north side, MP 240.9, 5.4 miles northeast of Conifer REGION 1 us2852409		Granite and migmatite with foliated schist and gneiss; some spheroidally weathered granite in outcrop adjacent to cut	Height: 100 ft Length: 875 ft 78 to 79 degree south to southeast facing slope	Westbound 12 seconds; Eastbound 26 seconds; Static view possible from houses on south side below US 285; private driveway on south side of US 285 faces cut slope	The rock excavation in the location locally referred as “Windy Point” utilized cushion blasting techniques for most of the cut. Spot rock bolting was applied to location to selected locations throughout the face of the cut as the excavation was removed. Shotcrete was then applied to the entire excavated slope and then cultured stone was installed as the final facing. The cultured stone was attached using convention masonry techniques.	It was determined during the planning phases of the US 285 corridor that the walls would use an ashlar pattern as the final facing. The cut at Windy Point is an approximately 200 feet high, six-tier wall configuration. To mimic an ashlar pattern, it was determined that to construct the facing, smaller masonry units placed individually would be the only practical method to construct the wall facing.
US Highway 285, westbound, northwest side, MP 242.8, 7.1 miles northeast of Conifer REGION 1 sh2852428		Biotite gneiss with schist, foliated, some pegmatite	Height: 70 ft Length: 1,250 ft 42 degree southeast facing slope	Westbound 50 seconds; Eastbound 36 seconds; static view from intersection of Surrey Drive with US 285 southeast of cut	Most of the cuts in this area were excavated using ripping techniques with a dozer and an excavator. Minimal blasting was required in the more resistive zones in the bedrock. The upslope cut wall was constructed using soil nails/rock bolts as the reinforcing elements and shotcrete as the primary wall facing. The final facing used a cast-in-place concrete with an ashlar patten which was subsequently colored with a brownish stain.	The upslope wall was constructed to protect a group of trees and provide variability to the slope configuration.
US Highway 285, westbound, northwest side, MP 243.2, 7.4 miles northeast of Conifer REGION 1 us2852432		Biotite gneiss with schist, foliated, some pegmatite	Height: 60 ft Length: 800 ft Weathered rock at 41 degree southeast facing slope; Intact rock at 70 to 80 degree southeast facing slope	Westbound 19 seconds; Eastbound 50 seconds; static view from intersection of Surrey Drive with US 285 south of cut	The cuts in this area were excavated using ripping techniques with a dozer and an excavator. Cushion blasting was required in the more resistive zones in the bedrock. A pattern of rock bolts was installed in the steeper portion of the rock slope.	The steepened portion of the rock cut was constructed to provide variability to the slope configuration and to protect a natural rock outcrop that was important to the local community.

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 285						
US Highway 285, westbound, west side, MP 244.2, 8.5 miles northeast of Conifer REGION 1 us2852442		Granodiorite with pegmatite and foliated granodiorite with biotite	Height: 70 ft Length: 1,300 ft South end of cut rock at 86 degree east-southeast facing slope; north end of cut at 70 degree northeast facing slope	Westbound 14 seconds; Eastbound 36 seconds; static view from residential and commercial on south side of US 285; westbound deceleration lane next to cut	Cushion blasting and machine scaling were used to allow the excavation to follow natural planes of weakness in the formation.	Flatter slopes and natural weathering promoted establishment of vegetation over the long term. Weathering around rock bolts has exposed the reinforcement. Use of fully grouted dowels can prevent this.
US Highway 285, westbound, northwest side, MP 245.6, 9.2 miles NE of Conifer, and 7.2 miles SW of intersection US Hwy 285 and Colorado State Highway 470 (west Denver) REGION 1 us2852456		Gneiss, generally foliated/layered, granitic appearance; may include migmatite	Height: 100 ft at center Length: 1,080 ft 59 to 67 degree east to northeast facing slope on curve	Westbound 12 seconds; Eastbound 22 seconds; static view from deceleration land and S. Turkey Creek Road intersection across-east of-cut, and Parmalee Gulch Rd overpass	To achieve the rock slope configuration, the slope angle was chosen based on the primary rock structure that dips toward the roadway. The contractor utilized a cushion blasting drilling and the prevalent rock structure to reduce overbreak. Ripping with an excavator was also used to remove the rock and round the cut slopes to transition into the natural slopes. In many areas, the excavator also pulled portions of the rock at the face back to the existing fractures resulting in a more stable and natural appearing slope.	This site is an example of the use of cushion blasting followed by machine scaling to create a more natural rock slope that follows existing joint structure. The result is a more natural appearing slope with flatter benches for vegetation.
US Highway 285, westbound, NW side, MP 245.9, 9.5 miles NE of Conifer, and 6 miles SW of Morrison; Indian Hills area/Parmalee Gulch Road intersection US Hwy 285 REGION 1 us2852459		Gneiss, generally foliated/layered, migmatite; a NW-SE trending fault across middle of cut is part of parallel faults in area	Height: 70 to 80 ft Length: 270 ft 77 degree southeast facing slope	Westbound 12 seconds; Eastbound 22 seconds; static view from Parmalee Gulch Road instersection and overpass; acceleration and left turn lane have slower to stopped traffic	The contractor utilized a cushion blasting drilling pattern in their blast plan. Very little was done during this project to minimize blast damage to the final rock face. This practice coupled with the poor rock structure led to a marginally stable rock face after construction.	Following construction of the original rock slope, a subsequent contractor was selected to scale and remove the unstable portions of the rock cut and apply the draped wire mesh. This type of wire mesh was one of the first installed in the State of Colorado. At the time, colored wire mesh was not available, and the installed system used a galvanized coating. As a result, the draped wire mesh is very visible especially during certain angles of the sun and the observer's viewpoint.
US Highway 285, westbound, NW side, MP 246, 9.5 miles NE of Conifer, and 6 miles SW of Morrison; Indian Hills area/Parmalee Gulch Road intersection US Hwy 285 REGION 1 us2852460		Gneiss, generally foliated/layered, migmatite; a NW-SE trending fault across middle of cut is part of parallel faults in area	Height: 100 ft Length: 1,150 ft 69 to 72 degree southeast facing slope	Westbound 23 seconds; Eastbound 29 seconds; static view from Parmalee Gulch Rd intersect, overpass, on ramp, decel and accel lanes; houses on north end Brookmont Rd S of cut	Cushion blasting and machine scaling were used to follow existing major joint patterns in the formation. Where the cut crosses zones of more closely spaced joints, scaling and draped mesh were used to reduce the rockfall hazard.	Light colored draped rockfall mesh blends well with the natural rock.
US Highway 287						
US Highway 287, northbound, northeast side, MP 363.4, 17.5 miles north-northwest of Ft. Collins REGION 4 us2873634		Sedimentary rock-layers sandstone, shale, limestone; areas of shale undercut sandstone ledges; dip of rock layers 17 degrees to the east-southeast direction	Height: 40 to 50 ft Length: 700 ft 80 degree south-southwest facing slope	Northbound 35 seconds; Southbound 19 seconds; possible static view from nearby residence to the west on Gratitude Road	Presplit drilling and blasting were used to excavate even and near vertical faces through interlayered sandstones and shales. The highest parts of the cut were terraced to provide a more natural appearance and to encourage revegetation.	Nearby natural slopes are near vertical cliffs. Half casts from presplit drilling are visible in the more massive sandstone layers. Differential weathering in the softer sandstone and shale layers has eroded the half casts.

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
US Highway 287						
US Highway 287, southbound, southwest side, MP 363.4, 17.5 miles north-northwest of Ft. Collins REGION 4 us2873634sw		Sedimentary rock-layers sandstone, shale, limestone; areas of shale undercut sandstone ledges; dissolution cavities with vegetation, apparent water seepage; dip of rock layers 17 degrees to the east-southeast direction	Height: 40 to 50 ft Length: 940 ft 77 degree north-northeast facing slope	Southbound 22 seconds; Northbound 18 seconds; possible static view from residence to the northwest near intersection of W Co Rd 72 and US 287	Presplit drilling and blasting were used to excavate even and near vertical faces through interlayered sandstones and shales.	Nearby natural slopes are near vertical cliffs. Half casts from presplit drilling are visible in the more massive sandstone layers. Differential weathering in the softer sandstone and shale layers has eroded the half casts
US Highway 550						
US Highway 550, southbound, west side, MP 2.3, 15 miles south of Durango REGION 5 us55023		Sedimentary rock-layered sandstone and shale; weaker shale undercuts massive sandstone; dip of rock layers estimated as nearly horizontal	Height: 60 to 70 ft Length: 1,380 ft 60 to 90 degree east-southeast to southeast, cut on curve	Southbound 20 seconds; Northbound 61 seconds; possible static view from two-track road intersects SH 550 at rock cut; residence to SE has view of cut; possible fishing activity Animas River adjacent to highway	Cushion blasting and machine scaling were used to avoid half casts common with presplit methods. The underlying shale is highly erodible and was buried after excavation to prevent erosion and undercutting of the overlying sandstone.	The excavated face matches well with the surrounding natural cliffs. The fill placed to cover the erodible shale provided a medium for revegetation and reduced the rockfall hazard without the use of reinforcement or draped materials.
US Highway 550, southbound, west side, MP 68.5, 2 miles south of Silverton REGION 5 us550685		Granodiorite with feldspar phenocrysts	Height: 80 to 90 ft Length: 350 ft, 45 to 70 degrees east-southeast facing slope	Southbound 13 seconds; Northbound 29 seconds; No static view identified.	Cushion drilling and blasting along with machine scaling were used to avoid half casts. Where possible, the excavation follows natural fractures in the rock. Rock bolts were used to stabilize large blocks and light-colored draped mesh was installed as rockfall mitigation. Excavation of the pioneer road to access the top of the cut created an unstable slope at the south end of the project.	Rock reinforcement and draped mesh have been effective at mitigating he rockfall hazard. The mesh blends well with the excavated rock face. Additional restrictions in the plans and specifications regarding site access may have prevented creation of unstable slope conditions.
US Highway 550, northbound, east side, MP 90.5, Bear Creek Bridge REGION 5 us550905		Slate and phyllite, foliated, jointed and fractured.	Height: 60 ft Length: 235 ft 70 to 75 degree south-southeast facing slope	Northbound 17 seconds; Southbound 6 seconds; Static view from scenic pullout and Bear Creek Bridge overlook structure	Presplit drilling angled to final cut slope. Machine and hand scaling to remove majority of half cast traces. Limited catchment ditch required draped mesh for rockfall mitigation.	Excavated face closely resembles adjacent natural cliffs. Light colored rockfall mesh is visible. Construction picture shows temporary brown mesh is less visible.
US Highway 550, northbound, northeast side, MP 106.3, 2.6 miles north of Ridgway REGION 5 us5501063		Sedimentary rock-layered sandstone, mudstone, shale, siltstone, conglomerate; areas of shale undercutting sandstone ledges; dip of rock layers estimated as nearly horizontal.	Height: 65 ft Length: 630 ft 80 to 85 degree southwest facing slope	Northbound 35 seconds; Southbound 9 seconds; static view from nearby residential and path west-southwest of cut on west side of US 550; visible from CR 24 to the southwest for one mile	Pre-split and cushion blasting. A pioneer road provided access to the drilling bench that was initially approximately 60 feet above the highway. Hand scaling and machine excavation used to remove loose materials from final cut face. Removal of claystone in lower shotcrete section after blasting was performed hydraulic excavators. Rock dowels were installed across the claystone and covered by pigmented shotcrete.	Half-casts from drill holes may have been prevented by angle drilling but this would have required additional bench width. The dark brown color of the draped mesh helps reduce visual impact. There was not a project special provision for the textured shotcrete. A specification would have provided means of quality control that could have improved the final appearance of the rock cut.

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
State Highway 65						
State Highway 65, northbound, north side, MP 55.1, 13 miles NE of Palisade REGION 3 sh65551		Sedimentary rock; massive sandstone with minor mudstone;	Height: 20 to 25 ft Length: 195 ft 85 to 90 degree south facing slope	Northbound 10 seconds; Southbound 31 seconds; pullout on south side and driveways at east end may have static view of cut	Two different blast techniques were used excavate the rock. The intent of using two different drilling and blasting techniques was to evaluate the appearance and performance of the methods. The right half or upstream portion of the cut was drilled and shot using a traditional presplit and production blast pattern.	The site photos illustrate the different results from two blasting methods.
State Highway 65, northbound, north side, MP 58.2, 10 miles NE of Palisade REGION 3 sh65582		Sedimentary rock; Interbedded sandstone and shale, some carboniferous; dipping approximately 10 degrees toward north; river gravel on top of cut	Height: 50 to 60 ft Length: 640 ft 80 to 90 degree SE facing slope	Northbound 36 seconds; Southbound 14 seconds; driveway at west end may have static view of cut	This cut is excavated through several different materials and rock types. The top of the cut is capped with a cemented alluvial deposit composed of rounded cobble sized rocks over layers of interbedded sandstone and shale. A presplit line is still visible in the more resistive sandstone layers.	Use of terraced excavation along the soft shale layers allows revegetation on the slope.
State Highway 82						
State Highway 82, eastbound, west side, MP 29, 10 miles NW of Aspen REGION 3 sh82290		Sedimentary rock-layered siltstone, claystone, sandstone, conglomerate, lenticular bedding; dipping approximately 10 to 20 degrees toward NE.	Height: 80 to 100 ft Length: 535 ft 60 to 75 degree NE facing slope	Eastbound 16 seconds; Westbound 36 seconds; static view from private residences and trail NE of cut	The blast pattern for this cut was adjusted and offset at the bottom of each lift to create benches similar to the natural terrain. An excavator was used to remove the soil and highly weathered overburden material and to remove excess loose material from the high wall as the cut was brought down.	A shotcrete-faced soil nail wall was used to stabilize the unconsolidated overburden deposits. To contain the loose material, the facing was tapered onto the newly excavated rock face and anchored using rock bolts and soil nails. The shotcrete was colored reddish-brown to match the natural outcrops using an integral concrete pigment and then stained to simulate the natural weathering, such as limonite and iron oxide patina.
State Highway 119						
State Highway 119, northbound, east side, MP 5.8 to 6.2, 0.5 miles southeast of Black Hawk REGION 1 sh11958		Metamorphic rock; gneiss with biotite and pegmatite, strongly foliated	Height: 50 to 60 ft Length: 690 ft 71 to 74 degree SW facing slope	Northbound 17 seconds; Southbound 32 seconds; static view from trail/path and fishing access SW of cut	The majority of the rock cut was blasted using a presplit and production drill pattern due to the poor quality of the rock and prevalent adverse rock structure. The ditch width varied along the rock cut to accommodate the hydraulic requirements and to break-up the appearance of the newly excavated rock face. Brown colored draped wire mesh was applied to the final face. Rock bolts used to stabilize large blocks.	The varied foliation of the bedrock helps obscure the half-casts and rock bolts. The dark color of the draped wire mesh makes it less visible. The green-colored mesh anchors are more visible than the mesh. Note that the mesh anchors are designed to extend above the ground surface at the brow. This feature helps catch rockfall from above the cut.
State Highway 119, northbound, east side, MP 6.2 to 6.4, 0.25 miles southeast of Black Hawk REGION 1 sh11962		Metamorphic rock; gneiss with biotite and pegmatite, strongly foliated	Height: 60 to 80 ft Length: 1,020 ft 73 degree SW facing slope	Northbound 34 seconds; Southbound 24 seconds; static view from trail/path SW of cut	The majority of the rock cut was blasted using a presplit and production drill pattern due to the poor quality of the rock and prevalent adverse rock structure. The slope brow was rounded using an excavator to limit erosion in less resistive rock and soils. The ditch width varied along the rock cut to accommodate the hydraulic requirements and to break-up the appearance of the newly excavated rock face. Brown colored draped wire mesh was applied to the final face.	The half-casts are less visible in areas of bedrock foliation. Unpainted (green) rock anchors and mesh anchors are visible. The brown-colored mesh blends well with the rock face. Due to variability of the soil cover, the brow line undulates across the site.

Location	Example (ctrl click link or photo for more)	Geology	Slope Dimensions	Visibility	Construction Methods	Comments
State Highway 119						
State Highway 119, northbound, north side, MP 6.4 to 6.6, entrance to Black Hawk REGION 1 sh11964		Metamorphic rock; gneiss with biotite and pegmatite, strongly foliated	Height: 40 to 60 ft Length: 270 ft 85 degree SE facing slope	Northbound 19 seconds; Southbound 10 seconds; static view from commercial building/casino west of cut	The excavation was made several decades ago using production blasting methods that created an uneven slope face. Vegetation has reestablished and gives a natural appearance.	Signs of excessive 'overbreak' are visible as radial cracks in some locations. The rock face is a source of rockfall hazard.
State Highway 119, northbound, north side, MP 6.6 to 6.9, Black Hawk REGION 1 sh11966		Metamorphic rock with igneous; strongly foliated gneiss with biotite, and pegmatite, granite and granodiorite intrusions	Height: 40 to 60 ft Length: 1,785 ft 60 to 70 degree south facing slope	Northbound 59 seconds; Southbound 43 seconds; static view from commercial buildings/casino and sidewalks south of cut	The majority of the rock cut was blasted using a presplit and production drill pattern due to the poor quality of the rock and prevalent adverse rock structure. The ditch width varied along the rock cut to accommodate the hydraulic requirements and to break-up the appearance of the newly excavated rock face. Stained shotcrete with shallow rock bolt was applied to the upper portion of the cut to reduce erosion along the brow. The final rock slope was draped with brown colored wire mesh.	Weep holes were installed in the shotcrete to provide drainage an reduce the potential for hydrostatic pressure buildup.
State Highway 119, northbound, south side, MP 39.3, 1.7 miles west of west Boulder REGION 4 sh1193931		Granodiorite, granitic rocks weakly to strongly foliated	Height: 140 ft Length: 220 ft 45 degree north-northeast facing slope	Eastbound 13 seconds; Westbound 14 seconds; Static view from recreational trail users along Boulder Creek NE of SH 119	Blasting and ripping were used so that the excavation follows existing rock structure.	Rock bolts were used to stabilize large blocks in areas of adverse jointing.
State Highway 133						
State Highway 133, westbound, north side, MP 24.1 to 24.4, north of Paonia dam at Paonia Reservoir,16 miles NE of Paonia; 33 aerial miles SW of Aspen REGION 3 sh133241		Sedimentary rock; Interbedded sandstone and shale, some carboniferous; dipping approximately 6 degrees toward NE	Height: 50 to 65 ft Length: 1,535 ft 65 to 85 degree SE facing slope	Westbound 49 seconds; Eastbound 45 seconds; Boats near Paonia dam picnic area, cabins and residence to SW may have static view of cut	The cut was originally excavated using presplit and conventional production blasting methods. Some of the half casts are still visible in portions of the rock face. Due to the differential erosion between the bedrock units, the slope has experienced frequent and large rockfall events. The most recent project recut the final face of the cut slope and a soil nail wall was installed to reduce the erosion in the lower shale units.	The cuts in this area have been excavated and modified over several years. The most recent project in 2018 is an attempt to provide stability to the cut slope. The project included removing portions of the unstable rock face using presplit blasting. Additional rockfall mitigation measures included draped wire mesh, rock bolting, scaling and a soil nail wall constructed at the base of the slope covering the shale/claystone bedrock.

APPENDIX C – FIELD DATA SHEETS

ROCK SLOPE CHARACTERIZATION

Highway: I-70 EB north side **MP:** 3.9 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 11/18/2019

SLOPE PROFILE

Height (ft)	estimated 15 to 20
Length (ft)	815
Inclination and Direction	85 degrees facing 140 degrees
Offset from highway (ft)	*Width of Shoulder*: 4; *Width of Ditch*: 26 to 31 (in scallop)
Surface Variation (ft)	0.5 to 1 / (1 to 2) / some 2 to 5 / 5+ / Other:vert. scallops offset 3 to 5 ft

SETTING

Posted speed (mph): 75	**Number of travel lanes:** 2EB	**AADT:** 8300

Visibility — *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 815 ft=7.5 seconds*

Travel direction #1=0.24 mi=12 sec				Travel direction #2 =not seen from WB			
NB	SB	(EB)	WB	NB	SB	EB	WB
(Foreground/Short Range: to 0.5 mi)				Foreground/Short Range: to 0.5 mi			
Middleground/Long Range: to 3-5 mi				Middleground/Long Range: to 3-5 mi			
Background: to 5 mi to infinity				Background: to 5 mi to infinity			

Adjacent land use	Adjacent to McInnis Canyons Natl Conservation Area (BLM)	**Static viewer?** Rabbit Valley Rd trail south of I-70 may have view of top of cut

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):**	
Formation name	Morrison Formation, Salt Wash Member			**Outcrop description:** Massive sandstone interbedded with mudstone	

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracturespacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	(Occasional horizontal erosion features 10 to 40%)	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: 03 to 310- fluvial features
	Difference in erosion	Small difference 6 to 12 inches	(Moderate difference 1 to 2 ft)	(Few areas of large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods ~~OR continual water on slope~~	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Slopes are more vertical	Only few rocks in ditch area	10 to 20 ft spacing of vertical scalloping along cut. Scallop areas are approximately 3 to 5 feet offset from cut face. Apparent native vegetation types scrub and trees on ledges, top and in front of cut

CONSTRUCTION

Features	(Many Half-casts (blasting) - every 3 ft)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required? / Other:
Excavation method	(Blasting)	Breaking	Ripping	Other: Constructed in massive sandstone using standard presplit and production drilling to created zigzag rock face that contributes more natural appearance.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
11/18/2019	EB viewshed	1303	
11/18/2019	Cut view to NW	1327	
11/18/2019	Cut view to NE	1331	
11/18/2019	Varied ditch widths	1337	

ROCK SLOPE CHARACTERIZATION

Highway: I-70 EB north side **MP:** 3.9 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 11/18/2019

Eastbound Viewshed

View to northwest

View to northeast

Varied ditch widths

Return A12

ROCK SLOPE CHARACTERIZATION

Highway: I-70 EB south side **MP:** 3.9 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 11/18/2019

SLOPE PROFILE

Height (ft)	estimated 15 to 20				
Length (ft)	415				
Inclination and Direction	85 degrees facing 320 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	11.5		28		
Surface Variation (ft)	0.5 to 1	(1 to 2)	some 2 to 5	5+	Other:vert. scallops offset 3 to 5 ft

SETTING

Posted speed (mph): 75	**Number of travel lanes:** 2EB	**AADT:** 8300	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 415 ft=4 seconds*		
Travel direction #1=0.24 mi=12 sec		Travel direction #2 =not seen from WB	
NB SB (EB) WB		NB SB EB WB	
(Foreground/Short Range: to 0.5 mi		Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Adjacent to McInnis Canyons Natl Conservation Area (BLM)	**Static viewer?** Old Spanish Natl Historic Trail intersects cut east/west ,view possible from trail north ofI-70	

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):**	
Formation name	Morrison Formation, Salt Wash Member		**Outcrop description:** Massive sandstone interbedded with mudstone		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracturespacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	(Occasional horizontal erosion features 10 to 40%)	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: 03 to 310- fluvial features
	Difference in erosion	Small difference 6 to 12 inches	(Moderate difference 1 to 2 ft)	(Few areas of large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods ~~OR continual water on slope~~	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Slopes are more vertical	Only few rocks in ditch area	10 to 20 ft spacing of vertical scalloping along cut. Scallop areas are approximately 3 to 5 feet offset from cut face. Apparent native vegetation types scrub and trees on ledges, top and in front of cut

CONSTRUCTION

Features	(Many Half-casts (blasting) - every 3 ft)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required? / Other:
Excavation method	(Blasting)	Breaking	Ripping	Other: Constructed in massive sandstone using standard presplit and production drilling to created zigzag rock face that contributes more natural appearance.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
11/18/2019	EB viewshed	1303	
11/18/2019	Cut view to SW	1320	
11/18/2019	Cut view to SE	1333	
11/18/2019	Varied ditch widths	1309	

ROCK SLOPE CHARACTERIZATION

Highway: I-70 EB south side **MP:** 3.9 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 11/18/2019

Eastbound Viewshed

View to southwest

View to southeast

Varied ditch widths

Return A12

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 124.7 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 4/21/2021

SLOPE PROFILE

Height (ft)	estimated 85-90					
Width (ft)	350 (565 includes wall and cut to north)					
Inclination and Direction	80 to 85 degrees facing 100 degrees					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	10 paved			3 to 25		
	(30 total from white line to face of cut)					
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:	

SETTING

Posted speed (mph): 50 **Number of travel lanes:** 2 WB/2 EB **AADT:** 17000

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 350 ft=5 seconds,*

Travel direction #1=0.25 mi=18 sec				Travel direction #2 = 0.29 mi=21 sec			
NB	SB	EB	(WB)	NB	SB	(EB)	WB
(Foreground/Short Range: to 0.5 mi)				(Foreground/Short Range: to 0.5 mi)			
Middleground/Long Range: to 3-5 mi				Middleground/Long Range: to 3-5 mi			
Background: to 5 mi to infinity				Background: to 5 mi to infinity			

Adjacent land use: Unimproved land and cliffs to the NW and SE owned by Public Service Co of Colorado; rock cut in CDOT ROW. Colorado River east of cut and I-70.

Static viewer? Recreational users of Colorado River east of cut and users of paved path on east side and under I-70 at cut.

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):**	
Formation name	Biotite Granite (Precambrian)			**Outcrop description:** fine to coarse grained granite and granodiorite	

CASE 1- Crystalline, jointed rock	**Structural Condition with fracturespacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	(Adverse)	(Adverse)	
					(open 1 to 6 inches vertical and horizontal)	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap ~~open, closed,~~ clay, gouge infilling, or slickensided	
CASE 2- sedimentary/ or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Similar	Similar	Talus slope at north end of cut; blocks of rock in ditch area	Retaining wall west of WB lanes at north end of cut below talus slope is timber-faced mechanically stabilized earth wall retaining talus.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	Rockfall Mitigation	Access Road required? None	Other:
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Sliver rock cuts with minimal excavation using cushion blasting. Extensive rock scaling. Rock bolt pattern adjusted in field due to unstable slope conditions in discontinuities. Holes were drilled from a crane-suspended basket.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
4/21/2021	Eastbound view	1542	West end of cut
4/21/2021	Westbound view	1547	East end of cut
4/21/2021	View to northwest from EB lanes	1544	Looking west
4/21/2021	Wall at northeast end of cut	1556	Looking west

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 124.7 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 4/21/2021

Eastbound View

Westbound view

View to northwest from eastbound lanes

Wall at northeast end of cut, looking west

Return A12

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 127.2 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 4/21/2021

SLOPE PROFILE

Height (ft)	estimated 60
Width (ft)	510
Inclination and Direction	80 to 85 degrees facing 160 degrees
Offset from highway (ft)	*Width of Shoulder*: 6 paved; *Width of Ditch*: 0 to 19; ~280 ft from east end cut, concrete slab fill behind barrier
Surface Variation (ft)	0.5 to 1 / (1 to 2) / (2 to 5) / 5+ / Other:

SETTING

Posted speed (mph):	50
Number of travel lanes:	2 EB (2 WB in tunnel)
AADT:	17000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 510 ft=7 seconds,*
Travel direction #1=0.25 mi=18 sec	NB SB (EB) WB
Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	
Travel direction #2 N/A	NB SB EB WB
Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	
Adjacent land use	Unimproved land and cliffs to the north and south of CDOT ROW owned by US Forest Service.
Static viewer?	Recreational users of Colorado River south of cut and users of paved path on south/east side and under I-70 at cut.

