

# Emergency Relief Program Resilience Case Study – Colorado

## Reducing Risk through Rockfall Mitigation

Interstate 70 (I-70), the main east-west interstate in the State, provides a critical connection for both people and freight through Colorado and across the Rocky Mountains. On August 10, 2020, a fire broke out in the median of I-70 in Glenwood Canyon in Colorado. The Grizzly Creek wildfire grew out of control, burning over 32,000 acres. The canyon was evacuated, and the Interstate was closed for two weeks while the fire continued to burn adjacent to the highway. The flames caused significant damage to highway, bridges, fiber optic cable, signage, and other Colorado Department of Transportation (CDOT) transportation assets. The fire also triggered extensive rockfall activity that damaged additional CDOT assets, including rockfall fencing, guardrails, roadway surfaces, utility conduit, bike path and pedestrian facilities, and drainage structures. The damage from the original fire and the subsequent debris flows required over \$11 million in repairs. Motorists who needed to travel through the canyon faced a several hundred-mile, 4-hour detour.



*The Grizzly Creek fire left burn scars along I-70 in Glenwood Canyon. Source: FHWA*

Immediately following the Grizzly Creek fire event, CDOT began conducting emergency repairs to allow emergency vehicles to access the area and repair the damaged portion of I-70. CDOT also began assessing the need for permanent repairs to restore and replace the rockfall fences damaged by the fire. Because the section of I-70 through Glenwood Canyon had experienced numerous rockfall events since it was first constructed, CDOT analyzed options to improve the long-term resilience of the roadway.

### Project Snapshot

**Location:** Glenwood Canyon, Colorado

**Date of ER Event:** August 2020

**Nature of Event:** Wildfire followed by heavy precipitation

**Assets Impacted:** Interstate 70: roadway, barriers, parapet walls, electrical infrastructure, and landscaping

**Cost of Resilience Improvements:** \$2.7 million

**Type of Improvement:** Betterment, Rockfall fencing

**Economic Justification:** Benefit-cost ratio of 2.41

**Lead agency:** Colorado Department of Transportation

**Other agencies involved:** Federal Highway Administration, Colorado Division



## Resilience Features

CDOT staff followed the process outlined in its [Risk and Resilience Analysis Procedure](#), a manual for calculating risk to CDOT assets from flooding, rockfall, and fire debris flow. The manual provides standard data, assumptions, and a methodology that can be used across the State to calculate risk and resilience to inform the decision-making process for investment of Federal Highway Administration (FHWA) Emergency Relief (ER) Program funding for betterments, as well as risk-based asset management. The manual does not consider how climate change may affect geohazard impacts.

CDOT conducted debris flow modeling (i.e., modeling of how sediment and water travels down a slope) to determine the risk for small, medium, and large rockfall events, and explored many mitigation measures to reduce the damage caused by future rockfall events. CDOT used spreadsheet tools developed as part of the manual to calculate the return of investment over 1 year and 5 years for various mitigation measures. Through this analysis CDOT decided to focus on the small and medium rockfall events, for which the agency determined mitigation strategies had a high benefit-to cost ratio. In contrast, the agency determined that strategies to mitigate large rockfall events would be very costly and have minimal benefits.

Table 1 below presents CDOT’s cost benefit analysis comparing the anticipated owner consequences (i.e., costs focused on asset repairs and replacement, as well as cleanup costs where applicable) due to a realized threat over 1 year and 5 years with and without mitigation measures in place. The mitigation measures considered in this analysis included: a temporary rockfall fence, a rockfall fence designed to absorb 1 kilojoule (kj) of energy, and a rockfall fence designed to absorb 3 kj of energy.

*Table 1: Benefit-Cost Estimate of Resilience Features*

Owner consequences with no rockfall fencing (1 Year)	\$7,478,838
Owner consequences with rockfall fencing (1 Year)	\$1,000,923
<b>1 Year ER Savings (Benefits)</b>	<b>\$6,477,916</b>
Owner consequences with no rockfall fencing (5 Year)	\$18,949,679
Owner consequences with rockfall fencing (5 Year)	\$2,777,494
<b>5 Year ER Savings (Benefits)</b>	<b>\$16,172,184</b>
Estimated cost of rockfall fencing	\$2,692,000.00
<b>Benefit to Cost (1 Year)</b>	<b>2.41</b>
<b>Benefit to Cost (5 Year)</b>	<b>6.01</b>

*Notes: The cost assumptions are based on field observations of current rockfall events, historical precipitation values, freeze/thaw characteristics, and historical events. The pay items used to estimate the owner consequences is based on historical I-70 Glenwood Canyon projects and likely items to be damaged per event. The costs reflect owner costs only, and do not consider user costs, such as detour impacts. There is an assumed 20% reduction every year in rockfall likelihood as slopes re-establish stability and vegetation over a 5-year mitigation period.*

Based on the cost/benefit analysis, the FHWA Colorado Division determined that the cost of the resilience features was economically justified, as directly related to the ER Program, and, therefore, approved use of ER funding for the rockfall fences. CDOT contributed additional funds to extend the fencing beyond the ER event boundaries.

In Spring 2021, CDOT installed a temporary 7-foot-tall barrier rockfall fence, which will be removed once vegetation is re-established on the burn scar (in approximately 5 years). The agency also installed two new rockfall fences—a 1-kj fence at milepost 121 and a 3-kj fence at milepost 123—to reduce the risk of damage from future small and medium rockfall events. The rock wall fencing substantially decreased the number of closures of the roadway due to minor rockfall events and minimized disruption to the traveling public overall. In July 2021, shortly after the fences were installed, intense rainfall events caused flooding in the area. The resulting mudslides and extensive debris flow, which was a greater magnitude than the fencing was designed to absorb, destroyed some of the newly installed fencing. While it is difficult to mitigate for such low-probability extreme events, CDOT is planning to repair the fencing to minimize damage caused by more commonly experienced small and medium rockfall events.





Rockfall fencing. Source: FHWA



Section of rockfall fencing damaged by a debris flow. Source: FHWA

## Key Takeaways

The main purpose for incorporating resilience features into the project was to provide long-term mitigation of rockfall from the canyon walls. Having a standard process in place for assessing risk and resilience allowed CDOT to quickly produce the economic justification required for ER funding. By controlling the rockfall with additional and improved rockfall fencing, the resilience features are expected to generate significant long-term cost savings to the ER Program as well as for CDOT. Though not considered in the economic justification for ER funding, the rockfall fencing also should provide substantial cost savings and benefits to the traveling public and the regional economy by reducing highway closures and travel disruptions.

Building on lessons learned from this and other events, CDOT continues to utilize a quantitative risk assessment process to target improvements to its transportation system where building resilient infrastructure and making operational changes provide the greatest return on investment. In addition, CDOT has begun to investigate the impact of climate change on geohazards, and recently published [Changing Climate and Extreme Weather Impacts on Geohazards in Colorado \(2021\)](#). This agency's development of a standardized approach to analyzing risk and resilience and its research into how climate change may impact those risks may serve as a helpful example to other agencies facing risks from flooding, rockfall, and fire debris flow.

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