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary) / Igneous / Metamorphic
Other description (mixed, etc.):	
Formation name	Sawatch Formation (Cambrian)
Outcrop description:	Massive, medium-grain sandstone with conglomerate

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
					open 1 to 6 inches vertical and horizontal	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- sedimentary, or layered	**Structural Condition**	(Few differential horizontal erosion features < 10%)	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: 8 @ 090
	Difference in erosion	(Small difference 6 to 12 inches)	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Similar	Cobble to boulder size rocks behind barrier	Concrete filled in between barrier and cut for 40 feet slants toward roadway, approximately 280 feet west of east end of cut. Some small cobbles, gravel on top of concrete.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required? None; Other: Cut is on south side of tunnel bore for westbound lanes
Excavation method	(Blasting)	Breaking	Ripping	Other: Cushion blasting using precision blast techniques due to tunnel proximity. Little to no catchment area due to location to river and trail. Barrier slip forms could not fit and concrete cast directely to cut. Flexible rockfall barrier located on top of cut.	

PHOTO LOG

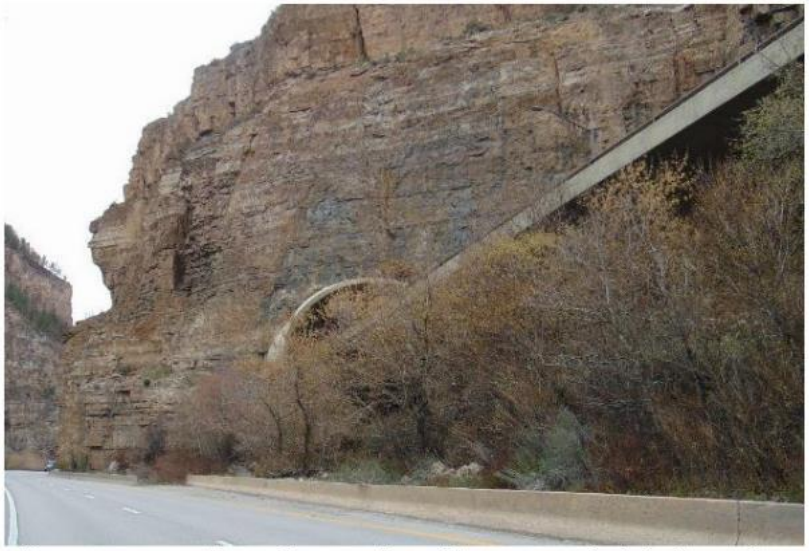
Date	*Description*	*Photo No.*	*Discussion*
4/21/2021	Eastbound View-cut on outside of tunnel	1549	Rockfall fence at top of lower ledge
4/21/2021	View to NE	1550	From eastbound lane
4/21/2021	View to WSW	1557	From EB lane below WB lane and tunnel
4/21/2021	View to WSW behind barrier	1552	Little to no ditch area behind barrier

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 127.2 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 4/21/2021

Eastbound View; rockfall fence at top of lower ledge

View to northeast from eastbound lane



View to west-southwest from eastbound lane; cut on far left of tunnel

View to west-southwest; little to no ditch area behind barrier

Return A12

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 183.9 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 9/30/2019

SLOPE PROFILE

Height (ft)	estimated 35 to 40					
Length (ft)	618					
Inclination and Direction	35 to 75 degrees facing 035 degrees					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	29			12		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 65	**Number of travel lanes: 2 EB, 2 WB**	**AADT:** 21,000
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 618 ft=6 seconds*		
Travel direction #1=0.82 mi=45 sec: NB SB (EB) WB	Travel direction #2 = 0.62 mi=34 sec: NB SB EB (WB)	
(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Long Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use Vacant land owned by U.S. Forest Service	**Static viewer?** View from bike path NE of and across interstate from cut	

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):**		
Formation name	Minturn Formation			**Outcrop description:** Sandstone, shale, conglomerate red to gray		

CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
	Favorable	Random	Adverse		Adverse	
Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar		Fracture gap-open, closed, clay, gouge infilling, ~~or slickensided~~	
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features (eroded shale) 40 to 80 %)		Major horizontal erosion features > 80%	Dip and direction: 10 @ 230
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	(Large difference 2 to 5 ft)		Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to natural outcrops	Similar to natural outcrops	Few cobbles to boulder size rocks in ditch area	Boulder size rocks have eroded from cut; sandstone undercut by weaker shale leaving hanging blocks of rock

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No blast marks or mitigation seen; terraced and vegetated
Excavation method	(Blasting-minimal)	Breaking	(Ripping)	Other: Excavator used to rip rock face leaving more resistive rock as vertical face and softer rock as slope incorporating planting pockets to revegetate cut area.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
1/8/2020	Eastbound view	166	Northeast end of cut
1/8/2020	Westbound view	91	
9/30/2019	Bedding plane cuts	92	Sandstone, shale and conglomerate bedding planes with trees
9/30/2019	Sandstone undercut by weaker shale	85	Boulders at base of cut; view to southwest

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 183.9 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 9/30/2019

Eastbound view-northeast end of cut

Westbound view

Bedding plane cuts with planting pockets

Sandstone undercut by weaker shale; boulders at base of cut

Return A12

ROCK SLOPE CHARACTERIZATION

Highway: I-70 (outside curve) **MP:** 185.5 **to** 186.5 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 9/30/2019

SLOPE PROFILE

Height (ft)	estimated 25 to 125 (Eagle County GIS)
Length (ft)	3800
Inclination and Direction	40 to 85 degrees facing 285 to 325 degrees; in middle, some overhang areas; at N. end more horizontal terraces
Offset from highway (ft)	*Width of Shoulder*: 8 to 11, some unpaved; *Width of Ditch*: 10 to 46
Surface Variation (ft)	0.5 to 1 / 1 to 2 / (2 to 5) / (5+) / Other:

SETTING

Posted speed (mph): 65	**Number of travel lanes:** 2 EB, 2WB	**AADT:** 21,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 3800 ft=40 seconds*	
Travel direction #1=0.95 mi=53 sec (NB SB EB (WB))	Foreground/Short Range: to 0.5 mi; Middleground/Long Range: to 3-5 mi; Background: to 5 mi to infinity	
Travel direction #2 = 1.0 mi=57 sec (NB SB (EB) WB)	Foreground/Short Range: to 0.5 mi; Middleground/Long Range: to 3-5 mi; Background: to 5 mi to infinity	
Adjacent land use	Vacant land owned by U.S. Forest Service	**Static viewer?** View from bike path west of and across interstate from cut

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):**		
Formation name	Maroon Formation			**Outcrop description:** Sandstone, mudstone and conglomerate, red to red-brown		

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: S. end= 14@196; see below
	Difference in erosion	Small difference 6 to 12 inches	(Moderate difference 1 to 2 ft)	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods and continual water on slope)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Similar to natural outcrops	Similar to natural outcrops	Many rocks on ledges/terraces, slopes and in ditch	**ADDITIONAL DIP/DIP DIRECTION:** middle area, 04 @ 210; near MM 186, 06 @ 120; near MM 185.5 (N. end), 07 @ 150. Parallel fault sets generally parallel cut face.

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required?	Other: Mitigation as terraced slopes
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Blast pattern used presplit line along final face. Production drill holes used to remove most of rock mass. Excavator used to create stepped rock with resistive rock as vertical face and soft rock as slopes. Benches were used for revegetation		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
9/30/2019	Westbound view	130	
9/30/2019	Eastbound view	102	
9/30/2019	Terraced slopes	120	Terraces toward middle of cut area
9/30/2019	Boulders at base of slope and in ditch	151	

ROCK SLOPE CHARACTERIZATION

Highway: I-70 (outside curve) **MP:** 185.5 **to** 186.5 **Travel direction closest to cut:** NB SB EB WB **Date:** 9/30/2019

Westbound view

Eastbound view

Terraced, bench slopes with revegetation

Boulders at base of slope and in ditch

Return A13

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 200 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 9/30/2019

SLOPE PROFILE

Height (ft)	estimated 80 to 100
Length (ft)	610
Inclination and Direction	50 to 85 degrees facing 150 degrees
Offset from highway (ft)	*Width of Shoulder*: 25; *Width of Ditch*: 25
Surface Variation (ft)	0.5 to 1 / 1 to 2 / (2 to 5) / 5+ / Other:

SETTING

Posted speed (mph): 65	**Number of travel lanes:** 2 EB, 2WB	**AADT:** 29,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 610 ft=9 seconds*	
Travel direction #1=0.32 mi=18 sec	NB SB EB (WB)	
Foreground/Short Range: to 0.5 mi	Middleground/Long Range: to 3-5 mi	Background: to 5 mi to infinity
Travel direction #2 = 0.6 mi=33 sec	NB SB (EB) WB	
Foreground/Short Range: to 0.5 mi	Middleground/Long Range: to 3-5 mi	Background: to 5 mi to infinity
Adjacent land use	Vacant land owned by U.S. Forest Service	**Static viewer?** View from bike path and campground SE of and across I-70 from cut

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary / Igneous / (Metamorphic) **Other description (mixed, etc.):**

Formation name: Gneiss **Outcrop description:** As named, Precambrian age, with mafic (dark) minerals

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
		Favorable	(Random)	Adverse	Adverse	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**				Joint set plane dips ~30 to 40 degrees,	
	Rock Friction/ Surface Variations	(Rough, irregular-at ends)	(Undulating, smooth-middle area)	Planar	oriented toward road; Joint spacing 2 to 5 ft; fracture gaps-open less than 0.5 ft to closed	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to natural outcrops except exposed iron staining	Similar to natural outcrops above cut	Few rocks in ditch; no large rocks noted on terraces	Wedge blocks are inclined toward road with major joint set plane oriented toward road and tilted at 30 to 40 degrees; Terraced cuts have vegetation-trees, shrubs, grasses; some random fractures may be from blasting.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: Mitigation as terraced slopes
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Conventional presplit and naturally occuring joints used to control overbreak during production blasting. Benches were formed in slope for planting zones.		

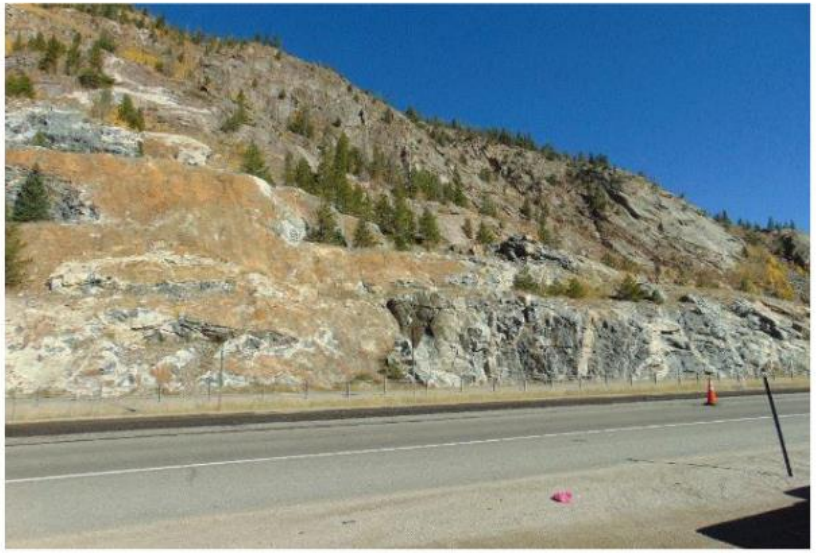
PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
9/30/2019	Westbound view	140	
9/30/2019	Eastbound view	172	
9/30/2019	Cut view to northwest	171	Iron staining on joint plane face; vegetated terraces
9/30/2019	Joint planar surface	145	Joints and fractures with wedges tilted toward road

ROCK SLOPE CHARACTERIZATION

Highway: I-70 **MP:** 200 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 9/30/2019

Westbound View



Eastbound View

Cut view to northwest of vegetated, terraced slope and iron staining

Joint planar surface dip toward roadway

Return A13

ROCK SLOPE CHARACTERIZATION

Highway: I-70, east of tunnels **MP:** 242.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/4/2019

SLOPE PROFILE

Height (ft)	estimated 100 to 125					
Length (ft)	600					
Inclination and Direction	68 to 73 degrees facing 161 to 174 degrees					
Offset from highway (ft)	*Width of Shoulder*: 11 to 21, becomes third lane in tunnel			*Width of Ditch*: 12 to 21, behind barrier		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 2 EB, 2WB	**AADT:** 53,000
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 600 ft=8 seconds*		
Travel direction #1=0.3 mi=20 sec — NB SB EB (WB)	Travel direction #2 = 0.13 mi=9 sec — NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi); Middleground/Long Range: to 3-5 mi; Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi); Middleground/Long Range: to 3-5 mi; Background: to 5 mi to infinity	
Adjacent land use	Vacant land north and south of cut owned by Clear Creek County	**Static viewer?** View from bike path and building south of and across I-70 from cut

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):** Feldspar Gneiss with other types gneiss		
Formation name	Gneiss			**Outcrop description:** As named, Precambrian age, interlayered dark/light minerals, some biotite		
CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*: Favorable	(Random)	Adverse-foliation areas	*Continuous Fractures Orientation*: Adverse		
CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	(Rough, irregular)	Undulating, smooth	Planar	Foliation layers at east end cut dip ~45 to 60 degrees at 350/into slope away from road; Foliation spacing 1 to 5 ft; fracture gaps-open less than 0.5 ft to closed		
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:	
CASE 2- Sedimentary, or layered: **Difference in erosion**	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft		

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Dark mesh against lighter rock	*Texture*: Similar to natural outcrops	*Stability*: Few rocks in ditch and behind mesh	*Other Visual Differences*: Iron staining on exposed foliation planes

CONSTRUCTION

Features	(Half-casts (blasting)- horizontal and vertical, few full casts)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	(Access Road required? Yes) — Other: Draped mesh on most of face-none at very top down to 5 ft above ground
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Horizontal drilling and blasting for access; blast holes drilled fan-shaped and parallel to road alignment using conventional presplitting and production drilling. Slope rounding removed overshot material and weathered rock.	

PHOTO LOG

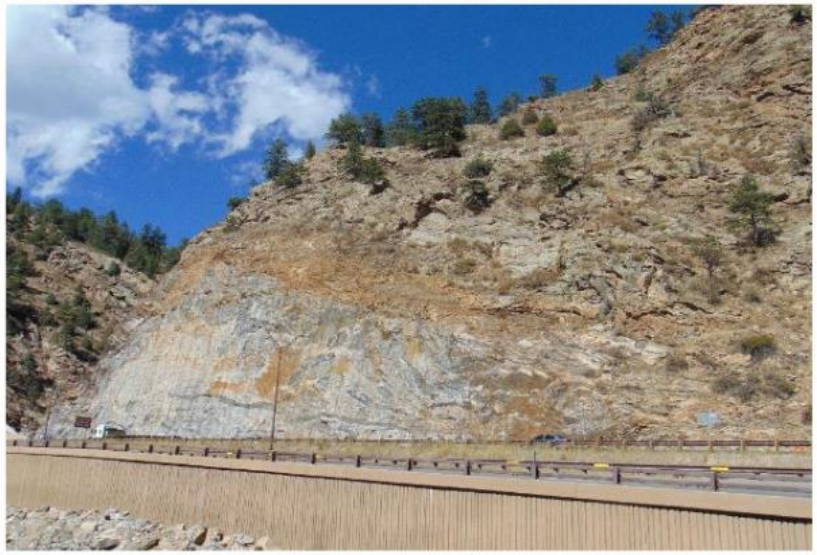
Date	*Description*	*Photo No.*	*Discussion*
10/4/2019	Westbound viewshed	517	Westbound view, cut is center, between yellow signs
10/4/2019	Eastbound viewshed	522	Eastbound view on exiting tunnel
10/4/2019	View to northwest	513	Draped mesh left of photo; tilted foliation layers on right
10/4/2019	View to northeast	450	Draped mesh, bolts

ROCK SLOPE CHARACTERIZATION

Highway: I-70, east of tunnels **MP:** 242.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/4/2019

Westbound Viewshed

Eastbound viewshed



View to northwest

View to northeast, mesh, bolts

Return A13

ROCK SLOPE CHARACTERIZATION

Highway: I-70, west of tunnels **MP:** 242.1 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/4/2019

SLOPE PROFILE

Height (ft)	estimated 40
Length (ft)	300
Inclination and Direction	West end-43 degrees facing 169 degrees; middle and east end-76 to 79 facing 170
Offset from highway (ft)	*Width of Shoulder*: 10 to 20; taper end of third lane in tunnel. *Width of Ditch*: 11 to 21-slopes down to west from top of west portal
Surface Variation (ft)	0.5 to 1 / 1 to 2 / (2 to 5) / (5+) / Other:

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 2 EB, 2WB	**AADT:** 53,000

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 300 ft=4 seconds*

Travel direction #1=0.1 mi=6 sec	Travel direction #2 = 0.35 mi=23 sec
NB SB EB (WB)	NB SB (EB) WB
Foreground/Short Range: to 0.5 mi	Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: Vacant land north of cut owned by Clear Creek County; private commercial and vacant land south of cut

Static viewer? View from bike path and building south of and across I-70 from cut

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary / Igneous / (Metamorphic)

Other description (mixed, etc.): Feldspar Gneiss with other types gneiss

Formation name: Gneiss

Outcrop description: As named, Precambrian age, interlayered dark/light minerals, some biotite

CASE 1- Crystalline, jointed rock

Structural Condition with fracture spacing	*Discontinuous Fractures Orientation/Spacing in feet*		*Continuous Fractures Orientation*
	Favorable	(Random)	(Adverse)
		(Adverse-foliation areas)	
		Foliation layers in lower mid-cut dip into slope away from road and upper west end layers dip toward the road; Foliation spacing 1 to 5 ft; fracture gaps-open less than 0.5 ft to closed	Joints spaced 3 to 5 feet apart with gaps less than 0.5 ft to closed; joint plane tilts toward tunnel (east); intersection of joints and foliation layers can create block failures
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to natural, mesh match to rock	Similar to natural outcrops	Many rocks in ditch	Failed rock anchor and large, approximately 5 feet diameter, detached slab of rocks from behind the mesh; iron staining on foliation layer face exposed in cut

CONSTRUCTION

Features	(Half-casts (blasting) horizontal and vertical, few full casts)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation) (Access Road required? Yes)	Other: Draped mesh on most of face down to ~3 to 5 ft above ground; failed rock bolt
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Horizontal drilling and blasting for access; blast holes drilled fan-shaped and parallel to road alignment using conventional presplitting and production drilling. Slope rounding removed overshot material and weathered rock.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/4/2019	Westbound viewshed	467	Westbound view, cut right of barrier
10/4/2019	Eastbound viewshed	520	Eastbound view middle, left of portal
10/4/2019	View to north	495	Joints and foliation layers
10/4/2019	View to west	488	Draped mesh

ROCK SLOPE CHARACTERIZATION

Highway: I-70, west of tunnels **MP:** 242.1 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/4/2019

Westbound Viewshed

Eastbound Viewshed

View to north, joints, foliation layers

View to west, draped mesh

Return A13

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 (Segment 1) **MP:** 217.4 **to** 217.6 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

SLOPE PROFILE	**Height (ft)**	estimated 10 to 25				**SETTING**	**Posted speed (mph):** 55	**Number of travel lanes:** 1EB/1WB	**AADT:** 5100
	Length (ft)	370					**Visibility**	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction, 370 ft=5 sec*	
	Inclination and Direction	50 degrees facing 170 degrees					Travel direction #1 = 0.25 mi=17 sec	Travel direction #2= 0.1 mi=6 sec
							NB SB EB (WB)	NB SB (EB) WB
	Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		~~Foreground/Short Range: to 0.5 mi~~	~~Foreground/Short Range: to 0.5 mi~~
		6 ft paved			13 ft		Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
							Background: to 5 mi to infinity	Background: to 5 mi to infinity
	Surface Variation (ft)	0.5 to 1	1 to 2	some 2 to 5	(5+)	Other:	**Adjacent land use**	Private, unimproved land north and south of road with house north; US Forest Service land to west	**Static viewer?** None noted
GEOLOGIC CHARACTERISTICS	**Rock type**	Sedimentary		(Igneous)		Metamorphic	Other description (mixed, etc.):		
	Formation name	Granodiorite porphyry, granite					**Outcrop description:** Granitic rock, spheroidally weathered outcrops		
	CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation*							*Continuous Fractures Orientation*
		Favorable		Random			Adverse		(Adverse)
	CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	(Rough, irregular)		Undulating, smooth			Planar		Fracture gap-closed, to open 2 in. ~~clay, gouge infilling, or slickensided~~
	CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%		Occasional horizontal erosion features 10 to 40%			Many horizontal erosion features 40 to 80 %		Major horizontal erosion features > 80%
	CASE 2- Sedimentary, or layered: **Difference in erosion**	~~Small difference 6 to 12 inches~~		Moderate difference 1 to 2 ft			Large difference 2 to 5 ft		Extreme difference > 5 ft
	Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope		Moderate precipitation OR short freezing periods, OR intermittent water on slope			(High precipitation OR long freezing periods ~~OR continual water on slope~~)		High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
	Compatibility with Nearby Slopes (describe)	*Color*		*Texture*		*Stability*	*Other Visual Differences*		
		Lighter than natural outcrops; mesh dark rust color		More angular than natural outcrops		Few rocks in ditch area			
CONSTRUCTION	**Features**	Half-casts (blasting)		Machine marks (excavation-machine blade/tooth)		(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh
	Excavation method	(Blasting)		Breaking		(Ripping)	Other: Cushion blasting drilling and loading to shape rock; ripping used to round the cut slopes to transition into natural slopes. Excavator also pulle rock back to existing fractures for more natural appearance.		

PHOTO LOG	*Date*	*Description*	*Photo No.*	*Discussion*
	10/8/2019	WB viewshed	741	Center of photo behind yellow sign
	10/8/2019	EB viewshed	738	Center left of photo beyond brown shrubs
	10/8/2019	View to NE	736	Cut with rock mesh
	10/8/2019	View to NNE	732	Rock mesh and catchment ditch

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 (Segment 1) **MP:** 217.4 **to** 217.6 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

Westbound viewshed

Eastbound viewshed, center left beyond brown shrubs

View to northeast, rock mesh

View to north-northeast, rock mesh and catchment ditch

Return A14

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 (Segment 2) **MP:** 217.6 **to** 217.8 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

SLOPE PROFILE

Height (ft)	estimated 5 to 25					
Length (ft)	300					
Inclination and Direction	65 degrees facing 150 degrees					
Offset from highway (ft)	*Width of Shoulder*: 6 ft paved			*Width of Ditch*: 13 ft		
Surface Variation (ft)	0.5 to 1	1 to 2	(some 2 to 5)	5+	Other:	

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 2EB/1WB	**AADT:** 5100

Visibility — *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 300 ft=4 seconds*

Travel direction #1=0.5 mi=33 sec	Travel direction #2 = 0.25 mi=16 sec
NB SB EB (WB)	NB SB (EB) WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: Private, unimproved land with house to NW

Static viewer: Intersection S. side road to driveway of apparently unimproved land

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary | (Igneous) | Metamorphic | Other description (mixed, etc.):

Formation name: Granodiorite

Outcrop description: Granitic rock, spheroidally weathered outcrops

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	(Adverse)	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed, to open 2 in. ~~clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features ~~40 to 80 %~~	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	~~Small difference 6 to 12 inches~~	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	~~Extreme difference > 5 ft~~	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Lighter than natural outcrops; mesh dark rust color	*Texture*: More angular than natural outcrops	*Stability*: Few rocks in ditch area	*Other Visual Differences*

CONSTRUCTION

Features	Half-casts (blasting)	(Machine marks (excavation-machine blade/tooth))	Rock anchors	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Controlled pre-split and cushion blasting techniques; decomposed granite machine excavated and scaling of rock face.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/8/2019	WB viewshed	743	Cut in distance between speed limit sign and yellow signs
10/8/2019	EB viewshed	739	Cut in left center just beyond sign and light on left
10/8/2019	View to northeast	710	Rock cut with draped mesh
10/8/2019	View to west-southwest	696	Rock cut without mesh to mesh area with angular gap

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 (Segment 2) **MP:** 217.6 **to** 217.8 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

Westbound viewshed, cut between speed limit & yellow signs, right

Eastbound viewshed, cut left of center, beyond sign with light on left

View to northeast, draped mesh

View to west-southwest, cut without mesh with angular gap

Return A14

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 **MP:** 217.8 **to** 217.9 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

SLOPE PROFILE

Height (ft)	estimated 20 to 30
Length (ft)	215
Inclination and Direction	65 to 70 degrees facing 150 degrees
Offset from highway (ft)	*Width of Shoulder*: 6 ft paved; *Width of Ditch*: 12 ft
Surface Variation (ft)	0.5 to 1 / 1 to 2 / (some 2 to 5) / (5+) / Other:

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 2EB/1WB	**AADT:** 5100
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 215 ft=3 seconds*	
Travel direction #1 =0.5 mi= 33 sec (NB SB EB (WB))	Travel direction #2=0.25 mi=16 sec (NB SB (EB) WB)	
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	Background: to 5 mi to infinity	
Adjacent land use	Private, unimproved land with house to northwest	**Static viewer:** Intersection S. side road to driveway of apparently unimproved land

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary / (Igneous) / (Metamorphic) / Other description (mixed, etc.):
Formation name	Granodiorite with biotite gneiss xenoliths/inclusions
Outcrop description:	Granitic rock, foliated biotite gneiss; spheroidally weathered outcrops

CASE 1- Crystalline, jointed rock

	Discontinuous Fractures Orientation			*Continuous Fractures Orientation*
Structural Condition with fracture spacing	Favorable	Random	Adverse	(Adverse)
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed, to open 2 in. ~~clay, gouge infilling, or slickensided~~

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Lighter than natural outcrops	More angular than natural outcrops	few rocks in ditch	

CONSTRUCTION

Features	Half-casts (blasting)	(Machine marks (excavation-machine blade/tooth))	(Rock anchors - only one bolt seen)	Rockfall Mitigation no mesh	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Controlled pre-split and cushion blasting techniques; decomposed granite machine excavated and scaling of rock face.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/8/2019	Westbound viewshed	682	Center view distance across from cut on left
10/8/2019	Eastbound viewshed	739	Cut in left center just beyond sign and light on left
10/8/2019	View to north-northeast	695	Cut
10/8/2019	View to NE with features	692	Machine marks, bolt

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 **MP:** 217.8 **to** 217.9 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

Westbound viewshed, center distance across from cut on left

Eastbound viewshed, cut in left center beyond sign and light on left

View to north-northeast

View to northeast with machine marks, bolt

Return A14

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 **MP:** 217.9 **to** 218.1 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

SLOPE PROFILE

Height (ft)	estimated 10 to 25				
Length (ft)	640				
Inclination and Direction	65 to 70 degrees facing 150 degrees				
Offset from highway (ft)	*Width of Shoulder*: 6 ft paved		*Width of Ditch*: 12 to 13 ft		
Surface Variation (ft)	0.5 to 1	1 to 2	(some 2 to 5)	5+	Other:

SETTING

Posted speed (mph): 55 **Number of travel lanes:** 2EB/1WB **AADT:** 5100

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction (55 mph, 10 sec=810 ft)*

Travel direction #1 =0.3 mi/1650 ft=20 sec	Travel direction #2 = 0.5 mi=33 sec
NB SB EB (WB)	NB SB (EB) WB
~~Foreground/Short Range: to 0.5 mi~~	Foreground/Short Range: to 0.5 mi
~~Middleground/Long Range: to 3-5 mi~~	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: Private, unimproved land with house north of cut

Static viewer? Private driveway intersects road NE end of cut

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary (Igneous) Metamorphic Other description (mixed, etc.):

Formation name: Granodiorite with biotite gneiss xenoliths/inclusions **Outcrop description:** Granitic rock, foliated biotite gneiss; spheroidally weathered outcrops

	Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	Favorable	Random	Adverse	(Adverse)	
CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed, to open 2 in. ~~clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
CASE 2- Sedimentary, or layered: **Difference in erosion**	Small difference ~~6 to 12 inches~~	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Lighter than natural outcrops; mesh dark color	More angular than natural outcrops	Some rockfall noted in ditch	Weathered, natural outcrops of nearby granitic rock at top of and north of cut

CONSTRUCTION

Features	(Half-casts (blasting) and full casts seen)	(Machine marks (excavation-machine blade/tooth))	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Controlled pre-split and cushion blasting techniques; decomposed granite machine excavated and scaling of rock face.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/8/2019	Westbound view	684	Draped mesh at west end, perched boulder above cut
10/8/2019	Eastbound view	739	Cut is center left of road
10/8/2019	Machine marks in cut below boulder	664	Mesh at west end of cut; view to west
10/8/2019	View to northeast	680	Draped mesh at west end

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 **MP:** 217.9 **to** 218.1 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

Westbound view

Eastbound viewshed, cut is center left of road

Machine marks in cut below perched boulder

View to northeast, draped mesh at west end

Return A14

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 **MP:** 218.1 **to** 218.3 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

SLOPE PROFILE

Height (ft)	estimated 35 to 40				
Length (ft)	650				
Inclination and Direction	65 to 70 degrees facing 130 degrees				
Offset from highway (ft)	*Width of Shoulder*: 6 ft paved		*Width of Ditch*: 13 to 14 ft		
Surface Variation (ft)	0.5 to 1	1 to 2	(some 2 to 5)	5+	Other:

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 2EB/1WB	**AADT:** 5100
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 650 ft=8 seconds*	
Travel direction #1 =0.7 mi= 44 sec — NB SB EB (WB)	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Travel direction #2=0.3 mi=20 sec — NB SB (EB) WB	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use	Private, unimproved land	**Static viewer?** Pullout on SE side of rd across from SE end of cut

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary (Igneous) Metamorphic — Other description (mixed, etc.):

Formation name: Foliated granodiorite w/biotite gneiss xenoliths/inclusions

Outcrop description: Foliated granitic rock and biotite gneiss; spheroidally weathered outcrops

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	(Adverse)	(Adverse)	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods OR continual water on slope)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Lighter than natural outcrops; mesh silver/rust color	More angular than natural outcrops	some rocks in ditch and in mesh	

CONSTRUCTION

Features	(Half-casts (blasting)- only one seen)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation mesh)	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Controlled pre-split and cushion blasting techniques and scaling of rock face.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/8/2019	Westbound viewshed	603	Center left
10/8/2019	Eastbound viewshed	739	Left of roadway, beyond vehicles
10/8/2019	View to northeast	633	Rock wedge missing between joints, fractures
10/8/2019	View to north	636	Draped mesh, foliation angle

ROCK SLOPE CHARACTERIZATION

Highway: US 24/285 **MP:** 218.1 **to** 218.3 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/8/2019

Westbound viewshed, center left

Eastbound viewshed, left of roadway, beyond vehicles

View to northeast, rock wedge missing

View to north, draped mesh, foliation angle

Return A14

ROCK SLOPE CHARACTERIZATION

Highway: US 24-frontage road CR 231/CR 25 **MP:** 283.8 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/9/2019

SLOPE PROFILE

Height (ft)	estimated 25 to 40				
Length (ft)	306				
Inclination and Direction	85 degrees facing 150 to 210 degrees (curves)				
Offset from highway (ft)	*Width of Shoulder*: None		*Width of Ditch*: 9 to 12		
Surface Variation (ft)	(0.5 to 1)	1 to 2	some 2 to 5	5+	Other: 2 to 6 in. grooves in shotcrete

SETTING

Posted speed (mph): 25 on frontage, 45 on US 24	**Number of travel lanes:** 2EB/2WB	**AADT:** 20,000 for US 24
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 306 ft=5 to 8 seconds(frontage rd)*		
Travel direction #1 =0.1 mi= 10 to 14 sec: NB SB EB (WB)	Travel direction #2=0.4 mi=32 to 58 sec: NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use: Unimproved private property to north, east, and west; roadway to south		**Static viewer?** Low speed frontage rd with bicycle lanes; house on S. side road

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	Other description (mixed, etc.):	
Formation name	Pikes Peak Granite/Pikes Peak Batholith			**Outcrop description:** Granite with shotcrete facing/Ute Pass Fault in area of cut	

CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation- **NOT SEEN, COVERED WITH SHOTCRETE***			*Continuous Fractures Orientation*	
	Favorable	Random	Adverse	Adverse	
Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Darker than outcrop nearby	More vertical than natural and grooves farther apart	No rocks in ditch	Leaching of shotcrete minerals through few cracks-white residue on shotcrete

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation shotcrete facing)	Access Road required? / Other: Drains at base of wall/shotcrete; fence at top of shotcrete wall
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit and cushion blasting methods used. Sculpted, stained shotcrete to mimic joints used to stabilize face. Revegetated on ends.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/9/2019	Westbound viewshed	801	Cut is right of yellow sign
10/9/2019	Eastbound viewshed	823	Cut in center, right of yellow sign
10/9/2019	View to NNE	802	Shotcrete covered cut
10/9/2019	View to NW	809	Shotcrete covered cut

ROCK SLOPE CHARACTERIZATION

Highway: US 24-frontage road CR 231/CR 25 **MP:** 283.8 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/9/2019

Westbound viewshed, cut right of yellow sign

Eastbound viewshed, cut in center, right of yellow sign

View to north-northeast

View to northwest

Return A15

ROCK SLOPE CHARACTERIZATION

Highway: US 24 **MP:** 298.4 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/9/2019

SLOPE PROFILE

Height (ft)	estimated 30 to 40				
Length (ft)	793				
Inclination and Direction	65 degrees facing 180 degrees				
Offset from highway (ft)	*Width of Shoulder*: 6 paved + 2 barrier			*Width of Ditch*: 12 to 17	
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 2EB/2WB	**AADT:** 32,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 793 ft=12 seconds*	
Travel direction #1 =0.5 mi= 38 sec	NB SB EB (WB)	
Travel direction #2=0.25 mi=23 sec	NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	Background: to 5 mi to infinity	
Adjacent land use	Unimproved private owned lots, and one City of Manitou Spgs lot above road cut to north and residential area across highway to the south	**Static viewer?** Houses on south side of rd may have view

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	Other description (mixed, etc.):		
Formation name	Fountain Formation			**Outcrop description:** Sandstone, conglomerate with boulder-size clasts, shale		
CASE 1- Crystalline, jointed rock		*Discontinuous Fractures Orientation*			*Continuous Fractures Orientation*	
Structural Condition with fracture spacing	Favorable	Random		Adverse	Adverse	
Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth		Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered						
Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: 09 @ 130 12 @ 138
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		(Large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Same red-brown	*Texture*: Similar	*Stability*: Few rocks in ditch area; areas of possible sapping	*Other Visual Differences*: Overhang competent sandstone over weaker shale layers; angular to subrounded conglomerates up to 12-inch diameter clasts eroding out of formation

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No construction features seen.
Excavation method	(Blasting)	Breaking	Ripping	Other: Controlled blasting using conventional presplitting method. Half-casts visible in resistant rock and have eroded in softer rock.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/9/2019	Westbound viewshed	753	Cut is lower left beyond white vehicle
10/9/2019	Eastbound viewshed	761	Cut is center, left of roadway
10/9/2019	View to northeast	766	Sedimentary rock layers
10/9/2019	View to north	784	Conglomerate layers with boulder size clasts

ROCK SLOPE CHARACTERIZATION

Highway: US 24 **MP:** 298.4 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/9/2019

Westbound viewshed, cut is lower left beyond white vehicle

Eastbound viewshed, cut is center, left of roadway

View to northeast

View to north, conglomerate layers with boulder size clasts

Return A15

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 77.5 **MP:** 77.4 **to** 77.6 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

SLOPE PROFILE

Height (ft)	estimated 75 to 150+				
Length (ft)	1120				
Inclination and Direction	45 to 75 degrees at 205 to 230 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	6		11 to 29		
Surface Variation (ft)	0.5 to 1	1 to 2	2 to 5	(5+)	Other:

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 EB with pullout/1WB	**AADT:** 5200
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1120 ft=17 seconds*	
Travel direction #1 =0.4 mi= 30 sec	NB SB EB (WB)	
Foreground/Short Range: to 0.5 mi	Middleground/Long Range: to 3-5 mi	Background: to 5 mi to infinity
Travel direction #2=0.45 mi=35 sec	NB SB (EB) WB	
Foreground/Short Range: to 0.5 mi	Middleground/Long Range: to 3-5 mi	Background: to 5 mi to infinity
Adjacent land use	BLM open land, unimproved	**Static viewer?** Pullout S. side across from cut;2-track rd and houses S. side

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	(Metamorphic)	Other description (mixed, etc.):		
Formation name	Granite, some schist/gneiss-metasedimentary			**Outcrop description:** Tonalite (granitoid), mica schist and gneiss		
CASE 1- Crystalline, jointed rock	*Discontinuous Fractures Orientation*				*Continuous Fractures Orientation*	
Structural Condition with fracture spacing	Favorable	Random		(Adverse)	Adverse	
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth		Planar	Fracture gap-closed to open up to 4 in. ~~open, clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered						Dip and direction:
Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Similar	Few rocks in ditch	One approximate 8-inch diameter cobble in travel way at time of visit

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: 2 tiers of draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Presplit blasting followed existing fractures. Western cut laid back after rock slide to follow foliation planes. East portion of cut benched. Mesh and bolts colored dark brown. Wider ditch allowed mesh to move higher on slope for less impact.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/16/2019	Westbound viewshed	1010	Cut in center right, across from treed slope
10/16/2019	Eastbound viewshed	1015	Cut in center behind sign on left
10/16/2019	View to east-southeast	1019	
10/16/2019	View to northwest	1069	Bolts, draped mesh, rocks caught behind mesh

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 77.5 **MP:** 77.4 **to** 77.6 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

Westbound viewshed, cut in center right, across from treed slope

Eastbound viewshed, cut in center behind sign on left

View to east-southeast

View to northwest, bolts, draped mesh, rocks caught behind mesh

Return A15

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 78.3, north side **MP:** 78.3 **to** 78.4 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

SLOPE PROFILE	**Height (ft)**	estimated 40 to 60					**SETTING**	**Posted speed (mph):** 45	**# travel lanes:** 1 EB/1 WB	**AADT:** 5200
	Length (ft)	240						**Visibility** *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 240 ft=4 seconds*		
	Inclination and Direction	50 degrees at 185 to 190 degrees						Travel direction #1 =0.2 mi= 16 sec NB SB EB (WB)	Travel direction #2=0.2 mi=14 sec NB SB (EB) WB	
	Offset from highway (ft)	*Width of Shoulder* 6			*Width of Ditch* 8 to back guardrail			Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
	Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:		**Adjacent land use**	City of Loveland open land, unimproved	**Static viewer?** Houses on W. end and S. side, above rd; possibly fishing activity in stream

GEOLOGIC CHARACTERISTICS	**Rock type**	Sedimentary	Igneous	(Metamorphic)	Other description (mixed, etc.):
	Formation name	Gneiss, schist, some garnetiferous			**Outcrop description:** As named, with some mica schist, possible metaconglomerate

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation*			*Continuous Fractures Orientation*	
		Favorable	Random	(Adverse)	Adverse	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed to open up to 4 in., ~~clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar, slightly lighter	Similar	Rocks in ditch	Boulders up to 4-foot diameter in ditch; raveling material in ditch; slot cut for roadway realignment

CONSTRUCTION	**Features**	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	Rockfall Mitigation	Access Road required?	Other: None
	Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit and production blasting along joint and foliation planes reduced appearance of half-casts and resulted in a more natural appearance. Adequate rockfall catchment eliminated need for mesh. Rock bolts colored.		

PHOTO LOG	*Date*	*Description*	*Photo No.*	*Discussion*
	10/16/2019	Westbound view	1006	
	10/16/2019	Eastbound view	994	Cut is center right, left of road beyond cut in foreground
	10/16/2019	View to northwest	1002	
	10/16/2019	View to east	970	

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 78.3, north side **MP:** 78.3 **to** 78.4 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

Westbound view

Eastbound view, cut is center right, left side of road

View to northwest

View to east

Return A15

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 78.3, south side **MP:** 78.3 **to** 78.4 **Travel direction closest to cut:** NB SB (EB) WB **Date:** 10/16/2019

SLOPE PROFILE

Height (ft)	estimated 70 to 80					
Length (ft)	300					
Inclination and Direction	50 degrees at 005 degrees					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	6 paved			9 to back guardrail		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:	

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 EB/1 WB	**AADT:** 5200	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 300 ft=5 seconds*		
Travel direction #1 =0.1 mi= 8 sec		Travel direction #2=0.15 mi=11 sec	
NB SB (EB) WB		NB SB EB (WB)	
(Foreground/Short Range: to 0.5 mi		(Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	City of Loveland open land, unimproved	**Static viewer?** House on W. end above road; possibly fishing activity in stream	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	Other description (mixed, etc.): River gravels above bedrock	
Formation name	Gneiss, schist, some garnetiferous			**Outcrop description:** As named, with some mica schist, possible metaconglomerate	

CASE 1- Crystalline, jointed rock

Structural Condition with fracture spacing	*Discontinuous Fractures Orientation*			*Continuous Fractures Orientation*	
	Favorable	Random	(Adverse)	Adverse	
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed to open up to 4 in., ~~clay, gouge infilling, or slickensided~~	

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Similar	Rounded gravel on top of cut	In area of no mesh, rounded gravels from deposit above cut have dropped into ditch

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: with wider ditch, draped mesh terminated higher above road for improved visual
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit and production blasting. Rock bolts and mesh for rockfall mitigation colored dark brown. Half-casts mitigated with rock staining.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/16/2019	Westbound viewshed	1007	Cut on right (south) side of road at curve
10/16/2019	Eastbound viewshed	1004	Cut on left (south) side of road at curve
10/16/2019	View to SW	986	Anchors at top of cut, draped mesh
10/16/2019	View to SE	972	

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 78.3, south side **MP:** 78.3 **to** 78.4 **Travel direction closest to cut:** NB SB (EB) WB **Date:** 10/16/2019

Eastbound viewshed, cut on right (south) side of road at curve

Westbound viewshed, cut on left (south) side of road at curve

View to southwest, anchors at top of cut, draped mesh

View to southeast

Return A15

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 78.5 **MP:** 78.4 **to** 78.6 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

SLOPE PROFILE

Height (ft)	estimated 35 to 40					
Length (ft)	650					
Inclination and Direction	70 degrees facing 245 to 250 degrees					
Offset from highway (ft)	*Width of Shoulder*: 6 paved			*Width of Ditch*: 13.5 to 18.0; behind guardrail		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+ at west end)	Other:	

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 EB/1 WB	**AADT:** 5200
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 650 ft=10 seconds*		
Travel direction #1 =0.18 mi= 14 sec — NB SB EB (WB)	Travel direction #2=0.20 mi=17 sec — NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use: City of Loveland and Larimer County, open land, unimproved	**Static viewer?** Fishing access west of and below cut	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	Other description (mixed, etc.):		
Formation name	Gneiss, schist, some garnetiferous			**Outcrop description:** As named, with some mica schist, possible metaconglomerate		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation*			*Continuous Fractures Orientation*	
		Favorable	Random	(Adverse)	Adverse	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed to open up to 4 in., ~~clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Similar	Few cobbles in ditch	Dark mesh-natural rocks are gray with rust color in fractured rocks along joints

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: with wider ditch, draped mesh terminated higher above road for improved visual
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit and production blasting. Rock bolts and mesh for rockfall mitigation colored dark brown. Half-casts mitigated with rock staining. Some blast holes visible		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/16/2019	WB viewshed	927	Cut on right (north) side next to yellow sign
10/16/2019	EB viewshed	996	Cut on left (north) side at curve
10/16/2019	View to north-northwest	960	Anchors at top of cut, draped mesh
10/16/2019	View to southeast	981	

ROCK SLOPE CHARACTERIZATION

Highway: US 34 MM 78.5 **MP:** 78.4 **to** 78.6 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

Westbound viewshed, cut on right (north) side next to yellow sign

Eastbound viewshed, cut on left (north) side at curve

View to north-northwest, anchors at top of cut, draped mesh

View to southeast

Return A16

ROCK SLOPE CHARACTERIZATION

Highway: US 36 **MP:** 7.8 **to** 7.9 Travel direction closest to cut: NB SB EB (WB) **Date:** 5/15/2020

SLOPE PROFILE

Height (ft)	75				
Length (ft)	490				
Inclination and Direction	76 degree facing toward 200 degrees				
Offset from highway (ft)	*Width of Shoulder*: 2 ft unpaved		*Width of Ditch*: 10		
Surface Variation (ft)	0.5 to 1	1 to 2	2 to 5	(5+)	Other:

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 2	**AADT:** 8300
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 490 ft=7 seconds*	
Travel direction #1=0.12 mi=9 sec	Travel direction #2 =0.13 mi=10 sec	
NB SB EB (WB)	NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	Background: to 5 mi to infinity	
Adjacent land use	US Forest Service	**Static viewer?** None

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	**Other description (mixed, etc.):**	
Formation name	Silver Plume Granite		**Outcrop description:** granite w/schist foliations		

CASE 1- Crystalline, jointed rock

	Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*
Structural Condition with fracture spacing	Favorable	Random	Adverse 2 joint sets, 5-10 ft spacing	Adverse
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	(Planar)	Fracture gap

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Few areas of large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods OR continual water on slope)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	lighter than adjacent natural slopes	more angular with larger smoother rock faces	Cobble-size rocks in ditch	Increased ditch with when compared to adjacent sites

CONSTRUCTION

Features	(Half-casts (blasting))	(Machine marks (excavation-machine blade/tooth))	Rock anchors	(Rockfall Mitigation)	Access Road required? None Other:
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Benching with vegetation including trees	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
5/15/2020	Vegetated benches in cut	4768	View to north
5/15/2020	South end of cut	4769	View to east
5/15/2020	Cobbles at base of cut	4765	View to northwest
5/15/2020	Cobbles in ditch	4666	View to southeast

ROCK SLOPE CHARACTERIZATION

Highway: US 36 **MP:** 7.8 **to** 7.9 Travel direction closest to cut: NB SB EB (WB) **Date:** 5/15/2020

Vegetated benches in cut, view to north

South end of cut, view to east

Cobbles at base of cut, view to northwest

Cobbles in ditch, view to southeast

Return A16

ROCK SLOPE CHARACTERIZATION

Highway: US 36 **MP:** 10.9 **to** 11.5 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/16/2019

SLOPE PROFILE

Height (ft)	estimated 15 to 40					
Length (ft)	3150					
Inclination and Direction	70 to 85 degrees facing 170 to 290 degrees, generally moving north to south					
Offset from highway (ft)	*Width of Shoulder*: 6 paved			*Width of Ditch*: 7 to 16; behind guardrail		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 WB/1 SB	**AADT:** 7800

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 3150 ft=48 seconds*

Travel direction #1 =0.9 mi= 72 sec	Travel direction #2=0.76 mi=61 sec
NB SB EB (WB)	NB SB (EB) WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use	Rocky Mtn Natl Pk W. side of NW end and N. side of SE end segment; other areas private unimproved land	**Static viewer?** House and pullout SSW of cut on W end

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	Other description (mixed, etc.):	
Formation name	Silver Plume Granite			**Outcrop description:** granite, as named	

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	(Adverse)	(Adverse)	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed, or open less than 2 in. ~~closed, clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered	**Structural Condition**	~~Few differential horizontal erosion features < 10%~~	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	~~Major horizontal erosion features > 80%~~	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	~~Extreme difference > 5 ft~~	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Light pink in cuts; outcrops appear gray-green	More angular than natural outcrops	Few rocks in ditch; occasional boulder up to 3-foot diameter	

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required? / Other:
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Presplitting blasting in taller portions of cut and cushion blasting in lower portion. Ripping used in softer bedrock. ROW limited slope rounding in upper cut	

PHOTO LOG

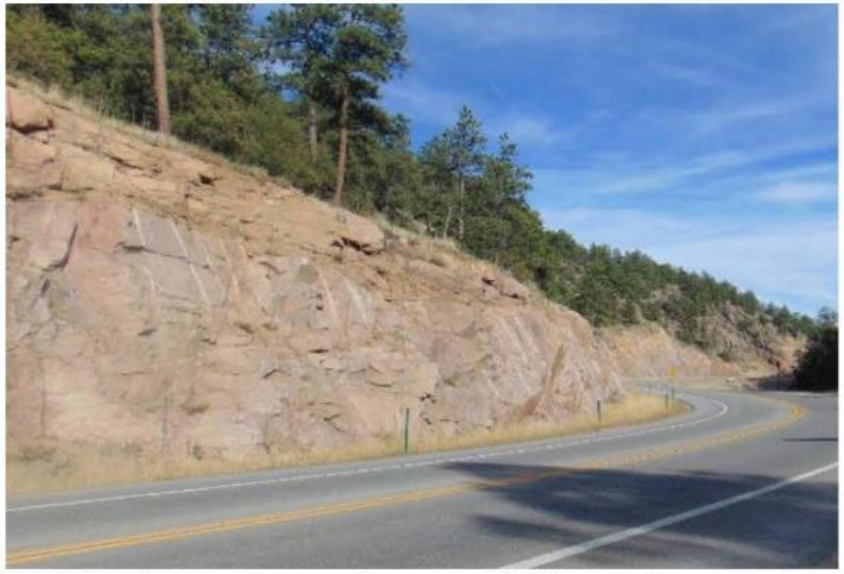
Date	*Description*	*Photo No.*	*Discussion*
10/16/2019	Westbound viewshed	1132	Cut around curve left (west) of drainage
10/16/2019	Eastbound viewshed	1080	Cut in center distance
10/16/2019	View to east	1089	Cut continues on north side around curves
10/16/2019	View to east-northeast	1101	Natural granite outcrops in middle area of cut length

ROCK SLOPE CHARACTERIZATION

Highway: US 36 MP: 10.9 to 11.5 Travel direction closest to cut: NB SB EB (WB) Date: 10/16/2019

Westbound viewshed, cut around curve left (west) of drainage

Eastbound viewshed, cut in center distance



View to east, cut continues on north side around curves

View to northeast, natural outcrops in middle area of cut length

Return A16

ROCK SLOPE CHARACTERIZATION

Highway: US 40 **MP:** 244.5 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 10/2/2019

SLOPE PROFILE

Height (ft)	Estimated 140 ft? (Clear Creek Co. map, 10 ft contours, 11,120 top and 10,980 bottom)				
Length (ft)	476				
Inclination and Direction	50 degrees facing 206 degrees north end; 75 degrees facing 216 degrees south end				
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*	
	12 paved			2 to 3 (filled)	
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 EB/2 WB	**AADT:** 4900	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 476 ft=7 seconds;* ***EB has two views***		
Travel dir #1 =0.15+0.1 mi= 12+8 sec		Travel direction #2=0.2 mi=18 sec	
NB SB (EB) WB		NB SB EB (WB)	
(Foreground/Short Range: to 0.5 mi		(Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Cut area CDOT property; adjacent property to north US Forest Service	**Static viewer?** Possible bicyclists	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	(Metamorphic)	**Other description (mixed, etc.):**		
Formation name	Silver Plume Granite			**Outcrop description:** Gneiss and granite		
CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
	Favorable	Random		(Adverse-gneiss)	(Adverse-granite)	
				1 to 2 feet spacing	3 to 5 feet spacing	
CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	(Rough, irregular)	Undulating, smooth		Planar	Fracture gap-open/closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
CASE 2- Sedimentary, or layered: **Difference in erosion**	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	similar	similar, scree match	Rockfall debris filling in behind jersey barriers	No ditch behind barrier. Space between barriers at edge of shoulder and cut is approximately 2 to 3 feet.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required? / Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting and production blasting methods. Excavator removed loose material and pulled back rock to natural seams in bedrock. Slope was heavily rounded for eroded appearance to match surrounding landscape.	

PHOTO LOG

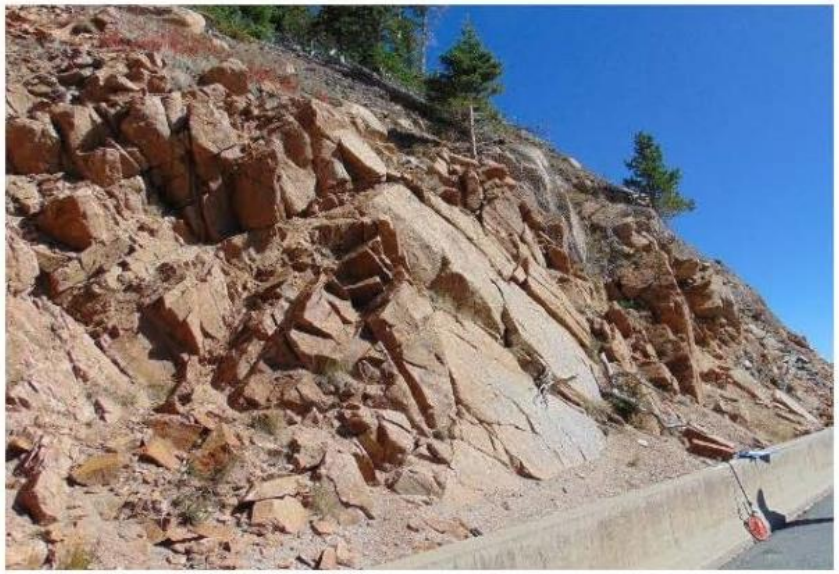
Date	*Description*	*Photo No.*	*Discussion*
10/2/2019	Eastbound view	180	View to west-northwest
10/2/2019	Westbound view	175	View to east-northeast
10/2/2019	Joint planes and fractures	173	Slabs of rock fallen from under mesh; roots wedging rocks; tree fallen on mesh
10/2/2019	Rock filling behind barrier	178	Rock spilling onto roadway

ROCK SLOPE CHARACTERIZATION

Highway: US 40 **MP:** 244.5 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 10/2/2019

Eastbound view

Westbound view



Joint planes and fractures

Rock filling behind barrier

Return A16

ROCK SLOPE CHARACTERIZATION

Highway: US 40 **MP:** 248.8 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/2/2019

SLOPE PROFILE	**Height (ft)**	Estimated 50 (Clear Creek County 2 ft contours 9910 top and ~9856 bottom)					**SETTING**	**Posted speed (mph):** 45	**Number of travel lanes:** 1SB/2NB	**AADT:** 7500
	Length (ft)	315						**Visibility** *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 315 ft=5 seconds*		
	Inclination and Direction	45 degrees facing 160 degrees						Travel direction #1=0.3 mi=23 sec NB SB EB (WB)		Travel direction #2 = 0.15 mi=11 sec NB SB (EB) WB
	Offset from highway (ft)	*Width of Shoulder* 9			*Width of Ditch* 9			(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity		(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity
	Surface Variation (ft)	0.5 to 1	1 to 2	(some 2 to 5)	5+	Other:		**Adjacent land use**	US 40 ROW, unimproved, trees on slopes surrounding cut; private residences south of and below cut	**Static viewer?** View from intersection CR 202(Jones Pass Rd), stop sign to NNE to cut
GEOLOGIC CHARACTERISTICS	**Rock type**	Sedimentary		(Igneous)		(Metamorphic)		**Other description (mixed, etc.):**		
	Formation name	Silver Plume Granite and metamorphic rocks						**Outcrop description:** As named, Precambrian age granite, gneiss and migmatite		
	CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet* Favorable			Random			(Adverse-foliated rock crumbles) Spacing 1 to 2 ft	*Continuous Fractures Orientation* (Adverse) Spacing at 2 to 5 feet-granite	
	CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	(Rough, irregular)			Undulating, smooth			Planar	(Fracture gap-open less than 0.5 ft, closed, clay, gouge infilling, or slickensided)	
	CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%			Occasional horizontal erosion features 10 to 40%			Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and Direction:
	CASE 2- Sedimentary, or layered: **Difference in erosion**	Small difference 6 to 12 inches			Moderate difference 1 to 2 ft			Large difference 2 to 5 ft	Extreme difference > 5 ft	
Climate and Presence of Water on Slope		Low to moderate precipitation; no freezing periods; no water on slope			Moderate precipitation OR short freezing periods, OR intermittent water on slope			(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods	
Compatibility with Nearby Slopes (describe)		*Color*		*Texture*		*Stability*		*Other Visual Differences*		
		Appears similar; granitic rocks lighter than natural		Bare scree, soil cover		Few rocks in ditch area		Some fallen trees across slope		
CONSTRUCTION	**Features**	Half-casts (blasting)		Machine marks (excavation-machine blade/tooth)		Rock anchors		Rockfall Mitigation	Access Road required?	Other: No blast marks or rockfall mitigation seen
	Excavation method	(Blasting)		Breaking		(Ripping)		Other: Cushion blasting and production blasting methods. Excavator removed loose material and pulled back rock to natural seams in bedrock. Slope was heavily rounded for eroded appearance to match surrounding landscape.		

PHOTO LOG	*Date*	*Description*	*Photo No.*	*Discussion*
	10/2/2019	View to west	195	View of cut looking west
	10/2/2019	View to east	198	View of cut looking east
	10/2/2019	Angular rock debris look east	197	Scree, angular rock debris on slope and at shoulder
	10/2/2019	Soil cover look west	196	Soil cover above cut with angular rock debris at shoulder

ROCK SLOPE CHARACTERIZATION

Highway: US 40 **MP:** 248.8 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/2/2019

Eastbound View

Westbound view

Angular rock debris (scree) on slope and at shoulder, looking east

Soil cover and angular debris at shoulder, looking west

Return A16

ROCK SLOPE CHARACTERIZATION

Highway: US 50 **MP:** 56 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 11/19/2019

SLOPE PROFILE

Height (ft)	Estimated 60				**Posted speed (mph):** 65	**Number of travel lanes:** 2EB/2WB	**AADT:** 10,000
Length (ft)	700				**Visibility**	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 700 ft=7 seconds*	
Inclination and Direction	At east end,75 degrees facing 212 degrees; at west end, 75 degrees facing 230 degrees				Travel direction #1=0.26 mi=14 sec		Travel direction #2 = 0.2 mi=12 sec
					NB SB EB (WB)		NB SB (EB) WB
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity		Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity
	9 to 10		13				
Surface Variation (ft)	0.5 to 1	(1 to 2)	(few 2 to 5)	5+ Other:	**Adjacent land use**	BLM land; across highway, SW of cut is Dominguez-Escalante Natl Conservation Area	**Static viewer?** Possible view from nearby trails-autos, bicycles, hikers

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):** Gravel mapped above cut		
Formation name	Mancos Shale			**Outcrop description:** Shale interlayered with sandstone; some carboniferous (coal) and gypsum		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: 08 at 233
	Difference in erosion	Small difference 6 to 12 inches	(Moderate difference 1 to 2 ft)	(Few areas with large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	similar	similar	Few rocks in ditch area	

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Ripping used in soft rock layers. Limited blasting followed by machine scaling in harder layers. Draped mesh to reduce rockfall hazard.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
11/19/2019	Westbound viewshed	1481	Westbound view on approach
11/19/2019	Eastbound viewshed	1505	Eastbound view on approach
11/19/2019	View to east-northeast	1515	View of cut on curve
11/19/2019	Draped mesh	1484	Draped mesh with carboniferous (coal) layer; gypsum present

ROCK SLOPE CHARACTERIZATION

Highway: US 50 **MP:** 56 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 11/19/2019

Westbound viewshed, looking northeast

Eastbound viewshed, looking southeast

View to east-northeast

Draped mesh and soft carboniferous (coal) layer

Return A17

ROCK SLOPE CHARACTERIZATION

Highway: US 50-east of truck ramp **MP:** 194.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/7/2019

SLOPE PROFILE

Height (ft)	estimated 30 to 40					
Length (ft)	315					
Inclination and Direction	65 to 70 degrees facing 150 to 155 degrees					
Offset from highway (ft)	*Width of Shoulder*: None			*Width of Ditch*: 4 to 10		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 2 EB/1 WB	**AADT:** 2,600
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 315 ft=5 seconds*		
Travel direction #1=0.1 mi=7 sec — NB SB EB (WB)	Travel direction #2 = 0.23 mi=18 sec — NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	Background: to 5 mi to infinity	
Adjacent land use: Vacant U.S. Forest Service land surrounds cut area		**Static viewer?** None noted

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	(Metamorphic)	**Other description (mixed, etc.):** Some areas with biotite; colluvial cover at top		
Formation name	Porphyritic Gneissic Granite			**Outcrop description:** As named, Precambrian age, intruded by finer grained granite		
CASE 1- Crystalline, jointed rock — **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*: Favorable	Random	Adverse	*Continuous Fractures Orientation*: Adverse		
				(Fracture spacing 2 to 5 ft)		
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	(Fracture gap-closed to open up to 0.5 ft)		
CASE 2- Sedimentary, or layered — **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:	
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft		

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	High precipitation OR long freezing periods OR continual water on slope	(High precipitation AND long freezing periods, OR continual water on slope and long freezing periods)
Compatibility with Nearby Slopes (describe)	*Color*: Lighter than nearby natural outcrops	*Texture*: More angular than natural outcrops	*Stability*: Few rocks in ditch area	*Other Visual Differences*

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No blast marks or mitigation seen
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion and production blasting methods with excavator sculpting rock face to natural rock structures forming benches and roundting top of cut		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/7/2019	Westbound viewshed	553	Westbound view, looking southwest
10/7/2019	Eastbound viewshed	582	Eastbound view, right of sign, looking northeast
10/7/2019	Rough, irregular cut	586	Vegetation growing in benches, emergency truck ramp on left (west)
10/7/2019	View to northeast of cut	589	Cut east of emergency truck ramp

ROCK SLOPE CHARACTERIZATION

Highway: US 50-east of truck ramp **MP:** 194.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/7/2019

Westbound viewshed, looking southwest

Eastbound viewshed, right of sign, looking northeast

View to southwest, benches with vegetation, emergency truck ramp onleft

View to northeast, cut east of emergency truck ramp

Return A17

ROCK SLOPE CHARACTERIZATION

Highway: US 50-at truck ramp **MP:** 194.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/7/2019

SLOPE PROFILE

Height (ft)	estimated 60					
Length (ft)	540					
Inclination and Direction	50 to 75 degrees facing 150 to 155 degrees					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	Runaway truck ramp with barrier parallel to cut			12 ft behind barrier		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 2 EB/1 WB	**AADT:** 2,600

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 540 ft=8 seconds*

Travel direction #1=0.16 mi=13 sec	Travel direction #2 = 0.4 mi=32 sec
NB SB EB (WB)	NB SB (EB) WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use	Vacant U.S. Forest Service land surrounds cut area	**Static viewer?** None noted

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	(Metamorphic)	**Other description (mixed, etc.):** Some areas with biotite; colluvial cover at top	
Formation name	Porphyritic Gneissic Granite			**Outcrop description:** As named, Precambrian age, intruded by finer grained granite	

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse Fracture spacing 2 to 5 ft
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-closed to open up to 0.5 ft
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft

Dip and direction:

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	High precipitation OR long freezing periods OR continual water on slope	(High precipitation AND long freezing periods, OR continual water on slope and long freezing periods)

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Lighter than nearby natural outcrops	More angular than natural outcrops	Many rocks in ditch area between barrier and cut.	Some rocks on barrier.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	Rockfall Mitigation	Access Road required?	Other: At least 5 failed bolts with rock loss; possible water in joint and/or freeze/thaw
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion and production blasting methods with excavator sculpting rock face to natural rock structures forming benches and rounding top of cut		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/7/2019	Westbound viewshed	554	Westbound view to east-southeast
10/7/2019	Eastbound viewshed	593	Eastbound approaching curve, view to north-northwest
10/7/2019	Rocks behind and on barrier	563	Fractured rock on slope, loose rocks behind and on barrier
10/7/2019	Failed bolts	559	Failed bolts in weathered joint area

ROCK SLOPE CHARACTERIZATION

Highway: US 50-at truck ramp **MP:** 194.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/7/2019

Westbound viewshed, view to west-southwest

Eastbound viewshed on approach curve, view to north-northwest

Fractured rock and loose rock on slope and behind barrier,view to east-northeast

Failed rock bolts at right side photo, view to west-southwest

Return A17

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 50 **MP:** 258 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 4/12/2021

SLOPE PROFILE

Height (ft)	estimated 60				
Width (ft)	820				
Inclination and Direction	45 to 60 degrees facing 310 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	8 paved		8 to 25		
Surface Variation (ft)	0.5 to 1	1 to 2	2 to 5	(5+)	Other:

SETTING

Posted speed (mph): 50	**Number of travel lanes:** 2 WB/2 EB	**AADT:** 2700	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 820 ft=11 seconds,*		
Travel direction #1=0.19 mi=14 sec		Travel direction #2 = 0.18 mi=13 sec	
NB SB (EB) WB		NB SB EB (WB)	
(Foreground/Short Range: to 0.5 mi)		(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Unimproved BLM land on both sides of Arkansas River and US 50	**Static viewer?** Pinnacle Rock parking area opposite cut and recreational users of Arkansas River	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):**		
Formation name	Gneiss			**Outcrop description:** Felsic and hornblende gneisses, separate and layered		
CASE 1- Crystalline, jointed rock	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
Structural Condition with fracture spacing	Favorable	Random		(Adverse)	Adverse	
					spaced 6 in. vertical; up to 5 ft ~45 degrees	
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth		Planar	Fracture gap-open 1 to 6 inches, vertical and ~45 degrees toward road	
CASE 2- sedimentary, or layered						Dip and direction:
Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods or continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Similar	Loose rock on slopes N and S of cut;	Railroad tie structure at south end of cut with drains near base is a timber-faced soil nail wall built to protect an archeological site.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No construction features noted.
Excavation method	(Blasting)	Breaking	Ripping	Other: Majority of rock was excavated using cushion blasting methods. Loose and blasted material was removed to natural joints. Continous, unfavorable fractures were rock bolted for stability.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
4/12/2021	Eastbound view	94820	looking northeast
4/12/2021	Westbound view	94642	looking south-southeast, rock bolts, rock face tilt toward road
4/12/2021	Structure east end of cut	94808	looking south-southwest

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 50 **MP:** 258 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 4/12/2021

Eastbound View, looking northeast

Westbound View, looking south-southeast at rock bolts, tilted rock

Structure east end of cut, looking south-southwest

Return A17

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 50 **MP:** 259.7 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 4/2/2021

SLOPE PROFILE

Height (ft)	estimated 60
Width (ft)	1009 (includes 470 ft of slope at east end of cut, then estimated 200 ft of cut continues to east)
Inclination and Direction	85 to 100 (overhang) degrees facing 20 degrees
Offset from highway (ft)	*Width of Shoulder*: 8 paved; *Width of Ditch*: 8 to 25
Surface Variation (ft)	0.5 to 1 / 1 to 2 / 2 to 5 / (5+) / Other:

SETTING

Posted speed (mph): 50	**Number of travel lanes:** 1 WB/1 EB	**AADT:** 2700
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 820 ft=14 seconds,*	
Travel direction #1=0.27 mi=19 sec: NB SB (EB) WB	Travel direction #2 = 0.26 mi=19 sec: NB SB EB (WB)	
Foreground/Short Range: to 0.5 mi	Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity	Background: to 5 mi to infinity	
Adjacent land use: Unimproved BLM land on both sides of Arkansas River and US 50	**Static viewer?** Salt Lick overlook at W end of cut; Five Points Campground at E end of cut; recreational users of Arkansas River	

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary / Igneous / (Metamorphic) **Other description (mixed, etc.):**

Formation name: Gneiss **Outcrop description:** Felsic and hornblende gneisses, separate and layered

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	(Adverse)	Adverse	
					up to 5 ft various directions	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-open 1 to 6 inches, nearly vertical intersecting and away from road	
CASE 2- sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods or continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Similar	*Texture*: Similar	*Stability*: Loose rock on and in ditch, up to boulder size	*Other Visual Differences*

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No construction features noted.
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Harder rock types were excavated using cushion blasting methods. Loose and blasted material was removed to natural joints. Softer material was removed with and excavator and dozer with a ripper.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
4/12/2021	Eastbound view	93757	Looking southeast at east end of cut
4/12/2021	Westbound view	93803	Looking west, rocks piling at bottom of cut
4/12/2021	Loose rock on slope, boulder in ditch	93906	Looking south
4/12/2021	Layered gneiss rock	93639	Looking east-southeast at east end of cut

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 50 **MP:** 259.7 **to** _____ **Travel direction closest to cut:** NB SB (EB) WB **Date:** 4/2/2021

Eastbound View, looking southeast at east end of cut

Westbound view, looking west, rocks piling at bottom of cut

View to east-southeast at east end of cut, layered gneiss rock

Looking south at loose rock on slope, boulder in ditch

Return A17

ROCK SLOPE CHARACTERIZATION

Highway: US 160 **MP:** 79.1 **to** 79.3 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/9/2019

SLOPE PROFILE

Height (ft)	estimated 60 to 90					
Length (ft)	1200					
Inclination and Direction	45 to 90 degrees facing 155 to 220 degrees (outside of curve)					
Offset from highway (ft)	*Width of Shoulder*: 4 paved			*Width of Ditch*: 0 to 8		
Surface Variation (ft)	0.5 to 1	(1 to 2)	(2 to 5)	5+	Other:	

SETTING

Posted speed (mph): 65	**Number of travel lanes:** 2 WB/ 1 EB	**AADT:** 9,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1200 ft=13 seconds*	
Travel direction #1=0.3 mi=17 sec — NB SB EB (WB)	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Travel direction #2 = 0.44 mi=24 sec — NB SB (EB) WB	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use	Residential or private, unimproved land south of cut, and north of cut on west half; north of cut east half unimproved land owned by State of Colorado	**Static viewer?** Residental south of cut across US 160; driveway intersects US 160 across from cut

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):** Massive sandstone beds above cut		
Formation name	Lower Point Lookout Sandstone of Mesaverde Group		**Outcrop description:** Thin sandstone, siltstone and shale beds			

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: ~ 05-10 degrees to N and NW
	Difference in erosion	Small difference 6 to 12 inches	(Moderate difference 1 to 2 ft)	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Gray; similar to natural outcrops	More angular than natural outcrops	Erosional debris fans at base of cut; ditch area filled with sediment, rocks	Nearby slopes are wooded. Lack of vegetation on cut with oversteepened slopes differs from natural rounded slopes of shale.

CONSTRUCTION

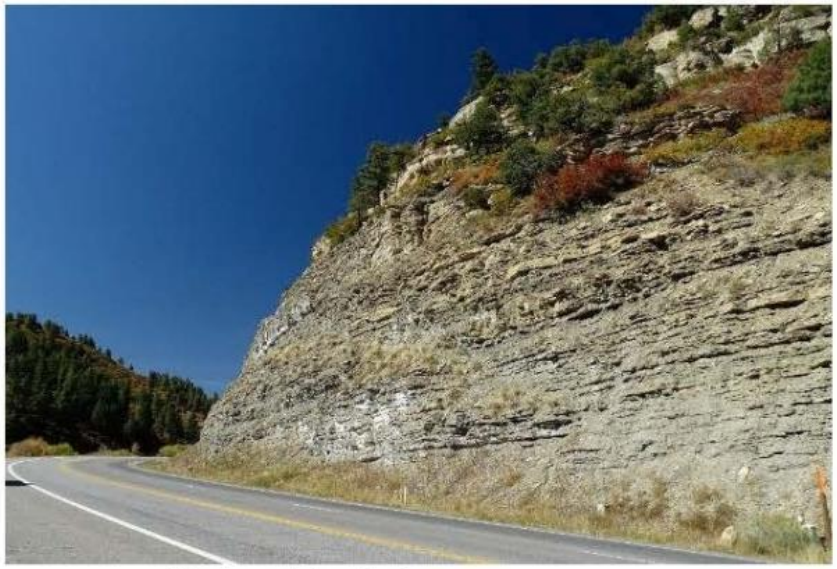
Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: None seen
Excavation method	Blasting	Breaking	(Ripping)	Other: Ripping used to reshape rock face during ditch widening. Limited ROW restricted access at top of cut.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/9/2019	Westbound viewshed	DSC00047	Westbound view, looking west
10/9/2019	Eastbound viewshed	DSC00037	Eastbound view, looking east
10/9/2019	Rock and sediment debris base of cut, look E	DSC00039	Erosional debris fans and ditch area filled with sediment and rocks
10/9/2019	Sandstone undercut by shale	DSC00045	Debris fans at base of cut; sandstone ledges above shale, looking NW

ROCK SLOPE CHARACTERIZATION

Highway: US 160 **MP:** 79.1 **to** 79.3 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/9/2019



Westbound viewshed

Eastbound viewshed

Rock and sediment debris at base of slope

Debris fans at base; sandstone undercut by shale

Return A18

ROCK SLOPE CHARACTERIZATION

Highway: US 160 **MP:** 174 **to** 174.5 **Travel direction closest to cut:** NB SB (EB) WB **Date:** 10/14/2019

SLOPE PROFILE

Height (ft)	estimated 80 to 100				
Length (ft)	2,890, includes 1,055 ft tunnel on EB lanes				
Inclination and Direction	80 to 90 degrees facing 235 to 270 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	12		12		
Surface Variation (ft)	(0.5 to 1)	1 to 2	2 to 5	5+	Other:

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 1 EB, 1WB	**AADT:** 3000	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 2,890 ft=44 seconds*		
Travel direction #1=0.77 mi=62 sec		Travel direction #2 = 0.72 mi=57 sec	
NB SB (EB) WB		NB SB EB (WB)	
(Foreground/Short Range: to 0.5 mi)		(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Forest Service land surrounds rock cut area; Big Meadows Rec area	**Static viewer?** Possibly fishing on Pass Creek west side of US 160/cut;	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	**Other description (mixed, etc.):**		
Formation name	Fish Canyon Tuff			**Outcrop description:** Tertiary age biotite-hornblende quartz latite ash-flow tuff		
CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
	Favorable	Random		(Adverse)	Adverse	
					Fracture spacing 1 to 5 ft	
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth		Planar	Some isolated fault gouge zones; Fracture gap-closed to open up to 0.5 ft	
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	High precipitation OR long freezing periods OR continual water on slope	(High precipitation AND long freezing periods, OR continual water on slope and long freezing periods)
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Cuts are stained and match natural; shotcrete and rock mesh too gray	Rough texture-native areas have rounded tops;shotcrete smooth	Some rocks in ditch up to 3 ft diameter and road side of barrier	Draped mesh is gray and very visible; shotcrete gray and smoother than cuts or natural with fractures and efflorescence on concrete surface; pattern on shotcrete doesn't match surface pattern of the surrounding rock

CONSTRUCTION

Features	(Half-casts (blasting) at tunnel)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required? No	Other: Draped mesh; half casts in most cut areas removed by chipping post blast
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplitting and limited cushion blasting using natural vertical fractures to control overbreak. Glacial till overburden anchored using soil nails and rock bolts covered with shotcrete. Slope covered with brown colored drape mesh.		

PHOTO LOG

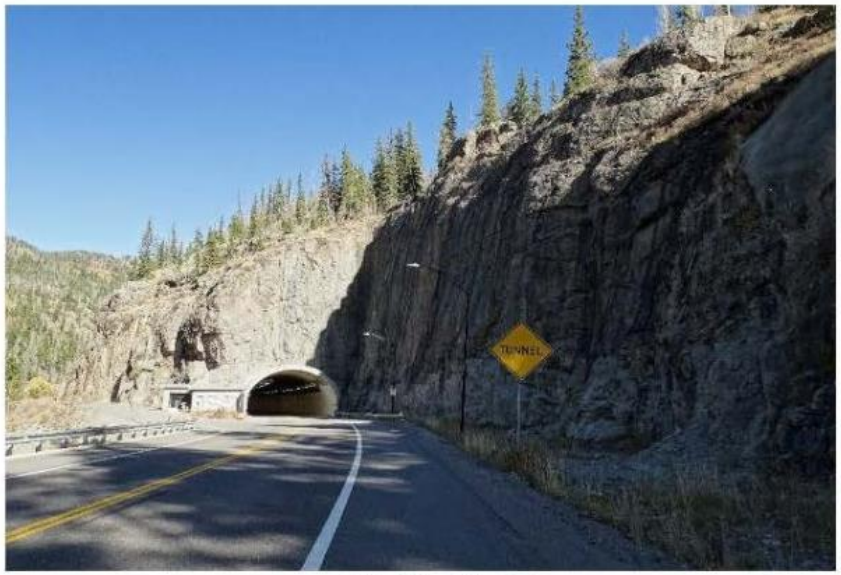
Date	*Description*	*Photo No.*	*Discussion*
10/14/2019	Eastbound view	DSC00081	Eastbound view rock cut and tunnel
10/14/2019	Westbound view	DSC00091	Westbound view rock cut and tunnel, mesh, anchors; rocks in ditch
10/14/2020	West Portal, mesh	DSC00084c	West portal, rock mesh and fracture pattern in rock
10/14/2020	Shotcrete	DSC00088	South of tunnel, shotcrete with efflorescence

ROCK SLOPE CHARACTERIZATION

Highway: US 160 **MP:** 174 **to** 174.5 **Travel direction closest to cut:** NB SB (EB) WB **Date:** 10/14/2019

Eastbound Viewshed

Westbound viewshed, rock cut with mesh and anchors; rocks in ditch



West Portal mesh

Shotcrete south of west portal

Return A18

ROCK SLOPE CHARACTERIZATION

Highway: US 160 **MP:** 180.2 **to** 181.2 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/14/2019

SLOPE PROFILE

Height (ft)	estimated 40 to 50				
Length (ft)	5,230; and ~750 ft of road cut in center continues along Forest Service Rd 433 that parallels and is above US 160, and ~620 ft of width is soil/gravel slope				
Inclination and Direction	70 degrees to nearly vertical, facing 145 to 165 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	6 to 10 paved		6 to 10		
Surface Variation (ft)	(0.5 to 1)	(1 to 2)	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 50	**No. of travel lanes:** 1EB, 1WB each with turn lanes	**AADT:** 2900

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 5230 ft=72 seconds*

Travel direction #1=1.07 mi=77 sec	Travel direction #2 = 1.02 mi= 74 sec
NB SB EB (WB)	NB SB (EB) WB
Foreground/Short Range: to 0.5 mi	Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use	Forest Service land adjacent to cut on west side and FS campground across from cut to east; private resorts at N and S ends east of cut.	**Static viewer?** At each end of cut, private resorts on east side US 160,west of South Fork Rio Grande-campers, cyclists, fishing

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	**Other description (mixed, etc.):**	
Formation name	Fish Canyon Tuff			**Outcrop description:** Tertiary age biotite-hornblende quartz latite ash-flow tuff	

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		(Favorable)	Random	(Adverse)	(Adverse)	
					Fracture spacing 1 to 5 ft	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	(Planar)	Some isolated fault gouge zones; Fracture gap-closed to open up to 0.5 ft	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	High precipitation OR long freezing periods OR continual water on slope	(High precipitation AND long freezing periods, OR continual water on slope and long freezing periods)

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Slightly lighter than native	Smoother face and more vertical in cut than native	Few rocks in ditch area	Blasting followed vertical joints; included variation in ditch width. Natural slopes have more terraces. Shotcrete in upper wall and above FS Rd 433 gray-similar to native.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh is darker than cut; rock face stain is good match; shotcrete with drainage
Excavation method	(Blasting)	(Breaking-to remove half casts)	Ripping	Other: Presplitting blasting in upper cut and cushion blasting in lower cut, use of natural vertical fractures to control overbreak. Glacial till overburden anchored using soil nails and rock bolts covered with shotcrete. Covered with brown color mesh.		

PHOTO LOG

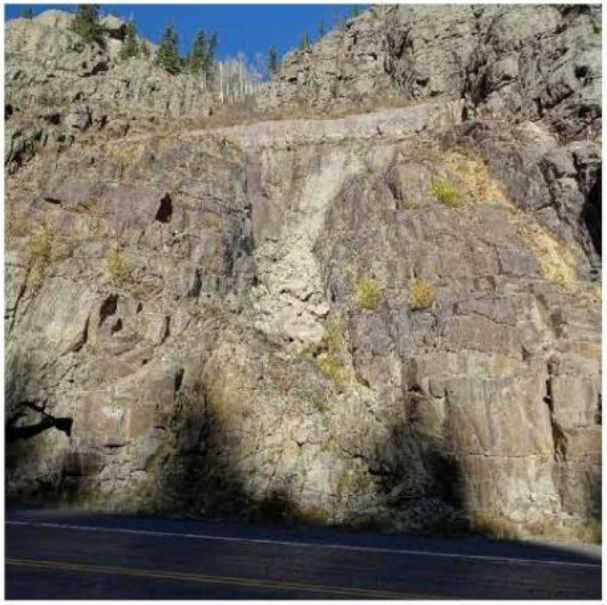
Date	*Description*	*Photo No.*	*Discussion*
10/14/2019	WB viewshed	DSC00132	WB viewshed
10/14/2019	EB viewshed	DSC00112	EB viewshed, cut on left side (NNW) US 160
10/14/2019	Shotcrete wall, drainage and mesh	DSC00102	Shotcrete wall above cut with drainage, mesh and anchors
10/14/2019	Cut face with mesh	DSC00120	Nearly vertical cut face with mess and anchors

ROCK SLOPE CHARACTERIZATION

Highway: US 160 **MP:** 180.2 **to** 181.2 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/14/2019

Eastbound viewshed

Westbound viewshed



Shotcrete wall, drainage and mesh

Cut face with mesh

Return A18

ROCK SLOPE CHARACTERIZATION

Highway: US 285 **MP:** 231 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

SLOPE PROFILE

Height (ft)	estimated 70 to 90				
Length (ft)	1160				
Inclination and Direction	W. end-68 degrees facing 168 degrees; middle-63 degrees at 152; E. end- 73 degrees at 120				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	2 to 16		3 to 19		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 55 WB has exit	**Number of travel lanes:** 2EB/1WB	**AADT:** 18,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1160 ft=14 seconds*	
Travel direction #1=0.3 mi=20 sec — NB SB EB (WB)	Travel direction #2 = 0.85 mi=56 sec — NB SB (EB) WB	
Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use	Private, unimproved land north of cut; industrial buildings and residence south and west of US 285 and cut.	**Static viewer?** View from house and industrial buildings south and west of cut; intersection for Elk Creek Rd with stop sign; exit ramps with slow traffic

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):**		
Formation name	Migmatitic Biotite Gneiss			**Outcrop description:** Precambrian age, metamorphic layering (foliation),lenses granitic gneiss		
CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
	Favorable	(Random)		(Adverse-in foliated rock)	Adverse	
		Fracture spacing follows foliation planes 0.5 to 1 ft				
CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	(Rough, irregular)	Undulating, smooth		Planar	(Fracture gap-open up to 0.5 ft)	
CASE 2- Sedimentary, or layered: **Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
CASE 2- Sedimentary, or layered: **Difference in erosion**	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Mesh color blends well	Granitic rocks generally lighter than native	Many cobble to boulder-size rocks in ditch and on shoulder	Cobble to boulder size rocks loose on slope and caught under mesh

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh; large fir trees on top of cut
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Presplitting blasting with excavated slope rounding to reduce erosion of less resistive rock; wire mesh cover		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/3/2019	Westbound viewshed	DSC00279	View looking west
10/3/2019	Eastbound viewshed	DSC00267	View from EB lanes
10/3/2019	Mesh on west end of cut	DSC00281	Looking north
10/3/2019	Rocks at base of cut slope	DSC00295	Rock debris up to boulder size

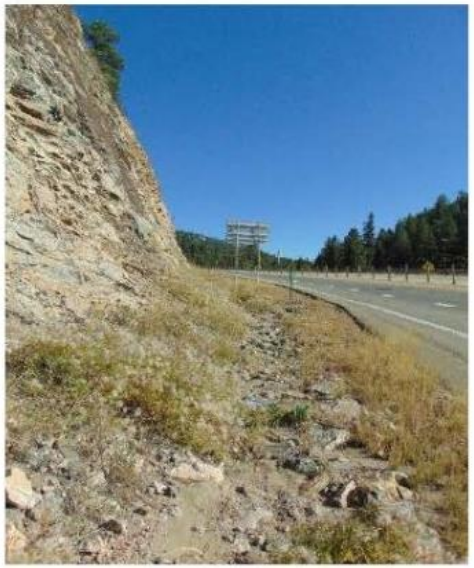
ROCK SLOPE CHARACTERIZATION

Highway: US 285 **MP:** 231 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

Westbound viewshed

Eastbound viewshed

Mesh on west end of cut



Rocks at base of cut slope

Return A18

ROCK SLOPE CHARACTERIZATION

Highway: US 285 **MP:** 233.0 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

SLOPE PROFILE

Height (ft)	estimated 35				
Length (ft)	700				
Inclination and Direction	West-55 degrees facing 154 degrees; middle-59 at 150; east-60 at 154				
Offset from highway (ft)	*Width of Shoulder*: 9 to 17; unpaved west to paved at east			*Width of Ditch*: 10 to 17	
Surface Variation (ft)	0.5 to 1	1 to 2	2 to 5	(5+)	Other:

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 1WB, 2EB	**AADT:** 17,000
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 700 ft=9 seconds*		
Travel direction #1=0.3 mi=20 sec — NB SB EB (WB)		Travel direction #2 = 0.4 mi=28 sec — NB SB (EB) WB
Foreground/Short Range: to 0.5 mi		Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity		Background: to 5 mi to infinity
Adjacent land use: Private, residential property north of cut; south of cut and US 285 owned by Jefferson County		**Static viewer?** Possible view from houses to SE; driveway intersects US 285 at east end of cut

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	(Metamorphic)	**Other description (mixed, etc.):**
Formation name	Silver Plume Granite	**Outcrop description:** Precambrian age, foliated, with inclusions of biotite schist		

CASE 1-Crystalline, jointed rock

Structural Condition with fracture spacing	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*
	Favorable	(Random-in foliated rock)	Adverse	Adverse
				2 to 5 ft fracture spacing-granite
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-open less than 0.5 ft, with one space open 4 ft diameter; foliation plane tilts toward roadway

CASE 2-Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittentwater on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to nearby cuts-no native outcrops in area	Similar to nearby cuts-no native outcrops in area	Some cobble to boulder size rocks in ditch area	One area of natural spheroidal weathering intact

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No mitigation
Excavation method	(Blasting)	Breaking	Ripping	Other: Cushion blasting used. Rock bolts to stabilize rock blocks.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/3/2019	Westbound viewshed	330	
10/3/2019	Eastbound viewshed	312	
10/3/2019	Rock cut view to north	303	
10/3/2019	Foliation plane tilted toward roadway	314	Tilted foliation plane and intersecting fractures

ROCK SLOPE CHARACTERIZATION

Highway: US 285 MP: 233.0 to _____ Travel direction closest to cut: NB SB EB (WB) Date: 10/3/2019

Westbound viewshed

Eastbound viewshed

Cut, looking north

Foliation plane tilted toward roadway

Return A19

ROCK SLOPE CHARACTERIZATION

Highway: Cut on old US 285 parallels US 285 **MP:** 240.5 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

SLOPE PROFILE

Height (ft)	estimated 40					
Length (ft)	420 (320 granite/100 weathered granite)					
Inclination and Direction	West end-66 degrees facing 130 degrees; middle-75 at 120; east end-63 at 107					
Offset from highway (ft)	*Width of Shoulder*: None		*Width of Ditch*: 7.5 to 13			
	(Old 285, between S Brandenburger Rd and Doubleheader Rd)					
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 55 (25 on old 285)	**Number of travel lanes: 2-no lines**	**AADT:** 27,000 on US 285	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 420 ft=5 seconds on US 285*		
Travel dir #1, US 285=0.35 mi=22 sec		Travel dir #2, US285 = 0.15 mi=10 sec	
NB SB EB (WB)		NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi)		(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Private, residential land north of cut; CDOT owns parcel south of cut across US 285	**Static viewer?** Driveway SSE of cut across US 285; accel/decel lanes on US 285; Adjacent to old 285 speed 25 mph	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	**Other :** Old 285,travel view at 25 mph-420 ft=11 sec/WB-0.2 mi=27 sec/EB-0.1 mi=17 sec	
Formation name	Silver Plume Granite		**Outcrop description:** As named, Precambrian age, may have gneiss inclusions		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse	
					Fracture spacing 2 to 5 ft	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-open less than 0.5 ft	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Blasted rock appears lighter color than natural outcrops	*Texture*: More angular than natural outcrops	*Stability*: Few boulders in ditch area	*Other Visual Differences*: Weathered granite is grusified-eroded into pea gravel size fragments or larger; native rounded granite outcrops adjacent to cut

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation-shotcrete in upper area of cut bowl)	Access Road required?	Other: Rock bolts as anchors; possible leftover unblasted pipe in rock; possible failed bolt
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting used. Some blast damage during construction. Excavator developed final slope. Rock bolts to stabilize rock blocks.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/3/2019	WB viewshed Old US 285	347	
10/3/2019	EB viewshed Old US 285	333	
10/3/2019	Rockfall mitigation	338	Shotcrete upper slope bowl, rock bolts, native rounded outcrops in upper right, grus (eroded granite debris) at bottom of slope
10/3/2019	Rock cut, looking west	344	View from US 285

ROCK SLOPE CHARACTERIZATION

Highway: Cut on old US 285 parallels US 285 **MP:** 240.5 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

Westbound viewshed

Eastbound viewshed

Rockfall mitigation, shotcrete, bolts

Rock cut, looking west from SH 285

Return A19

ROCK SLOPE CHARACTERIZATION

Highway: US 285 **MP:** 240.9 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

SLOPE PROFILE / SETTING

Height (ft)	Estimated 200; 6 tiers of walls vary in height averaging between 10 and 30 feet				**Posted speed (mph):** 55	**Number of travel lanes: 2EB, 2WB** / **AADT:** 27,000
Length (ft)	5 terraces and 6 walls with longest wall approximately 875 ft				**Visibility**	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 875 ft=11 seconds*
Inclination and Direction	West end-79 degrees facing 180 degrees; east end 78 facing 120				Travel direction #1=0.18 mi=12 sec: NB SB EB (WB)	Travel direction #2 = 0.4 mi=26 sec: NB SB (EB) WB
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*	(WB) Foreground/Short Range: to 0.5 mi; Middleground/Long Range: to 3-5 mi; Background: to 5 mi to infinity	(EB) Foreground/Short Range: to 0.5 mi; Middleground/Long Range: to 3-5 mi; Background: to 5 mi to infinity
	13			18 to 29		
Surface Variation (ft)	(0.5 to 1)	1 to 2	2 to 5	5+	Other: terraces 5-10 ft deep	
Adjacent land use	CDOT ROW north of and above cut; private, unimproved area of acreage above east end of cut; private residential south of cut and US 285				**Static viewer?** Private driveway faces cut on south side US 285;possible view from houses on south side below US 285.	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	(Metamorphic)	**Other description (mixed, etc.):** Granite xenoliths/float in migmatite		
Formation name	Silver Plume Granite and migmatite			**Outcrop description:** As described,Precambrian age, foliated schist and gneiss migmatite		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet- **NO NATURAL ROCK-COVERED***			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse-adjacent natural rock intersection joints	
	Rock Friction/ Surface Variations	Rough, irregular	(Undulating, smooth)	Planar	COVERED, fracture gaps not seen	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Similar to adjacent natural outcrops, but more pink	Smoother and flatter than natural outcrops	Good-no missing rocks in face of cut	Small rocks placed in face of cut create smoother surface than rounded, massive, natural outcrops. Terraces have grass cover, one shrub; surrounding natural outcrop has large fir trees. 4 to 5 ft diameter migmatite boulders s. of US 285 may be from cut

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required?	Other: Facing with rocks 3-20 in. diameter in shotcrete; concrete support pillars near top of cut. Power lines cross top of cut
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting with spot rock bolting as rock was removed. Shotcrete applied to entire slope. Cultured stone installed as facing. Chain link fence at top of cut area. Power lines cross top of cut.		

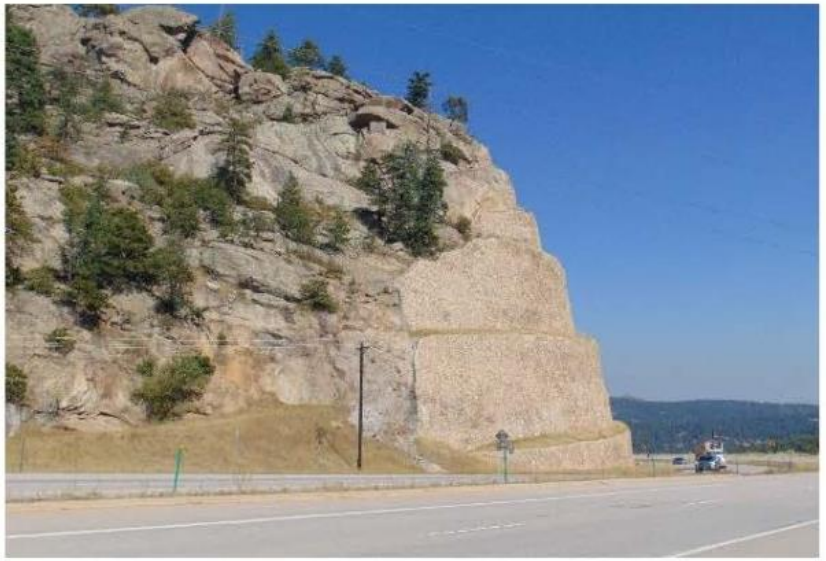
PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/3/2019	Westbound viewshed	352	
10/3/2019	Eastbound viewshed	380	Native granite outcrop behind cut facing
10/3/2019	Cut area with terraces and rock facing	355	Looking to northwest
10/3/2019	Concrete pillar at top of cut	377	East side of cut below chain link fencing; shotcrete on face

ROCK SLOPE CHARACTERIZATION

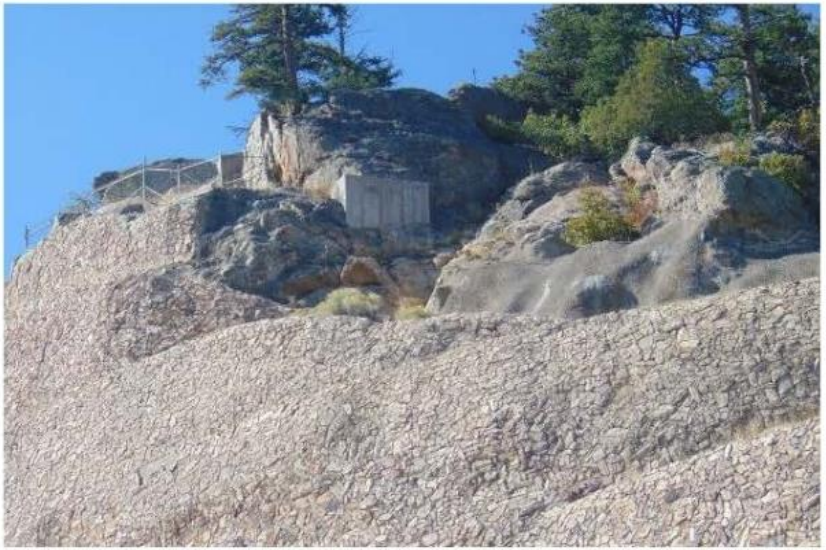
Highway: US 285 **MP:** 240.9 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

Westbound viewshed



Eastbound viewshed

Cut area with terraces and rock facing



Concrete pillar at top of cut, east side

Return A19

ROCK SLOPE CHARACTERIZATION

Highway: SH 285-west of Andrea Lane **MP:** 242.8 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

SLOPE PROFILE

Height (ft)	estimated 70
Length (ft)	1,250
Inclination and Direction	42 degrees facing 136 degrees
Offset from highway (ft)	*Width of Shoulder*: 9.5; *Width of Ditch*: 15
Surface Variation (ft)	0.5 to 1 / (1 to 2) / 2 to 5 / 5+ / Other:

SETTING

Posted speed (mph): 55	Number of travel lanes: 2 EB, 2WB	AADT: 27,000

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,250 ft=16 seconds*

Travel direction #1=0.75 mi=50 sec	Travel direction #2 = 0.55 mi=36 sec
NB SB EB (WB)	NB SB (EB) WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: N. of cut, east and west ends are residential, and middle is private, unimproved land; S. of cut and US 285 is ag/vacant land with 2 ponds

Static viewer? S. of cut, stop sign at Surrey Dr intersection with US 285 faces cut

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary / Igneous / (Metamorphic) **Other description (mixed, etc.):**

Formation name: Biotite Gneiss, with schist **Outcrop description:** As named, Precambrian age, may have pegmatite, foliated

CASE 1- Crystalline, jointed rock

Structural Condition with fracture spacing	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*
	Favorable	Random	(Adverse)	Adverse
				Fracture spacing 1 to 2 ft
Rock Friction/ Surface Variations	(Rough, irregular-under grass cover)	(to undulating, smooth)	Planar	Fracture gap-open less than 0.5 ft to closed

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittentwater on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes(describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to other slopes- no natural outcrops seen in area of cut	Similar to other slopes- no natural outcrops seen in area of cut	Minimal rocks in ditch area	Rilling/gullying in areas of increased soil cover

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required? Other: Upslope buttress wall with fencing on top at west end of cut; no blast marks or other mitigation seen
Excavation method	(Blasting-minimal)	Breaking	(Ripping)	Other: Excavator and dozer for ripping with minimal blasting in more resistive rock; upslope wall to protect trees stabilized with soil nails and rock bolts and faced with stained shotcrete.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/3/2019	Westbound viewshed	408	Looking southwest, beyond Andrea Lane sign
10/3/2019	Eastbound viewshed	386	Soil buttress wall at west end of slope cut
10/3/2019	Cut slope	396	Mix of soil and rock cut slope
10/3/2019	Rilling/gullying	411	View to NE of rilling and gullying on soil covered slope

ROCK SLOPE CHARACTERIZATION

Highway: SH 285-west of Andrea Lane **MP:** 242.8 to _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

Westbound viewshed

Eastbound viewshed with upslope wall

Cut slope mixed soil above rock

Rilling and gullying on upper soil covered slope

Return A19

ROCK SLOPE CHARACTERIZATION

Highway: US 285-East of Andrea Lane **MP:** 243.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

SLOPE PROFILE

Height (ft)	estimated 60
Length (ft)	800
Inclination and Direction	Weathered rock at 41 degrees facing 138 degrees; intact rock more vertical
Offset from highway (ft)	*Width of Shoulder*: 9.5; *Width of Ditch*: 17
Surface Variation (ft)	0.5 to 1; (1 to 2- weathered rock); (2 to 5- intact rock); 5+; Other:

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 2EB, 2WB	**AADT:** 27,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 800 ft=10 seconds*	
Travel direction #1=0.3 mi=19 sec (NB SB EB (WB))	Travel direction #2 = 0.75 mi=50 sec (NB SB (EB) WB)	
(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use: Private, unimproved, vacant land south of US 285 and between Andrea Lane and cut	**Static viewer?** Surrey Dr intersection with stop sign south of cut and US 285	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary; Igneous; (Metamorphic)
Other description (mixed, etc.):	
Formation name	Biotite Gneiss, with schist
Outcrop description:	As named, Precambrian age, may have pegmatite, foliated

	Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock: Structural Condition with fracture spacing	Favorable	Random	(Adverse)	Adverse	
				Fracture spacing 1 to 2 ft	
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-open less than 0.5 ft to closed	
CASE 2- Sedimentary, or layered: Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods OR continual water on slope)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Similar to other slopes- no natural outcrops seen in area of cut	*Texture*: Similar to other slopes- no natural outcrops seen in area of cut	*Stability*: Minimal rocks in ditch area	*Other Visual Differences*

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	Rockfall Mitigation	Access Road required? / Other: No blast marks seen at cut
Excavation method	(Blasting-minimal)	Breaking	(Ripping)	Other: Excavator and dozer used for ripping. Cushion blasting used in resistive rock with rock bolts to stabilize and protect rock outcrop important to community.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/3/2019	Westbound viewshed	388	
10/3/2019	Eastbound viewshed	391	
10/3/2019	View of cut to northeast	392	Schistose texture in intact rock on left, weathered rock on right
10/3/2019	Schistose texture of intact rock	406	Foliation planes visible as vertical "layers," with horizontal fractures

ROCK SLOPE CHARACTERIZATION

Highway: US 285-East of Andrea Lane **MP:** 243.2 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/3/2019

Westbound viewshed

Eastbound viewshed

View to northeast

Schistose texture of intact rock

Return A19

ROCK SLOPE CHARACTERIZATION

Highway: US 285 (oriented N-S) **MP:** 244.2 **to** 244.4 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

SLOPE PROFILE

Height (ft)	estimated 70					
Length (ft)	1,300					
Inclination and Direction	South end (granitic/pegmatite)-86 degrees facing 112 degrees; middle(biotitic granodiorite) 40 at 093; north end (granodiorite) 70 at 060					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	6 to 10 paved			15 to 20		
	with 3 to 6 unpaved					
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 55	**Number of travel lanes:** 3WB, 2EB	**AADT:** 27,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,300 ft=16 seconds*	
Travel direction #1=0.22 mi=14 sec	NB SB EB (WB)	
Foreground/Short Range: to 0.5 mi	Middleground/Long Range: to 3-5 mi	Background: to 5 mi to infinity
Travel direction #2 = 0.55 mi=36 sec	NB SB (EB) WB	
Foreground/Short Range: to 0.5 mi	Middleground/Long Range: to 3-5 mi	Background: to 5 mi to infinity
Adjacent land use	Turkey Creek Park owned by City and County of Denver adjacent to cut on east(across) and west (above). Possible view by park users	**Static viewer?** WB decel lane next to cut; intersection N Turkey Creek Rd on N and S side US 285;residential and commercial on S side US 285

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	**Other description (mixed, etc.):** Precambrian age		
Formation name	Granodiorite with Pegmatite at south end		**Outcrop description:** Foilated granodiorite with biotite and (coarse grained) pegmatite			

CASE 1- Crystalline, jointed rock	**Structural Conditon with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	(Adverse in biotite granodiorite with fracture spacing 1-2 ft)	(Adverse-in granodiorite/pegmatite with fracture spacing 2-5 ft)	
	Rock Friction/ Surface Variations	(Rough, irregular-in granodiorite)	(to undulating, smoother in foliated biotite granodiorite)	Planar	(Fracture gap-open less than 0.5 ft to closed)	
CASE 2- Sedimentary, or layered	**Structural Conditon**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intemittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatiblity with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Granodiorite/pegmatite lighter than, but well-foliated similar to natural	Granodiorite/pegmatite more angular than natural outcrops	Failed bolts in foliated biotite granodiorite slope; boulders in ditch	Granodiorite/pegmatite cut more pink/red than gray green natural outcrops across highway to east.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	Rockfall Mitigation	Access Road required?	Other: Rock bolts, some have failed in foliated biotitic granodiorite area,leaving exposed bolts
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting and machine scaling used along natural planes of weakness with rock bolts. Flatter slopes allowed revegetation.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/17/2019	Westbound viewshed	1147	
10/17/2019	Eastbound viewshed	1135	EB view show cut in distance, middle right
10/17/2019	Transition between foliated and granitic rock	1164	View to NW of transition foliated rock to granitic at cut N end
10/17/2019	Exposed bolts after rock loss	1170	View to SSW of exposed bolts in transition foliated to granitic

ROCK SLOPE CHARACTERIZATION

Highway: US 285 (oriented N-S) **MP:** 244.2 **to** 244.4 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

Westbound viewshed

View to northwest

Transition between foliated and granitic rock

Exposed rock bolts after rock loss

Return A20

ROCK SLOPE CHARACTERIZATION

Highway: US 285 MM 245.7 **MP:** 245.6 **to** 245.8 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

SLOPE PROFILE

Height (ft)	estimated 100				
Length (ft)	1,080				
Inclination and Direction	South end-59 degrees facing 082 degrees; north end-67 facing 031				
Offset from highway (ft)	*Width of Shoulder*: 10 ft paved; 2 ft unpaved		*Width of Ditch*: 18 to 20		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other: Very Blocky

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 2 WB,2 EB	**AADT:** 28,000	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,080 ft=16 seconds*		
Travel direction #1=0.16 mi=12 sec	NB SB EB (WB)	Travel direction #2 = 0.28 mi=22 sec	NB SB (EB) WB
Foreground/Short Range: to 0.5 mi		Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Private, residential above and WSW of cut; across US 285 to ENE, S. end is private, vacant land and N. end vacant, owned by Jefferson County	**Static viewer?** Decel lane and S. Turkey Creek Rd intersection across, E., of cut; Parmalee Gulch Rd overpass	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):** May include migmatite		
Formation name	Gneiss			**Outcrop description:** As named, Precambrian age, generally layered, granitic appearance		
CASE 1- Crystalline, jointed rock	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
Structural Condition with fracture spacing	Favorable	Random		Adverse	Adverse-joint plane orient toward road; joint/fracture spacing 5 ft	
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth		Planar	Fracture gap-open less than 0.5 ft to closed	
CASE 2- Sedimentary, or layered						Dip and direction:
Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Similar to outcrops above stream east of road and cut	*Texture*: Similar, but more angular than natural	*Stability*: Few rocks in ditch area	*Other Visual Differences*

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No blast marks or mitigation seen
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting and ripping along natural rock fractures for natural appearance. Cut slopes were rounded to transition to natural slopes.		

PHOTO LOG

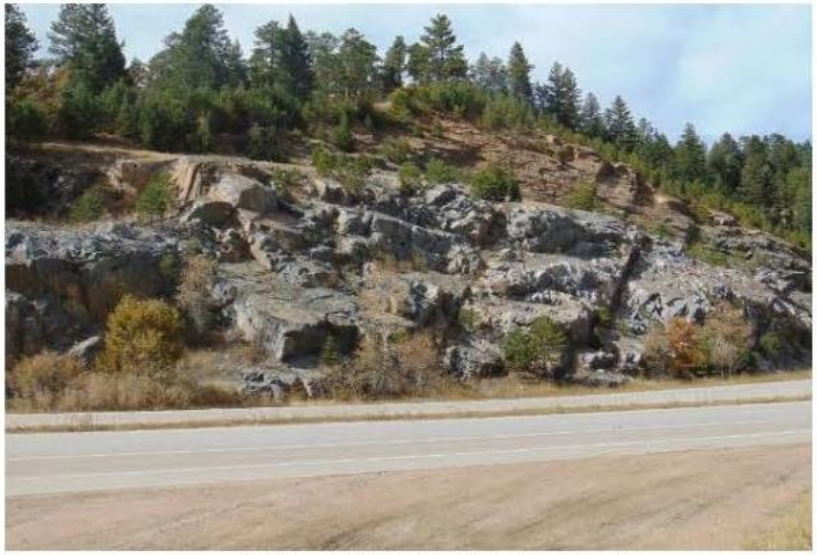
Date	*Description*	*Photo No.*	*Discussion*
10/17/2019	Westbound viewshed	1202	WB view cut beyond, south of, Parmalee gulch overpass
10/17/2019	Eastbound viewshed	1191	EB view cut in center of photo
10/17/2019	Blocky cuts showing joint planes	1194	View to SW of blocky cuts along joint planes oriented toward US 285
10/17/2019	Foliated rock in cut	1204	View to south of foliated rock zone at north end of cut

ROCK SLOPE CHARACTERIZATION

Highway: US 285 MM 245.7 **MP:** 245.6 **to** 245.8 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

Westbound viewshed

Eastbound viewshed



Blocky cuts showing joint/fracture planes

Foliated rock in cut

Return A20

ROCK SLOPE CHARACTERIZATION

Highway: US 285 **MP:** 245.9 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

SLOPE PROFILE

Height (ft)	estimated 70 to 80				
Length (ft)	270				
Inclination and Direction	77 degrees facing 135 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	6		14		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:

SETTING

Posted speed (mph): 45	**Number of travel lanes: 2EB/2WB**	**AADT:** 32,000
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 270 ft=4 seconds*		
Travel direction #1=0.22 mi=18 sec — NB SB EB (WB)	Travel direction #2 = 0.33 mi=26 sec — NB SB (EB) WB	
(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use	Vacant land owned by CDOT on NW (top) side of cut and Jefferson County SE of US 285 and cut	**Static viewer?** Parmalee Gulch Rd intersect and overpass with accel lane and left turn lane

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):** Fault in parallel set across middle of cut NW-SE	
Formation name	Gneiss			**Outcrop description:** As named, Precambrian age, generally layered, some migmatite	

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse	
					Joint spacing generally 3 to 5 ft	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-open less than 0.5 ft to closed	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to natural outcrops	Similar to natural outcrops	Few rocks in ditch area	Silver color draped mesh is highly visible

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting with little done to minimize damage to rock face in poor rock structure left marginally stable rock cut. Later work scaled to remove unstable rock and added draped mesh. Early version of mesh not colorized.		

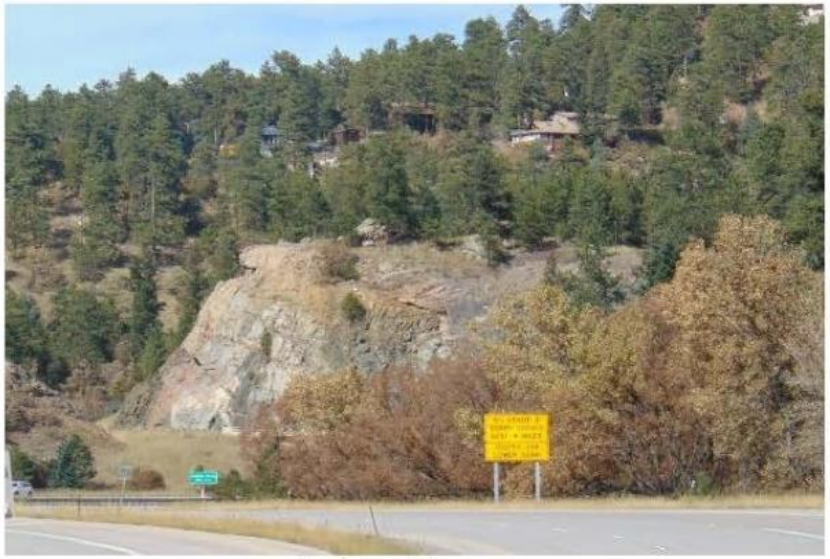
PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/17/2019	Westbound view	1249	Cut beyond brown and green information signs
10/17/2019	Eastbound view	1237	South corner of cut
10/17/2019	Draped mesh	1293	Silver draped mesh covering face of cut
10/17/2019	Joint planes and foliation	1289	Planar faces of parallel joints with oxidation/rust coloring and intersecting orthogonal foliation planes

ROCK SLOPE CHARACTERIZATION

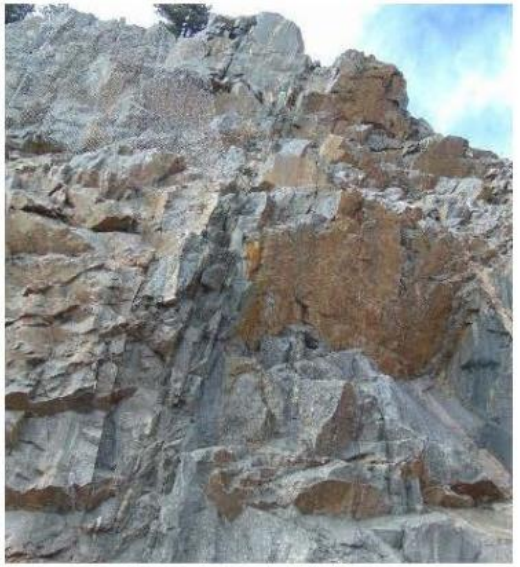
Highway: US 285 **MP:** 245.9 **to** _____ **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

Westbound view



Eastbound view

Draped mesh, view to northwest



Joint planes and foliation

Return A20

ROCK SLOPE CHARACTERIZATION

Highway: US 285 MM 246 **MP:** 246.0 **to** 246.2 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

SLOPE PROFILE

Height (ft)	estimated 100				
Length (ft)	1,150				
Inclination and Direction	West end-72 degrees facing 159 degrees; East end-69 at 136				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	West end- 5 paved		17		
	East end-12 paved,3 unpaved		14		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:

SETTING

Posted speed (mph): 45	**Number of travel lanes:** 2 EB/2 WB	**AADT:** 32,000	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,150 ft=18 seconds*		
Travel direction #1=0.3 mi=23 sec	NB SB EB (WB)	Travel direction #2 = 0.35 mi=29 sec	NB SB (EB) WB
(Foreground/Short Range: to 0.5 mi)	Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi)	Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity
Adjacent land use	Vacant land owned by private party on NW (top) side of cut and Jefferson County SE of US 285 and cut;east end of cut across from private own land to SE	Static viewer? Parmalee Gulch Rd intersect, overpass, on ramp, decel and accel lanes; houses on north end Brookmont Rd S of cut	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):** Fault in parallel set across middle of cut NW-SE	
Formation name	Gneiss			**Outcrop description:** As named, Precambrian age, generally layered, some migmatite	

CASE 1- Crystalline, jointed rock	**Structural Conditon with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse	
					(Joint spacing generally 3 to 5 ft)	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	(Fracture gap-open less than 0.5 ft to closed)	
CASE 2- Sedimentary, or layered	**Structural Conditon**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intemittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatiblity with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to natural outcrops	Similar to natural outcrops	Few rocks in ditch area; cobble size rocks under mesh	Jersey barrier at base/edge of catchment ditch for most of cut width; silver draped mesh highly visible

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh
Excavation method	(Blasting)	Breaking	Ripping	Other: Cusion blasting and machine scaling were used to follow existing natural joints with scaling and draped mesh used to reduce rockfall hazard.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/17/2019	Westbound view	1298	
10/17/2019	Eastbound view	1294	
10/17/2019	Draped mesh	1241	Silver draped mesh covering face of cut
10/17/2019	Blocky fracturing	1259 and 1250	1 to 2 ft fractured blocks

ROCK SLOPE CHARACTERIZATION

Highway: US 285 MM 246 **MP:** 246.0 **to** 246.2 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 10/17/2019

Westbound view

Eastbound view

Draped mesh

Blocky fracturing

Return A20

ROCK SLOPE CHARACTERIZATION

Highway: US 287, northeast side **MP:** 363.4 **to** _____ **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/15/2019

SLOPE PROFILE

Height (ft)	estimated 40 to 50					
Length (ft)	700					
Inclination and Direction	80 degrees facing 220 degrees					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	12.0 to 22.5			4 to 8		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+ = bench at top)	Other:	

SETTING

Posted speed (mph): 65	**Number of travel lanes:** 2 NB/1SB	**AADT:** 6600
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 700 ft=7 seconds*		
Travel direction #1 =0.6 mi= 35 sec		Travel direction #2=0.3 mi=19 sec
(NB) SB EB WB		NB (SB) EB WB
(Foreground/Short Range: to 0.5 mi		(Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity		Background: to 5 mi to infinity
Adjacent land use	Private, unimproved land	**Static viewer?** Possible view from house to the west off Gratitude Rd

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):**		
Formation name	Ingleside Formation (Permian)			**Outcrop description:** Sandstone, shale, and limestone		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation*			*Continuous Fractures Orientation*	
		Favorable	Random	~~Adverse~~	Adverse	
	Rock Friction/ Surface Variations	Rough, Irregular	Undulating, smooth	Planar	~~Fracture gap-open, closed, clay, gouge infilling, or slickensided~~	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: 17 @ 108
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	(Large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods ~~OR continual water on slope~~	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Similar	Some boulders in ditch	

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: Small diameter holes drilled horizontally and randomly spaced
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit drilling and blasting used; resulting half-casts visible in resisitive rocks and eroded in softer rock. Highest parts of cut terraced for use in revegetation.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/15/2019	Northbound view	913	Look direction northwest
10/15/2019	Southbound view	876	
10/15/2019	Rock type change, rocks in ditch	870	Differential weathering of rock layers
10/15/2019	Sandstone undermined by shale	855	Differential weathering of rock layers

ROCK SLOPE CHARACTERIZATION

Highway: US 287, northeast side **MP:** 363.4 **to** _____ **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/15/2019

Northbound view

Southbound view

Change in rock type; rocks in ditch with red boulder near face of cut

Sandstone undermined by softer shale

Return A20

ROCK SLOPE CHARACTERIZATION

Highway: US 287-south, west cut **MP:** 363.4 **to** _____ **Travel direction closest to cut:** NB (SB) EB WB **Date:** 10/15/2019

SLOPE PROFILE

Height (ft)	estimated 40 to 50				
Length (ft)	940				
Inclination and Direction	77 degrees at 019 degrees				
Offset from highway (ft)	*Width of Shoulder*: 9 to 20		*Width of Ditch*: 6.5		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:

SETTING

Posted speed (mph): 65 **Number of travel lanes:** 2 NB/1SB **AADT:** 6600

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 940 ft=10 seconds*

Travel direction #1 =0.4 mi= 22 sec	Travel direction #2=0.3 mi=18 sec
NB (SB) EB WB	(NB) SB EB WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: Private, unimproved land **Static viewer?** Possible view from house near intersect W Co Rd 72 and US 287

GEOLOGIC CHARACTERISTICS

Rock type: (Sedimentary) Igneous Metamorphic Other description (mixed, etc.):

Formation name: Ingleside Formation (Permian) **Outcrop description:** Sandstone, shale and limestone

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: 12 @ 116
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	(Large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods ~~OR continual water on slope~~	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Similar	Similar	Some boulders in ditch	Dissolution cavities in rock with vegetation; apparent water seepage areas

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required? Other: No construction features seen.
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit drilling and blasting used; resulting half-casts visible in resisitive rocks and eroded in softer rock.	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/15/2019	Southbound view	918	
10/15/2019	Northbound view	845	
10/15/2019	View to east-northeast	916	Dissolution cavities visible; boulders in ditch
10/15/2019	Dissolution cavites and boulders in ditch	865	Vegetation at dissolution areas; apparent water seepage

ROCK SLOPE CHARACTERIZATION

Highway: US 287-south, west cut **MP:** 363.4 **to** _____ **Travel direction closest to cut:** NB (SB) EB WB **Date:** 10/15/2019

Southbound view

Northbound view

View to east-northeast

Dissolution cavities and boulders in ditch

Return A21

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 550 **MP:** 2.3 **to** 2.6 **Travel direction closest to cut:** NB (SB) EB WB **Date:** 10/9/2019

SLOPE PROFILE

Height (ft)	estimated 60 to 70				
Length (ft)	1,380				
Inclination and Direction	60 to 90 degrees facing 100 to 135 degrees				
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*	
	10			10	
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 65	**Number of travel lanes: 2 SB/2 NB**	**AADT:** 9100
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,380 ft=14 seconds*	
Travel direction #1=0.4 mi=20 sec	NB (SB) EB WB	
Travel direction #2 = 1.1 mi=61 sec	(NB) SB EB WB	
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi	(Middleground/Long Range: to 3-5 mi)	
Background: to 5 mi to infinity	Background: to 5 mi to infinity	
Adjacent land use	South end of cut area is on Southern Ute Reservation land; private, unimproved land is above cut on north and west, and across SH 550 to east	Static viewer? 2-track rd intersects SH 550 at rock cut; residence to SE has view of cut; possible fishing activity Animas River adjacent to hwy

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):** Sandstone over weaker shale		
Formation name	Nacimiento Formation			**Outcrop description:** Sandstone and shale		
CASE 1- Crystalline, jointed rock: **Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*				*Continuous Fractures Orientation*	
	Favorable	Random		Adverse	Adverse	
CASE 1- Crystalline, jointed rock: **Rock Friction/ Surface Variations**	Rough, irregular	Undulating, smooth		Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered: **Structural Condition**	(Few differential horizontal erosion features < 10%)	Occasional horizontal erosion features 10 to 40%		Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: Estimated nearly horizontal
CASE 2- Sedimentary, or layered: **Difference in erosion**	(Small difference 6 to 12 inches)	Moderate difference 1 to 2 ft		Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Lighter color than natural in middle section	Similar, but less rounded than natural, especially in massive sandstone	Similar to natural with boulders on slopes	Vegetation on natural slopes that is missing on rock cut; Cut slope has more vertical, even face than natural; undercutting in weak shale causes large blocks of sandstone to fall into ditch; cut is approximately 20 years old.

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: Shale layer at bottom of cut has been buried to reduce erosion and undercutting of sandstone
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Cushion blasting and machine scaling used to avoid half-casts. Highly erodable shale buried after excavation and provides area for revegetation.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/9/2019	Southbound view	DSC 00059	Boulders behind guardrail
10/9/2019	Northbound view	DSC 00049	
10/9/2019	South end of cut looking southwest	DSC 00059	Rock face lighter than natural; little to no vegetation
10/9/2019	Buried shale layer	DSC 00065	Buried shale layer below sandstone cliff; boulders in ditch

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 550 **MP:** 2.3 **to** 2.6 **Travel direction closest to cut:** NB (SB) EB WB **Date:** 10/9/2019

Southbound view

Northbound view

South end of cut looking southwest

Buried shale layer

Return A21

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 550 **MP:** 68.5 **to** _____ **Travel direction closest to cut:** NB (SB) EB WB **Date:** 9/16/2019

SLOPE PROFILE

Height (ft)	estimated 80 to 90				
Length (ft)	350				
Inclination and Direction	45 to 70 degrees facing 110 degrees				
Offset from highway (ft)	*Width of Shoulder*: 2			*Width of Ditch*: 12	
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 30 **Number of travel lanes: 1 SB/1 NB** **AADT:** 2200

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 350 ft=8 seconds*

Travel direction #1=0.1 mi=13 sec				Travel direction #2 = 0.2 mi=29 sec			
NB	(SB)	EB	WB	(NB)	SB	EB	WB
(Foreground/Short Range: to 0.5 mi)				(Foreground/Short Range: to 0.5 mi)			
Middleground/Long Range: to 3-5 mi				Middleground/Long Range: to 3-5 mi			
Background: to 5 mi to infinity				Background: to 5 mi to infinity			

Adjacent land use: Private, unimproved land-mining claims from BLM data **Static viewer?** None identified

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	(Igneous)	Metamorphic	**Other description (mixed, etc.):** Granodiorite with feldspar phenocrysts
Formation name	Granodiorite		**Outcrop description:** As named, Oligocene intrusive (25-27 Ma)	

CASE 1- Crystalline, jointed rock

Structural Condition with fracture spacing	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*
	Favorable	Random	Adverse	(Adverse)
				Major joint set apparent trend N-S
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Fracture gap-open up to 0.5 ft to closed

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods OR continual water on slope)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Lighter than natural outcrops; mesh drape is highly visible	Similar	Many cobbles to boulder size clasts in ditch area	Rock cut approximately 10 years old; appears fresh and unweathered

CONSTRUCTION

Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required? Yes; pioneer road	Other: Draped mesh-light color and color highly variable; attached to fence at top of cut
Excavation method	(Blasting)	Breaking	Ripping	Other: Following natural fractures, cushion drilling and blasting with machine scaling used to avoid half-casts. Rock bolts to stabilize large blocks ; draped mesh over face. Pioneer road excavation created unstable slope at south end.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
9/16/2019	Northbound viewshed	DSC00026	
9/16/2019	View to southwest	DSC00029	
9/16/2019	Foliation and joints	DSC00031	Foliation and joints, fractures
9/16/2019	Draped mesh and bolts	DSC00030	Draped mesh and bolts looking north

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 550 **MP:** 68.5 **to** _____ **Travel direction closest to cut:** NB (SB) PB WB **Date:** 9/16/2019

Northbound viewshed

View to southwest

Foliation and joints

Draped mesh and bolts

Return A21

ROCK SLOPE CHARACTERIZATION

Highway: US 550 **MP:** 90.50 **to** 90.54 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 8/4/2020

SLOPE PROFILE

Height (ft)	estimated 60				
Length (ft)	235				
Inclination and Direction	70 to 75 degrees facing 157 degrees				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	10		8		
Surface Variation (ft)	(0.5 to 1)	(1 to 2)	2 to 5	5+	Other:

SETTING

Posted speed (mph): 25	**Number of travel lanes: 2**	**AADT:** 2200
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 235 ft=14 seconds*		
Travel direction #1=0.12=17 sec		Travel direction #2 = 0.4 mi=6 sec
(NB) SB EB WB		NB (SB) EB WB
(Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity		Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity
Adjacent land use U.S. Forest Service		**Static viewer?** Bear Creek and Falls overlook SW of cut across highway

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):** with quartzite	
Formation name	Uncompahgre		**Outcrop description:** Slate and phyllite		

CASE 1- Crystalline, jointed rock

	Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*
Structural Condition with fracture spacing	Favorable	(Random) 0.5 to 1 ft spacing	Adverse	(Adverse) 1 to 2 directions
Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	(Planar)	Fracture gap-open, < 1/4 inch

CASE 2- Sedimentary, or layered

Structural Condition	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Gray, similar to surrounding; mesh visible as light gray	Similar to surrounding	Good	New cut that is very similar to natural surroundings; silver mesh reflects light and is noticeable

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	(Rockfall Mitigation)	Access Road required? Yes, existing mine road Other: Mesh
Excavation method	(Blasting)	Breaking	Ripping	Other: Terraces	

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
8/4/2020	Long view northbound	DSC 00179	Gray (galvanized?) mesh highly visible
8/4/2020	Short view northbound	DSC 00180	Gray (galvanized?) mesh highly visible
8/4/2020	Adjacent cut northbound	DSC 00181	Terracing along joints
8/4/2020	Installation of mesh, view southbound		Wire mesh installation photo 2011

ROCK SLOPE CHARACTERIZATION

Highway: US 550 **MP:** 90.50 **to** 90.54 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 8/4/2020

Northbound long view

Northbound short view

Terraces and adjacent cut northbound

Installation of mesh in 2011, view southbound

Return A21

ROCK SLOPE CHARACTERIZATION

Highway: US Highway 550 **MP:** 106.3 **to** 106.4 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 9/12/2019

SLOPE PROFILE

Height (ft)	estimated 65
Length (ft)	630
Inclination and Direction	80 to 85 degrees facing 245 degrees
Offset from highway (ft)	*Width of Shoulder*: 15 unpaved; *Width of Ditch*: 15 (flat); (30 total from white line to face of cut)
Surface Variation (ft)	0.5 to 1 | (1 to 2) | 2 to 5 | 5+ | Other:

SETTING

Posted speed (mph): 60	**Number of travel lanes:** 1 NB/1 SB	**AADT:** 7500

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 630 ft=7 seconds, *AND view CR24*

Travel direction #1=0.58 mi=35 sec	Travel direction #2 = 0.16 mi=9 sec
(NB) SB EB WB	NB (SB) EB WB
Foreground/Short Range: to 0.5 mi	Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: CDOT and Ouray County unimproved land above/east of cut; north & west of cut Ridgway State Park open area with trail; private, residential to south & west

Static viewer? Residences & recreational path WSW of cut on west side of SH550; Also visible from CR 24 to SW.

GEOLOGIC CHARACTERISTICS

Rock type: (Sedimentary) Igneous Metamorphic

***Travel visibility from CR 24,25 mph, EB view 1 mi=143 seconds**

Formation name: Morrison Formation (Jurassic Age)

Outcrop description: Sandstone, mudstone, shale, siltstone, conglomerate

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	(Few differential horizontal erosion features < 10%)	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: Estimated nearly horizontal
	Difference in erosion	(Small difference 6 to 12 inches)	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar	Less vegetation; more angular than natural	Some rocks at base of cut	Draped mesh blends into rock face; light tan to gray shotcrete covers lower cut face up to height ~10-20 feet for erosion control of weaker shale layer below massive sandstone..

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required? Pioneer road used
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Pre-split and cushion blasting with hand scaling and machine excavation. Hydraulic excavation of claystone in lower cut and rock dowels and pigmented shotcrete for stabilization.	

Other: Draped mesh from ~20 ft from top of cut to ~30 feet above base secured with anchors & fence at top

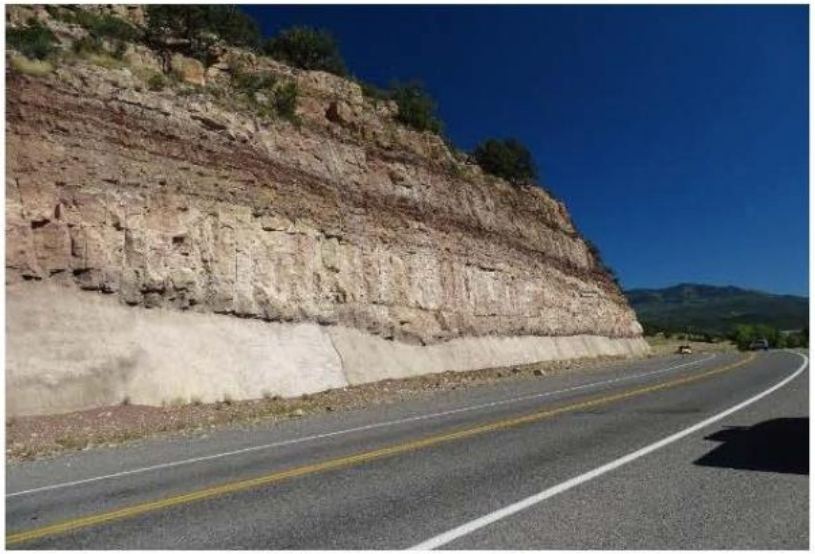
PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
9/12/2019	Northbound viewshed	DSC00018	
9/12/2019	Southbound view	DSC00019	
9/12/2019	Draped mesh & Shotcrete base	DSC00021	Draped mesh, upper half and shotcrete at base
9/12/2019	Rocks in ditch	DSC00022	Boulder and other rocks in ditch/catchment area

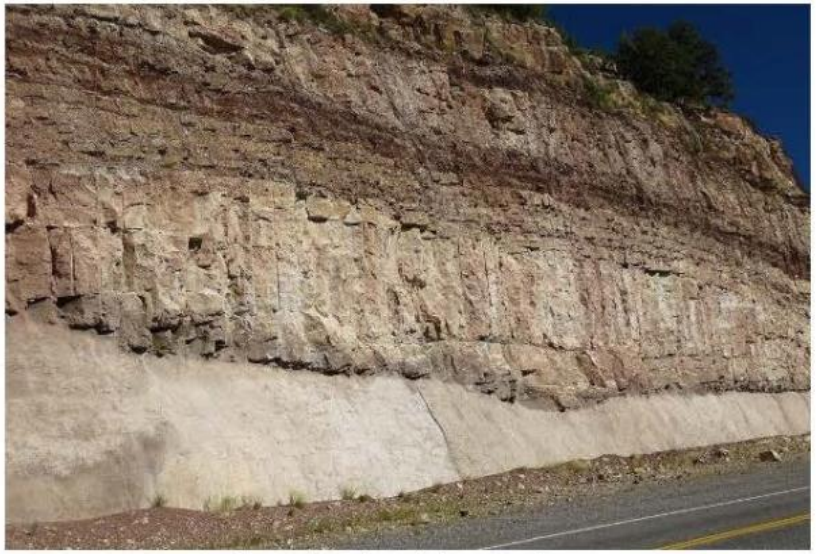
ROCK SLOPE CHARACTERIZATION

Highway: US Highway 550 **MP:** 106.3 **to** 106.4 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 9/12/2019

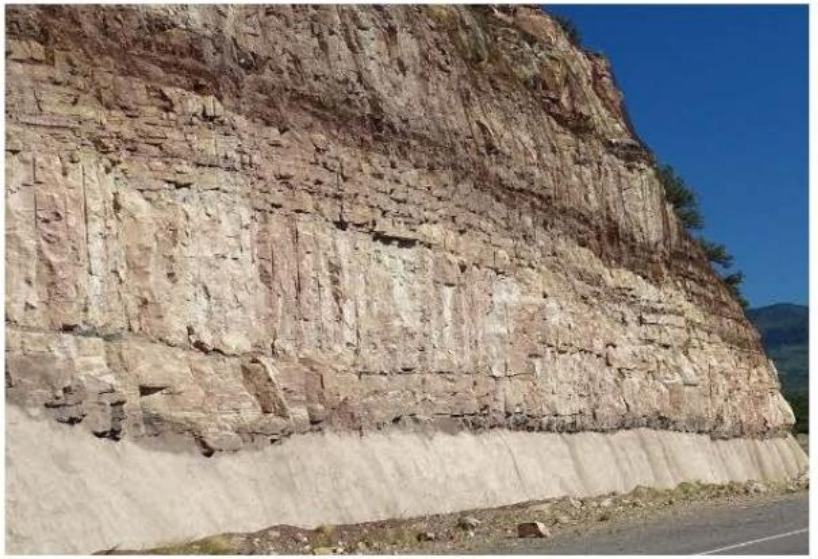
Northbound viewshed



View to northwest



Draped mesh and shotcrete base



Rocks in ditch

Return A21

ROCK SLOPE CHARACTERIZATION

Highway: SH 65 **MP:** 55.1 **to** _____ **Travel direction closest to cut:** (NB) SB EB WB (WB) **Date:** 11/18/2019

SLOPE PROFILE

Height (ft)	estimated 20 to 25
Length (ft)	195
Inclination and Direction	85 to 90 degrees facing 185 degrees
Offset from highway (ft)	*Width of Shoulder*: 5.5 pave + 3 gravel; *Width of Ditch*: 16.5
Surface Variation (ft)	(0.5 to 1) 1 to 2 2 to 5 5+ Other:

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 NB/1 SB	**AADT:** 2600

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 195 ft=3 seconds*

Travel direction #1 =0.1 mi= 10 sec	Travel direction #2=0.4 mi=31 sec
(NB) SB EB WB	NB (SB) EB WB
Foreground/Short Range: to 0.5 mi	Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: Unimproved private land, with residence and outbuildings approximately 250 feet north of

Static Viewer? Driveways intersect SH 65 at E. end of cut; pullout S. side of cut

GEOLOGIC CHARACTERISTICS

Rock type: (Sedimentary) Igneous Metamorphic **Other description (mixed, etc.):**

Formation name: Mesaverde Formation (lower) **Outcrop description:** Massive sandstone

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	(Few differential horizontal erosion features < 10%)	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: None-massive sandstone
	Difference in erosion	(Small difference 6 to 12 inches)	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	Rock cuts similar; lighter than native	rock cut surface flatter and more vertical than native on south end.	No apparent missing rocks; few rocks in ditch; more west of cut	"Vug"~ 1-ft diameter hole of weathered out shale; Drainage and rock face west of cut have river gravels above bedrock that are raveling off rock face and landing on roadway-3 rocks 6-12 inch diameter were observed in road day of visit

CONSTRUCTION

Features	(Half-casts (blasting))	(Machine marks (excavation-machine blade/tooth))	Rock anchors	Rockfall Mitigation	Access Road required?	Other:
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Two different blasting techniques used for evaluation with the right/south end using traditional presplit/production blasting. Ripping on left/north end.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
11/18/2019	Northbound viewshed	1358	
11/18/2019	Southbound viewshed	1338	
11/18/2019	View to NW	1342	Cut with half casts
11/18/2019	View to ENE	1354	Cut with half casts abuts no half casts; two blast techniques

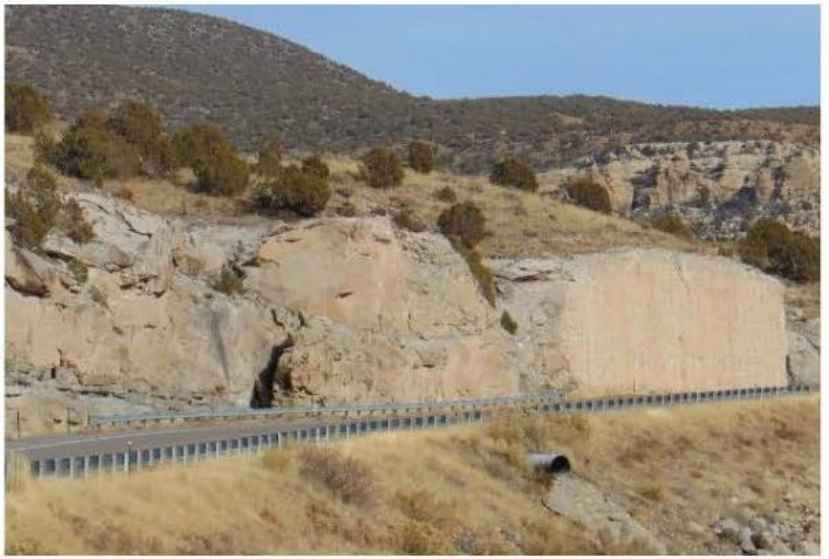
ROCK SLOPE CHARACTERIZATION

Highway: SH 65 **MP:** 55.1 **to** _____ **Travel direction closest to cut:** (NB) SB EB WB **Date:** 11/18/2019

Northbound Viewshed

Southbound Viewshed

NW view of two different blast techniques (far left of photo and center)



NE view of two different blast techniques (far left of photo and center to right)

Return A22

ROCK SLOPE CHARACTERIZATION

Highway: SH 65 **MP:** 58.2 **to** _____ **Travel direction closest to cut:** (NB) SB EB WB (WB) **Date:** 11/18/2019

SLOPE PROFILE

Height (ft)	estimated 50 to 60				
Length (ft)	640				
Inclination and Direction	80 to 90 degrees facing 100 to 150 degrees, on outside of curve				
Offset from highway (ft)	*Width of Shoulder*: 5.5 to 6.5 paved		*Width of Ditch*: 18.0 to 19.5		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:

SETTING

Posted speed (mph): 45	**# travel lanes:** 1 NB/1 SB	**AADT:** 2100
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 640 ft=10 seconds*	
Travel direction #1 =0.44 mi= 36 sec	(NB) SB EB WB	Travel direction #2=0.2 mi=14 sec (SB) NB EB WB
Foreground/Short Range: to 0.5 mi		Foreground/Short Range: to 0.5 mi
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity		Background: to 5 mi to infinity
Adjacent land use	Unimproved private land at cut and north, with BLM land adjacent to west	**Static Viewer?** Driveway intersects SH 65 at west end of cut

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	Other description (mixed, etc.):		
Formation name	Mesaverde Formation (lower)			**Outcrop Description:** Shale, some carboniferous, sandstone; river gravel on top of cut		

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: 10 @ 350
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	(Large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	lighter than native	rock cut surface flatter than native	Many fallen river gravel from above rock cut in ditch	Horizontal ledges to east; ledges slope toward road on west end. Shale at base is falling away from rock face and undercutting sandstone; a small area at east end of cut has apparent natural surface with crossbedding and rounded surface.

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other:
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit blasting through several different materials and rock types		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
11/18/2019	Northbound viewshed	1396	Cut is center left of photo
11/18/2019	Southbound viewshed	1361	Cut is center, left side of roadway in photo
11/18/2019	View to NW	1370	North end of cut, shale undercut sandstone
11/18/2019	View to SE	1372	Middle area of cut, half casts and shale undercut sandstone

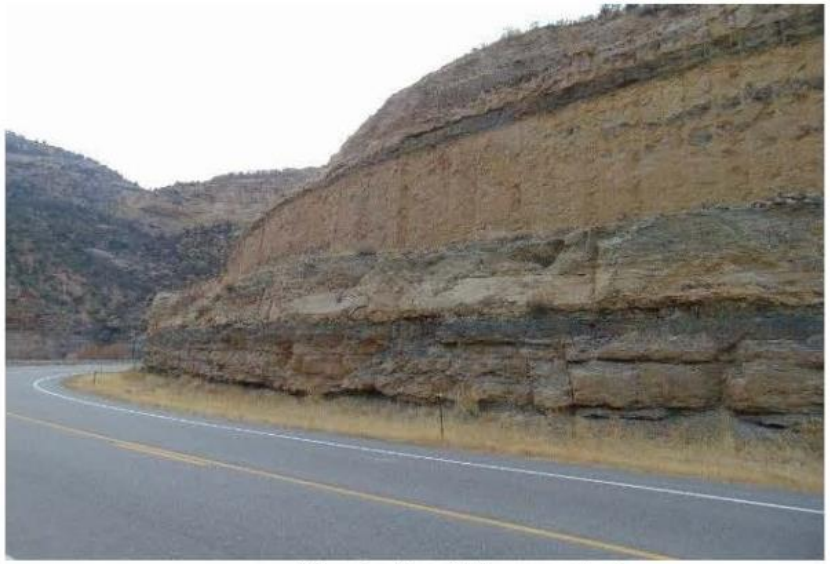
ROCK SLOPE CHARACTERIZATION

Highway: SH 65 **MP:** 58.2 **to** _____ **Travel direction closest to cut:** (NB) SB EB WB **Date:** 11/18/2019

Northbound viewshed

Southbound viewshed

View to NW, north end of cut



View to SE, middle area of cut

Return A22

ROCK SLOPE CHARACTERIZATION

Highway: SH 82 **MP:** 29 **to** 29.1 **Travel direction closest to cut:** NB SB (EB) WB **Date:** 9/11/2019

SLOPE PROFILE

Height (ft)	estimated 80 to 100 (Pitkin Co GIS contours)					
Length (ft)	535					
Inclination and Direction	60 to 75 degrees facing 060 degrees					
Offset from highway (ft)	*Width of Shoulder*			*Width of Ditch*		
	EB 8 to 9 ft/bridge			3 to 35 to bridge		
	WB 4 to 9			40 to 75 to barrier		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 50	**Number of travel lanes:** 2 EB/2 WB	**AADT:** 21,000	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 535 ft=7 seconds*		
Travel direction #1=0.2 mi=16 sec		Travel direction #2 = 0.5 mi=36 sec	
NB SB (EB) WB		NB SB EB (WB)	
(Foreground/Short Range: to 0.5 mi)		(Foreground/Short Range: to 0.5 mi)	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Vacant, unimproved property adjacent to cut owned by State of Colorado; private residential property NE of & across SH 82 with trail owned by RFTA.	**Static viewer?** View from private residences and Rio Grande trail NE of cut across SH 82	

GEOLOGIC CHARACTERISTICS

Rock type	(Sedimentary)	Igneous	Metamorphic	**Other description (mixed, etc.):**	
Formation name	Maroon Formation (Pennsylvanian-Permian age)		**Outcrop description:** Siltstone, claystone, sandstone, conglomerate, lenticular beds		

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, Irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	(Few differential horizontal erosion features < 10%)	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction: Est. 10 to 20 degrees to NE
	Difference in erosion	(Small difference 6 to 12 inches)	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~OR continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Similar to natural outcrops	Benched/terraced along bedding planes	Few boulders in ditch at NW end	Shotcrete well matched to rock color; cobble to boulder size clasts on terraces; some terraces have vegetation-grasses, shrubs, trees. Irrigation tubing at NW end.

CONSTRUCTION

Features	(Half-casts (blasting) not seen; horizontal boreholes for blasting noted)	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh top 1/4 of cut for ~70 ft width; terracing; shotcrete top of cut face
Excavation method	(Blasting)	Breaking	(Ripping)	Other: Blast pattern created benches like natural terrain. Excavator removed soil and weathered rock. Colored shotcrete-faced soil nail wall stabilized loose material.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
9/11/2019	EB viewshed	81	Eastbound view from below eastbound elevated roadway
9/11/2019	WB viewshed	79	Westbound view from below eastbound elevated roadway
9/11/2019	Vegetated terraces	62	Terraces with shrubs and grass
9/11/2019	Shotcrete top of cut	60	Bolts visible below shotcrete; view to southwest

ROCK SLOPE CHARACTERIZATION

Highway: SH 82 **MP:** 29 **to** 29.1 **Travel direction closest to cut:** NB SB (EB) WB **Date:** 9/11/2019

Eastbound Viewshed

Westbound viewshed

Vegetated terraces

Shotcrete at top of cut

Return A22

ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 5.8 **to** 6.2 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

SLOPE PROFILE

Height (ft)	estimated 50 to 60
Length (ft)	690
Inclination and Direction	71 to 74 degrees facing 231 to 236 degrees
Offset from highway (ft)	*Width of Shoulder*: 11 to 31 (unpaved); *Width of Ditch*: 8.5 to 11
Surface Variation (ft)	0.5 to 1 / 1 to 2 / (2 to 5) / (5+) / Other:

SETTING

Posted speed (mph): 40	**Number of travel lanes:** 1 NB, 1 SB	**AADT:** 14,000

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 690 ft=12 seconds*

Travel direction #1=0.18 mi=17 sec	Travel direction #2 = 0.35 mi=32 sec
(NB) SB EB WB	NB (SB) EB WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: Vacant land owned by CDOT and BLM east of and above cut; unknown owner vacant land west of cut

Static viewer? View from bike path ESE of parallel cut and across SH 119 from cut; possible fishing access

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary / Igneous / (Metamorphic)

Other description (mixed, etc.): Gneiss with biotite and pegmatite inclusions

Formation name: Gneiss

Outcrop description: As named, Precambrian age, strongly foliated, some weathered

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	(Random)	Adverse	(Adverse) varied fracture spacing	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	(Foliation layers oriented varied directions; fracture gaps-open less than 0.5 ft to closed)	
CASE 2- Sedimentary/ or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Dark mesh on light color rocks; cut rock similar to natural	Similar to natural outcrops above cut	Few rocks in ditch	

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh, attenuator fence at top of cut
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit and production blasting with varied ditch width to break up appearance of newly excavated cut. Brown color mesh covered final face.		

PHOTO LOG

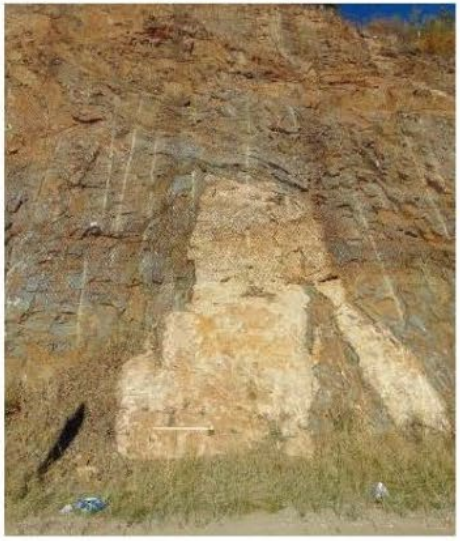
Date	*Description*	*Photo No.*	*Discussion*
10/2/2019	Northbound view	203	Vertical foliation planes
10/2/2019	Southbound view	232	Weathered foliation/fracture planes
10/2/2019	Draped mesh over half cast blast features	207	Varied rock type and blocky fracturing behind mesh
10/2/2019	View to east, varied foliation	216	Varied foliation planes with pegmatite zones, north end cut

ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 5.8 **to** 6.2 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

Northbound view

Foliation/fractures with weathered zones



Draped mesh over half cast blast features

View to east, varied foliation, north end cut

Return A22

ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 6.2 **to** 6.4 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

SLOPE PROFILE

Height (ft)	estimated 60 to 80
Length (ft)	1,020
Inclination and Direction	73 degrees facing 234 degrees
Offset from highway (ft)	*Width of Shoulder*: 10; *Width of Ditch*: 21
Surface Variation (ft)	0.5 to 1 / 1 to 2 / (2 to 5) / 5+ / Other:

SETTING

Posted speed (mph): 40	**Number of travel lanes:** 1 NB, 1 SB	**AADT:** 14,000	
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,020 ft=18 seconds*		
Travel direction #1=0.38 mi=34 sec		Travel direction #2 = 0.27 mi=24 sec	
(NB) SB EB WB		NB (SB) EB WB	
Foreground/Short Range: to 0.5 mi		Foreground/Short Range: to 0.5 mi	
Middleground/Long Range: to 3-5 mi		Middleground/Long Range: to 3-5 mi	
Background: to 5 mi to infinity		Background: to 5 mi to infinity	
Adjacent land use	Vacant land owned by City of Black Hawk east of and above cut and west of cut across SH 119	**Static viewer?** View from bike path ESE of parallel cut and across SH 119 from cut	

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary / Igneous / (Metamorphic) **Other description (mixed, etc.):** Gneiss with biotite and pegmatite inclusions

Formation name: Gneiss **Outcrop description:** As named, Precambrian age, strongly foliated

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	(Random)	Adverse	(Adverse) varied fracture spacing
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	(Foliation layers oriented varied directions; fracture gaps-open less than 0.5 ft to closed)
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft

Dip and direction:

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: Dark mesh on light color rocks; cut rock similar to natural	*Texture*: Similar to natural outcrops above cut	*Stability*: Few rocks in ditch	*Other Visual Differences*

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Draped mesh, attenuator fence at top of cut
Excavation method	Blasting	Breaking	Ripping	Other: Presplit and production blasting with varied ditch width to break up appearance of newly excavated cut. Brown color mesh covered final face.		

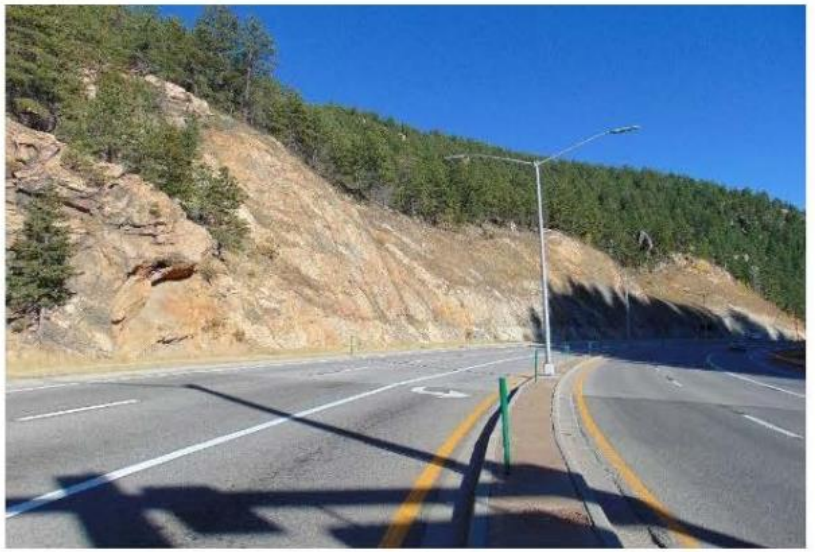
PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/2/2019	Northbound view	222	
10/2/2019	Southbound view	234	
10/2/2019	Fence, mesh and bolts	229	Foliation directions, blocky fracturing-note fallen tree across mesh
10/2/2019	Draped mesh across middle of cut	220	Fence is below top outcrop, view to NE

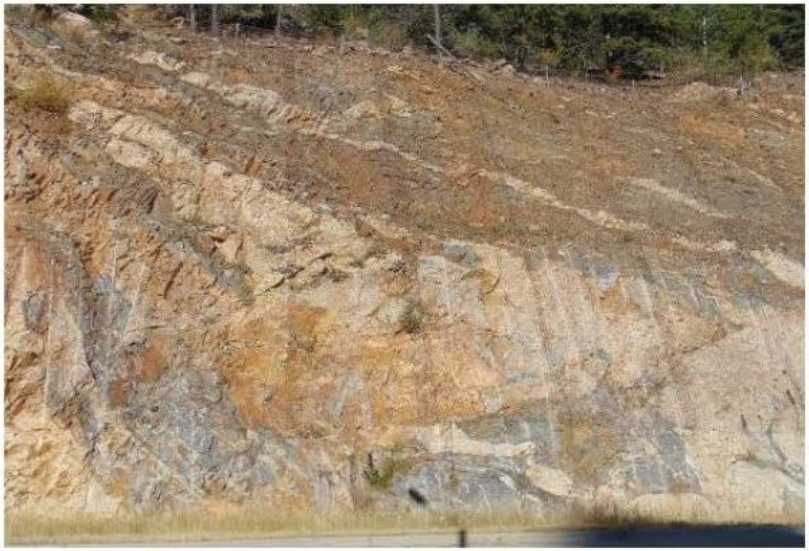
ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 6.2 **to** 6.4 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

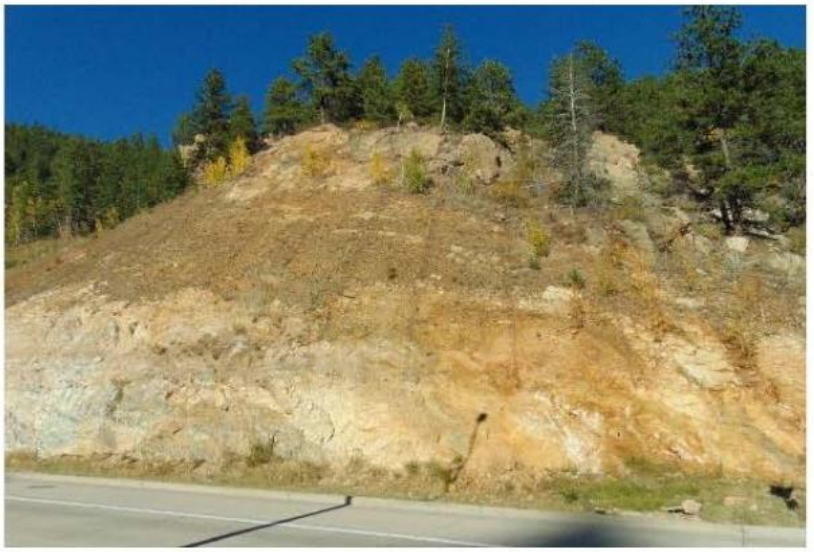
Northbound view



Southbound view



Fence, mesh and bolts



Draped mesh across middle of cut

Return A22

ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 6.4 **to** 6.6 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

SLOPE PROFILE

Height (ft)	estimated 40 to 60					
Length (ft)	270					
Inclination and Direction	85 degrees facing 165 degrees					
Offset from highway (ft)	*Width of Shoulder*: None			*Width of Ditch*: 12	mantled with rock	
Surface Variation (ft)	0.5 to 1	1 to 2	2 to 5	(5+)	Other:	

SETTING

Posted speed (mph): 40	**Number of travel lanes:** 1 NB, 1 SB	**AADT:** 14,000
Visibility	*Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 270 ft=5 seconds*	
Travel direction #1=0.2 mi=19 sec: (NB) SB EB WB	Travel direction #2 = 0.1 mi=10 sec: NB (SB) EB WB	
(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	(Foreground/Short Range: to 0.5 mi) Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use: Vacant land apparently owned by City of Black Hawk north and south of cut; privately owned vacant land also south of cut across SH 119	**Static viewer?** View from commercial building/casino to the west	

GEOLOGIC CHARACTERISTICS

Rock type	Sedimentary	Igneous	(Metamorphic)	**Other description (mixed, etc.):** Gneiss with biotite and pegmatite inclusions	
Formation name	Gneiss			**Outcrop description:** As named, Precambrian age, strongly foliated	

CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	*Discontinuous Fractures Orientation/Spacing in feet*			*Continuous Fractures Orientation*	
		Favorable	Random	(Adverse)	Adverse	
	Rock Friction/ Surface Variations	(Rough, irregular)	Undulating, smooth	Planar	Foliation layers generally tilted to the east; fracture gaps-open less than 0.5 ft to closed	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	cut rock similar to natural outcrops	Similar to natural outcrops above cut	Few rocks in ditch	

CONSTRUCTION

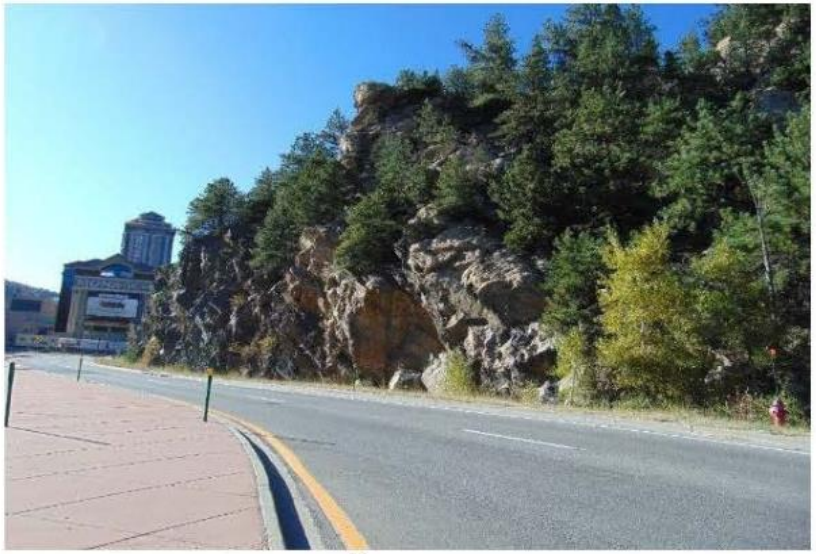
Features	Half-casts (blasting)	Machine marks (excavation-machine blade/tooth)	Rock anchors	Rockfall Mitigation	Access Road required?	Other: No mitigation features seen
Excavation method	(Blasting)	Breaking	Ripping	Other: Production blasting done several decades ago created uneven slope face. Reestablished vegetation gives natural appearance. Excessive overbreak visible as radial cracks. Rock face is source of rockfall hazard.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
1/14/2020	Rock cut view to west	235	Rock cut north of intersection Main and SH 119
1/14/2020	View to ENE	237	Foliation planes/layers tilted to east
10/2/2019	Tilt of foliation planes	238	
10/2/2019	Rocks mantling ditch	244	

ROCK SLOPE CHARACTERIZATION

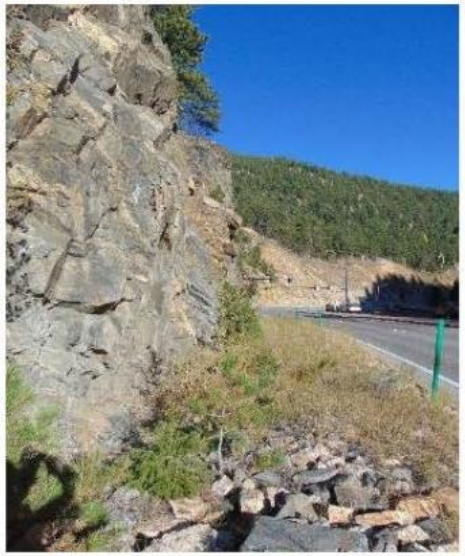
Highway: SH 119 **MP:** 6.4 **to** 6.6 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019



View to west

View to east-northeast

Tilt of foliation planes



Rocks mantling ditch

Return A23

ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 6.6 **to** 6.9 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

SLOPE PROFILE

Height (ft)	estimated 40 to 60					
Length (ft)	1,785					
Inclination and Direction	60 to 70 degrees facing 175 to 195 degrees					
Offset from highway (ft)	*Width of Shoulder*: None			*Width of Ditch*: 8 to 16 behind curb		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:	

SETTING

Posted speed (mph): 35 **Number of travel lanes:** 1 NB, 1 SB **AADT:** 6.6 to 6.7=14,000; 6.7 to 6.9=4,400

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1,785 ft=35 seconds*

Travel direction #1=0.57 mi=59 sec				Travel direction #2 = 0.41 mi=43 sec			
(NB)	SB	EB	WB	NB	(SB)	EB	WB
(Foreground/Short Range: to 0.5 mi)				(Foreground/Short Range: to 0.5 mi)			
Middleground/Long Range: to 3-5 mi				Middleground/Long Range: to 3-5 mi			
Background: to 5 mi to infinity				Background: to 5 mi to infinity			

Adjacent land use: Vacant land apparently owned by City of Black Hawk north of and above cut; south of cut across SH 119 are casinos/commercial buildings

Static viewer? View from commercial buildings/casinos, sidewalks, south of cut

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary (Igneous) (Metamorphic) **Other description (mixed, etc.):** Gneiss with biotite and pegmatite & granite

Formation name: Gneiss and Boulder Creek Granodiorite **Outcrop description:** As named, Precambrian age, strongly foliated; granodiorite may be massive

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	(Random)	Adverse	(Adverse open < 0.5 ft to closed)	
	Rock Friction/ Surface Variations	(Rough, irregular)	(Undulating, smooth along shotcrete at top)	Planar	(Foliation layer planes in varied directions and various widths)	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation OR short freezing periods, OR intermittent water on slope	(High precipitation OR long freezing periods ~~or continual water on slope~~)	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

	Color	*Texture*	*Stability*	*Other Visual Differences*
Compatibility with Nearby Slopes (describe)	cut rock similar to natural outcrops with light color mesh	Similar to natural outcrops above cut	Rocks mantling ditch and loose in ditch	Shotcrete at top of cut appears smoother and more gray than natural; one terraced area with trees below shotcrete

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Shotcrete at top of cut; draped mesh; Near base of cut-1-inch PVC pipes on ~30 ft spacing with some areas of shotcrete
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit and production blasting with varied ditch width to break up appearance of newly excavated cut. Stained shotcrete with rock bolts used on upper portion of cut. Brown color mesh covered final face.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
10/2/2019	Northbound view	251	Shotcrete at top of cut above mesh; terrace below shotcrete
10/2/2019	Southbound view	252	
10/2/2019	Drains in cut	264	Shotcrete around drain below mesh; rocks in ditch
10/2/2019	Rocks in ditch	263	

ROCK SLOPE CHARACTERIZATION

Highway: SH 119 **MP:** 6.6 **to** 6.9 **Travel direction closest to cut:** (NB) SB EB WB **Date:** 10/2/2019

Northbound view

Southbound view

Drains in cut

Rocks in ditch

Return A23

ROCK SLOPE CHARACTERIZATION

Highway: SH-119 **MP:** 39.31 **to** 39.36 Travel direction closest to cut: NB SB (EB) WB **Date:** 2/8/2021

SLOPE PROFILE

Height (ft)	140 feet				
Length (ft)	220 feet				
Inclination and Direction	45 degrees, towards 015				
Offset from highway (ft)	*Width of Shoulder*		*Width of Ditch*		
	6 feet		20 feet		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	5+	Other:

SETTING

Posted speed (mph): 40	**Number of travel lanes: 2**	**AADT: 7,200**
Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 220 ft=4 seconds*		
Travel direction #1= 0.15 mi= 13 sec	Travel direction #2 = 0.16 mi= 14 sec	
NB SB (EB) WB	NB SB EB (WB)	
Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	Foreground/Short Range: to 0.5 mi Middleground/Long Range: to 3-5 mi Background: to 5 mi to infinity	
Adjacent land use City of Boulder open space, includes Flagstaff Mountain Park	**Static viewer?** Recreational trail users along Boulder Creek NE of SH 119	

GEOLOGIC CHARACTERISTICS

Rock type: Sedimentary (Igneous) Metamorphic **Other description (mixed, etc.):**

Formation name: Boulder Creek Granodiorite **Outcrop description:** Granodiorite with biotite; weak to strong foliation

		Discontinuous Fractures Orientation/Spacing in feet			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	(Adverse) (1-2 ft spacing avg)	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	(Planar)	(Fracture gaps)	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	Many horizontal erosion features 40 to 80 %	Major horizontal erosion features > 80%	Dip and direction:
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	Few areas of large difference 2 to 5 ft	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods
Compatibility with Nearby Slopes (describe)	*Color*: similar-light gray to light brown	*Texture*: similar shape to natural; more angular	*Stability*: brittle, est friction angle 45 deg	*Other Visual Differences*: Less vegetation on new cut; rock bolts are obvious

CONSTRUCTION

Features	Half-casts (blasting)	(Machine marks (excavation-machine blade/tooth))	(Rock anchors)	Rockfall Mitigation	Access Road required? NO	Other:
Excavation method	(Blasting)	Breaking	(Ripping)	Other:		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
2/8/2021	Cut slope post construction	Cut 2 (1)_2-8-2021.jpg	View to west
2/8/2021	Cut slope post construction	Cut 2 (2)_2-8-2021.jpg	View to SSE
5/22/2019	Cut slope early construction phase	Cut 2_PreEx 1.jpg	View to WNW
6/20/2019	Cut slope early construction phase	Cut 2_PreEx 3.jpg	View to SSE

ROCK SLOPE CHARACTERIZATION

Highway: SH-119 **MP:** 39.31 **to** 39.36 Travel direction closest to cut: NB SB (EB) WB **Date:** 2/8/2021

Cut slope post construction view to west

Cut slope post construction view to SSE

Cut slope early construction view to WNW

Cut slope early construction view to SSE

Return A23

ROCK SLOPE CHARACTERIZATION

Highway: SH 133 **MP:** 24.1 **to** 24.4 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 11/19/2019

SLOPE PROFILE

Height (ft)	estimated 50 to 65				
Length (ft)	1535				
Inclination and Direction	65 to 85 degrees facing 160 to 165 degrees				
Offset from highway (ft)	*Width of Shoulder*: 3 to 4, paved		*Width of Ditch*: 14 to 38		
Surface Variation (ft)	0.5 to 1	1 to 2	(2 to 5)	(5+)	Other:

SETTING

Posted speed (mph): 30	**# travel lanes:** 1 NB/1 SB	**AADT:** 1000

Visibility *Travel direction(s) and Est Range of sight for 10 sec or more for each travel direction; for 1535 ft=35 seconds*

Travel direction #1 =0.41 mi= 49 sec	Travel direction #2=0.37 mi=45 sec
NB SB EB (WB)	NB SB (EB) WB
(Foreground/Short Range: to 0.5 mi)	(Foreground/Short Range: to 0.5 mi)
Middleground/Long Range: to 3-5 mi	Middleground/Long Range: to 3-5 mi
Background: to 5 mi to infinity	Background: to 5 mi to infinity

Adjacent land use: BLM unimproved land north, south, and east; US Forest Service land to west

Static viewer? Boats near dam and picnic area, cabins, home to SW may have view uphill to

GEOLOGIC CHARACTERISTICS

Rock type: (Sedimentary) Igneous Metamorphic **Other description (mixed, etc.):**

Formation name: Mesaverde Formation **Outcrop description:** Shale and sandstone

		Discontinuous Fractures Orientation			*Continuous Fractures Orientation*	
CASE 1- Crystalline, jointed rock	**Structural Condition with fracture spacing**	Favorable	Random	Adverse	Adverse	
	Rock Friction/ Surface Variations	Rough, irregular	Undulating, smooth	Planar	Fracture gap-open, closed, clay, gouge infilling, or slickensided	
CASE 2- Sedimentary, or layered	**Structural Condition**	Few differential horizontal erosion features < 10%	Occasional horizontal erosion features 10 to 40%	(Many horizontal erosion features 40 to 80 %)	Major horizontal erosion features > 80%	Dip and direction: 06 at 040
	Difference in erosion	Small difference 6 to 12 inches	Moderate difference 1 to 2 ft	(Large difference 2 to 5 ft)	Extreme difference > 5 ft	

Climate and Presence of Water on Slope	Low to moderate precipitation; no freezing periods; no water on slope	(Moderate precipitation OR short freezing periods, OR intermittent water on slope)	High precipitation OR long freezing periods OR continual water on slope	High precipitation AND long freezing periods, OR continual water on slope and long freezing periods

Compatibility with Nearby Slopes (describe)	*Color*	*Texture*	*Stability*	*Other Visual Differences*
	Rock cuts similar; shotcrete too pink for natural	Rock cuts similar; shotcrete smoother than natural	Many rocks, some up to 5 ft diameter in ditch.	Rock catchment ditch full

CONSTRUCTION

Features	(Half-casts (blasting))	Machine marks (excavation-machine blade/tooth)	(Rock anchors)	(Rockfall Mitigation)	Access Road required?	Other: Bolted, draped mesh at top; shotcrete at base,10-20 ft tall; drainpipes in shotcrete; eyebolts at top of shotcrete
Excavation method	(Blasting)	Breaking	Ripping	Other: Presplit blasting and conventional blasting methods used for several fixes over the years with rock bolting and scaling. Soil nail wall with shotcrete facing constructed over softer rock layer at bottom of cut.		

PHOTO LOG

Date	*Description*	*Photo No.*	*Discussion*
11/19/2019	WB viewshed	1415	Cut in center distance
11/19/2019	EB viewshed	1451	Cut in center distance
11/19/2019	View to west	1417	Undercut sandstone in cut; shotcrete cover on lower slope
11/19/2019	View to east-northeast	1454	Shotcrete on lower slope; boulders up to 5 ft diam. In ditch

ROCK SLOPE CHARACTERIZATION

Highway: SH 133 **MP:** 24.1 **to** 24.4 **Travel direction closest to cut:** NB SB EB (WB) **Date:** 11/19/2019

Westbound viewshed, cut in center distance

Eastbound viewshed, cut in center distance

View to west, undercut sandstone, shotcrete lower slope

View to ENE, shotcrete lower slope, boulders up to 5 ft diam. In ditch

Return A23

APPENDIX D – EXAMPLE PROJECT SPECIAL PROVISION: ROCK EXCAVATION

REVISION OF SECTION 203
ROCK EXCAVATION

Section 203 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

General. This work consists of blasting, scaling, excavation, and disposal of all materials in the excavation areas in accordance with these specifications and in conformity with the limits, lines and grades shown on the plans or as established in the field by the Engineer.

Special Considerations. The Contractor shall utilize controlled blasting techniques for all excavations to reduce overbreak and to control slope contour. The Contractor shall conduct the work in a manner that ensures the safety of employees, CDOT personnel, adjacent properties, and the public. The Engineer will schedule a Rock Excavation Pre-Construction Conference prior to any rock excavation. Attendance at this conference by the rock excavation and blasting subcontractors shall be mandatory. At specified milestones in the rock excavation activities; the Engineer, the Contractor, and the rock excavation and blasting subcontractors shall meet to consult with the Landscape Architect and other CDOT Staff Branches, as deemed appropriate by the Engineer. The purpose of these meetings is to review site conditions and refine or modify rock excavation methods as necessary to achieve the project goals for safety, appearance and stability of the rock excavations as shown on the plans. Prior to these milestone meetings, the blasting subcontractor shall review the plans and the site conditions and be prepared to submit revised blasting plans that achieve the stated goals.

Milestones and activities requiring Landscape Architect Consultation:

(a) Rock Excavation Pre-Construction Conference prior to any rock excavation.
(b) At least one week prior to and during implementation of specific blasting techniques to mitigate visual impacts from rock excavation.
(c) At least one week prior to and during rock staining of test panel areas and during production stain application.
(d) At least two weeks prior to and during planting.
(e) During field location for installation of rock reinforcement, rock bolts, anchors, or other rock slope stabilization measures that will result in exposed hardware, cementitious materials, or bonding agents.
(f) During field location for installation of rockfall mitigation measures including nets, mesh, anchors and catchment ditches.

♦

The Contractor shall prevent damage outside the excavation limits, and shall prevent rocks and blast debris from entering adjacent streams, or properties. All damages resulting from rock excavation or rock over-excavation operations shall be repaired and items replaced to the satisfaction of the Engineer, at the Contractor's expense.

DEFINITIONS

Production Blasting. The controlled use of explosives and blasting accessories in carefully spaced and aligned drill holes to provide a distribution of charge that will excavate the rock to the required limits and minimize overbreak, stressing and fracturing of the rock beyond the design lines.

Controlled Blasting. The use of explosives and blasting accessories in carefully spaced and aligned drill holes to produce a free surface or shear plane along the controlled blast line.

Trim (Cushion) Blasting. A controlled blasting method involving the drilling of a single row of holes which are loaded with light, decoupled, well distributed charges and are fired either after the main excavation is removed or in the last delay of a single blast.

Pre-splitting. A controlled blasting method involving a single row of drilled holes which are lightly loaded and fired before any holes in the main excavation are fired. Pre-splitting is intended to provide stress relief which will form and typically result in a planar, more stable rock cut.

Line Drilling. A controlled blasting method, which includes a single row of closely spaced, unloaded, small diameter drilled holes providing a plane of weakness in the rock mass to which the primary blast can break.

Controlled Blast Line. The single row of holes used to achieve the results of all controlled blasting methods including trim blasting, line drilling, and pre-splitting.

Trial Blast. A blast or series of blasts to assist in determining the combination of blast parameters that are most appropriate to achieve the desired result as described in this special provision.

Final Wall Face. The remaining slope surface after all excavation is complete.

▲

CONSTRUCTION REQUIREMENTS

Pre-Construction Submittals. One week prior to the Rock Excavation Pre-Construction Conference and at least two weeks prior to start of excavation, the Contractor shall submit the following to the Engineer for approval:

(a) Copies of all Contractor's forms that shall be used to meet the requirements of this specification. At a minimum, these shall include blast design and blast report forms.

(b) Manufacturers' data sheets for all explosives, primers and initiators to be used.

(c) The proposed excavation plans and procedures, including:

(1) Equipment and methods for accessing the work area.

(2) Equipment and methods to be used for drilling, loading and firing blastholes.

(3) Equipment and methods to be used for blast monitoring

(4) Locations, dimensions and sequence of blasts.

(5) Intended direction of rock movement and delay plan.

(6) Methods of removing shot rock from the cut bench.

(7) Expected excavation rates.

(8) Methods of stabilizing or protecting adjacent structures and vegetation.

(9) Proposed method of controlling flyrock.

(10) Methods for protecting the traffic and roadway from debris produced by the Contractor's excavation operations.

(11) A description of the pre-blast warning system to be used.

(12) Method of identifying and handling misfires..

(d) Traffic control procedures and procedures for cleaning of blast debris in accordance with subsection 104.04 and the traffic control specification.

(e) Excavation plans, schedules and procedures.

(f) Rock Scaling procedures.

(g) Proof of current blasting related insurance.

(h) Seismographic equipment specifications.

(i) Documentation confirming that blasting supervisors have a minimum of five years of experience in designing, supervising, loading and firing of blasts for rock slopes or tunnel excavations, as applicable, and have all licenses and permits required by local agencies and others having jurisdiction.

Construction Submittals. Unless otherwise directed, the following shall be submitted prior to each blast as noted below:

(a) A blast design for the initial blast at each rock cut shall be submitted not later than seven days prior to beginning drilling at that cut location. A blast design shall be submitted for each subsequent blast at that rock cut or foundation excavation not later than 24 hours prior to drilling for that blast if there are differences from the original other than location. If no differences other than location between the initial blast plan and the subsequent blast plan, a plan shall be submitted 24 hours prior to the blast. Blast plans shall include the following:

(b)

(1) Location of blast.

(2) Drilling pattern, including diameters, spacing, depth, and orientation of drill holes.

(3) Types, strengths and quantities of explosives proposed for use in each hole, on each delay and for each blast.

(4) Distribution of the charge in the holes, priming of each hole and stemming of holes.

(5) Type, sequence and number of delays, delay pattern, diagram for blast, size and type of hookup lines and lead lines, and type and capacity of blast initiation device.

(6) Name and signature of blasting supervisor.

(c) Procedures for the control and disposal of water during excavation.

(d) Daily records of scaling and excavation work shall be maintained, and one copy of the record of each day's work shall be submitted to the Engineer on the following day. No further blasts may be performed until the previous blast's report is received. Daily records shall include:

(1) Locations of scaling work.

(2) A blast report for each round of blasting that includes a complete description of each blast conducted. The report shall be furnished to the Engineer no later than 24 hours after the round is fired, and shall include:

(i) Date, time and limits of blast by station and offset from centerline of roadway.

(ii) Diagram of the blast pattern and delay sequence drawn to scale with diameter, spacing, depth and orientation of drill holes. Indicate holes that were not drilled, drilled but not loaded, and changes in spacing, pattern, delays or loading of holes.

(iii) General response to drilling action (noting especially any soft zones or voids encountered) and what, if any, adjustments were made in the blast parameters as a result.

(iv) Quantity of explosives used by weight and number of cartridges per hole and per round and distribution of explosives in holes.

(v) Total number of delays used, number of holes for each delay period, maximum charge per delay and type of detonators.

(vi) Powder factor (the weight of explosives per cubic yard of rock in place as determined from the blast pattern).

(vii) Name and signature of blasting supervisor.

(viii) An evaluation of the blast indicating areas of significant overbreak and planned adjustments to the blast design for the next blast.

(ix) Unusual occurrences (including rock falls, unstable ground, groundwater problems, equipment malfunction and the location, elevation and time of each occurrence).

(x) Seismographic data.

Explosives. Explosives and Blasting Agents shall be stored in accordance with all applicable laws and ordinances. The Contractor shall submit a copy of all permits required for the storage of said materials prior to the placement. Records must be kept of the stored materials and updated daily as materials are used or added. No blasting caps or explosives greater than one year old shall be allowed for use on the project.

Excavation General. Excavation shall not extend beyond the dimensions and elevations shown on the plans except as approved by the Engineer.

The Contractor shall complete slope staking of the site prior to beginning excavation.

Excavation, rock reinforcement. stabilization, or both, carried out beyond the lines and grades shown on the plans, below or beyond that established by the Engineer, or for the convenience of the Contractor, shall be completed within CDOT owned ROW, at the Contractor's expense and with the Engineers written approval.

The Contractor shall provide surveyed points on 25 foot stations and 10 foot maximum vertical spacing, indicating grade and centerline offset on the backslope after each lift has been excavated and before drilling begins for the next lift. This work shall be performed under the supervision of a Licensed Professional Surveyor in the State of Colorado.

Excavation shall be staged to allow the installation of rock reinforcement as the cut is brought down. Drilling of the next lift shall not begin until rock reinforcement for the preceding lift is completed.

The rock on this project is not homogeneous. The Contractor shall perform trial blasts and or adjust the blast parameters as required by the existing rock conditions, in order to comply with all other specifications.

Blasts shall be conducted in conformance with the following limitations as required by the Engineer. These limitations shall remain in effect unless it is demonstrated through trial blasts that the desired results can be achieved when said limitations are exceeded.

Drilling General. The inclination of vertical holes shall not exceed a positive (no undercut) 1(Horizontal): 10 (Vertical).

Bench height shall be a maximum of 20 feet.

Blasts shall be sized such that the requirements of the traffic control specifications are fulfilled.

Maximum depth of sub-drilling for all blastholes at final grade shall be 6 inches.
Drillhole conditions may vary from dry to filled with water. The Contractor shall use explosives or blasting accessories that are appropriate for the hole conditions at no additional cost to the project.

The blast design shall take into consideration the natural joints, seams, fractures and bedding of the slope.

Where possible, hole alignment and stemming techniques shall be used to maximize the contribution of the natural slope characteristics to the final face. The Engineer will approve locations where the use of natural slope characteristics shall be used to shape the final wall face.

The Contractor shall use blasting mats suitable to prevent flyrock during each round fired if required by the Engineer. At the request of the Contractor and upon demonstration that flyrock can be prevented by other means, elimination of the blasting mat may be approved by the Engineer. Elimination of the blasting mat requirement shall not relieve the Contractor of responsibility for damages caused by blasting.

Blasts shall be designed so as not to exceed a maximum peak particle velocity (largest single component) of one inch per second measured 100 feet from the blast. If peak particle velocity exceeds this value, the Contractor shall modify charge weight per delay, sequence, and other applicable blast parameters to achieve acceptable vibration levels.

Blasting at distances less than 200 feet from concrete that has not developed 0.8 f'_c strength will not be permitted.

All blasts shall be drilled, loaded, tied-off, and detonated under the direct charge of the approved blasting supervisor.

Production Blasting. Blast parameters such as hole size, hole depth, hole spacing, burden, charge size, charge distribution and delay sequence shall be carefully designed and controlled to provide a distribution of charge that will excavate the rock to the required limits.

Production blastholes shall not exceed 3 inches in diameter when pourable explosives or emulsions are used. Packaged charges shall not exceed 3 inches in diameter when used in production blastholes that exceed 3 inches in diameter. The production blastholes shall be sequenced to provide the highest degree of relief to the final excavation surfaces.

The burden for production blastholes shall not exceed ½ the bench height.

Production blastholes shall not be drilled closer than 6 feet to the controlled blast line. The bottom of the production holes shall not be drilled deeper than the bottom of the Controlled Blast Line blastholes.

Controlled Blasting. Controlled blasting shall be used for all drill and blast operations required to carry out the work. Non-electric detonation systems shall be used.
♥

Trim blasting will be permitted on this project.

Trim blasting may be used to create the final wall face on all blasts where the distance from the cut face to the existing face is less than 15 feet, unless otherwise approved by the Engineer.

Presplitting shall be used to create the final wall face on all blasts, unless otherwise approved by the Engineer.

Line drilling shall be permitted on this project.

Pourable explosives and emulsions shall not be used in controlled blast line holes. The maximum charge diameter in controlled blast line holes shall not exceed ½ of the diameter of the hole, unless the Contractor can demonstrate through trial blasting that a greater amount of explosive is acceptable.

Controlled blast line holes shall not deviate from the neat excavation line by more than 12 inches unless directed by the Engineer. If approved, over excavation will not be paid for separately but shall be included in the cost of pay item 203 Rock Excavation as tabulated in the plan quantities.

Controlled blast line holes shall be 2 ½ to 3 inches in diameter.

The Contractor shall control drilling operations such that no controlled blast line holes shall deviate from the plane of the planned slope by more than 12 inches.

The length of controlled blast line holes shall not exceed 30 feet, unless otherwise approved.

The burden shall not exceed 1.3 times the spacing of the trim blastholes.

Pre-split holes shall extend a minimum of 30 feet horizontally beyond the limits of the production holes or to the end of the cut, whichever is less.

Pre-split holes shall be spaced such that presplitting is ensured. The spacing of presplit holes shall not exceed 14 times the diameter of the holes.

Blast Monitoring. Blast induced vibrations shall be monitored by the Contractor for every blast. Data shall be made available to the Engineer no later than the next working day following each blast. The Contractor's seismograph equipment shall, as a minimum:

(1) Be equipped with a self-triggering device.

(2) Be capable of measuring vibrations in three planes.

(3) Automatically calculate peak resultant particle velocity.

(4) Be capable of providing a hard copy of the wave form and a summary of the results.

Rock Scaling. Immediately after each blast, the Contractor shall scale loose rock and blast debris and shall inspect rock surfaces.

All rock on the cut face that is loose, hanging, or that creates a potentially dangerous situation shall be removed or stabilized, to the Engineer's satisfaction, during or upon completion of the excavation in each lift. Drilling of the next lift shall not proceed until this work has been completed.

The slopes shall be scaled throughout the duration of the Contract and at such frequency as required to remove all hazardous loose rock or overhangs.

The slopes shall be scaled using a suitable standard steel mine-scaling rod. Subject to the Engineer's approval, other methods such as machine scaling, hydraulic splitting, or incidental, low-quantity blasting may be used in lieu of or to supplement hand scaling. Rock scaling shall not be paid separately.

Traffic Control. Traffic control for blasting work shall be in accordance with the Traffic Control Plan.
The time of blast initiation for each blast shall be furnished to the Engineer by the Contractor's Traffic Control Supervisor. This notification shall occur at least 12 hours prior to the blast and shall be confirmed 30 minutes prior to the blast by phone or traffic control radio network.

Special Blasting Techniques. ♥

It may be necessary to use hand drilling, blasting, and hand excavation methods to access some of the top of cuts. For sliver cuts, pioneering the top of cuts and preparing a working platform to begin operations may require specialized working methods and equipment. The Contractor may use angle drilled holes or fan drilled holes during the initial pioneering operation to obtain the required rock face and bench.

Rock Excavation (Special) as shown in the Plans associated with wire mesh systems may also require use of hand drilling, blasting, hand excavation, and/or mechanical rock breaking methods to achieve minimum reinforcement lengths at the base of the wire mesh systems.

♣METHOD OF MEASUREMENT

Rock Excavation and Rock Excavation (Special) will not be re-measured but will be the quantities designated in the Contract. Exceptions to the plan quantities will be made when field changes are ordered or when it is determined that there are discrepancies on the plans in an amount of at least plus or minus two percent of the plan quantity. All accepted excavation shall be measured in its original position by cross-sectioning the area excavated. The Contractor shall bear the expense of excavation outside the lines and grades shown on the plans or outside the limits established by the Engineer.

All equipment and materials required to access and complete the excavation shall not be measured and paid for separately but shall be included in the cost of the work.

♣BASIS OF PAYMENT

The accepted quantities will be paid for at the unit price bid for the pay items listed below:

REVISION OF SECTION 203
ROCK EXCAVATION

Pay Item	**Pay Unit**
Rock Excavation	Cubic Yard
Rock Excavation (Special)	Cubic Yard

Payment for Rock Excavation and Rock Excavation (Special) will be full compensation for furnishing all materials, labor, tools, equipment, and incidentals necessary to complete the work.

Rock scaling associated with the blasting will not be measured and paid for as part of the Rock Scaling (Hourly) item but shall be included in the work.

Blasting will not be measured and paid for separately but shall be included in the work.

****

INSTRUCTIONS TO DESIGNERS (delete instructions and symbols from final draft):

♦ Insert appropriate project specific event or percent completion milestones. These may be when rock excavation has encountered specific geologic features identified on the plans, before or immediately after events such as: test blasts, production blasting, scaling, installation of rockfall mitigation, seeding, planting, etc. Multiple meetings and consultations should be anticipated.

▲ This list is not all-inclusive. Additional definitions of rock excavation methods may be necessary for the methods required under the **Controlled Blasting** and **Special Blasting Techniques** sections.

♥ The designer should consult with the geotechnical engineer, landscape architect, geohazards group, and other stakeholders to determine the rock excavation/mitigation methods most likely required (or disallowed) to achieve the project goals. Refer to the reports "Rock Excavation Best Management Practice Phase I" and "Phase II", the *Table of Best Management Practices*, and the *Rock Excavation Catalog by Highway Corridor* included in these reports to select rock excavation methods to be discussed here. Refer to notes and descriptive figures on the plans that show specific areas where geologic features such as joint patterns or changes in rock type, topographic features such as drainages, existing vegetation, ROW limits, geohazards, etc. dictate that certain types of blasting and excavation should be used.

♣ Method of measurement and basis of payment should be determined during the design phase. Depending on the complexity of the blasting methods required to achieve project goals, it may not be possible to calculate the Rock Excavation accurately during design. Milestone meetings and consultation with the Landscape Architect and other Staff Branches during construction could result in changes to quantities. Modern surveying techniques such as Lidar and photogrammetry make it possible to quickly and accurately measure volumes removed by excavation. Stipulate that the Construction Surveying subcontractor shall perform pre and post-excavation surveys to document quantities.