Canadian Consulting Engineering Awards 2017
Southern Alberta Rock Slope Stabilization & Other Work
Amec Foster Wheeler

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	Editor, Canadian Consulting Engineer magazine
Date	April 20, 2017
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1.0 Introduction

Amec Foster Wheeler would like to submit the Southern Alberta Rock Slope Stabilization & Other Work project for consideration of the Canadian Consulting Engineering Awards 2017, in the categories of:

- F. Special Projects

This project was initiated in 2013 with the preliminary design, the detailed design and tendering followed in 2014/2015 and construction was completed in 2016.

As part of Alberta Transportation's Flood Mitigation Program, Amec Foster Wheeler undertook the study of geohazard sites in southern Alberta to assess rock fall, debris flow and flood related hazards during regular climatic conditions and peak precipitation events. Three sites were identified to have high potentials for rock fall and these sites were consequently investigated, analyzed and had mitigation measures designed and implemented. One site is adjacent Crowsnest Lake on Hwy. 3:02 and the other two sites are at Mt. Baldy and Mt. Galatea on Hwy. 40:12.

The Hwy. 3 Crowsnest Lake site is 3.6 km east of the B.C. border. Designated as the Crowsnest Highway, Hwy. 3:02 connects Hope, BC with Medicine Hat, AB and carries an average of 4,200 vehicles per day. The site is subject to high winds, rapidly changing weather, heavy snow and rain, and rock fall and debris flows. At the rock fall site the highway is pinched between a near-vertical 20-50 m high cut that slices into the north base of Sentry Mountain south of the highway and to the north by Crowsnest Lake. The site is about 400 m long and is at risk from persistent, naturally occurring large rock fall. Rock fall originates from a talus slope that was undermined by the highway cut, and from a bluff on the lower portion of Sentry Mountain. An erosion gully has formed in the talus slope that releases large volumes of rock fall. Cobbles and small boulders frequently reach the highway surface, and occasionally very large rocks detach and tumble onto the road. The highway surface at this location is pitted as a result of rock falls. The Crowsnest Lake site has been part of the Southern Region Geohazard Assessment Program since 1999, when a large rock fall reached the highway centreline.

The other two rock fall sites are located on Hwy. 40:12 at Mt. Baldy and near the Galatea Creek Provincial Recreation Area, about 12 and 32 km south of Hwy 1 respectively. This section of highway is a major tourist attraction, is open year-round and carries an average of 2,400 vehicle per day. The Mt. Baldy site is located at a rock cut slope near the western base of Mt. Baldy, above the southeast shore of Barrier Lake, within the Bow Valley Provincial Park. This location has a 175 m long, near-vertical rock cut that has cobble-sized rock fall. The Mt. Baldy site has been a part of the Southern Region Geohazard Assessment Program since 2005. The Galatea site is a through-cut along the west side of a mountain labeled as "The Wedge" and includes a near vertical east cut slope with a maximum vertical height of approximately 16 m that has small boulder sized rock fall. The Galatea site has been a part of the Southern Region Geohazard Assessment Program since 2004. Both sites have frequent small rock fall deposits in the driving lanes.

2.0 Project Outline

2.1 Data Collection

Rock fall assessment required detailed topography and characterization of the rock fall source, path, and ground cover. These parameters are difficult to obtain in steep, mountainous terrain. The topography at these sites precluded conventional survey methods to collect this information. The need for high-resolution photos along with detailed survey data extending hundreds of metres beyond the rock cut area up mountain slopes required a unique approach to data collection. An unmanned aerial vehicle (UAV) equipped with photogrammetry survey equipment and complemented with terrestrial-based photogrammetry, for the steeper rock cuts, was utilized for all three sites. UAV is an emerging survey technology that enables the capture of high-resolution aerial imagery and the creation of extremely detailed digital elevation models (DEM). UAV surveys are very cost-effective compared to conventional technologies such as LiDAR, particularly for smaller sites (<15 km2) and the resulting elevation data offered a high degree of accuracy that was suitable as input for the rock fall analysis and for detailed design and drawing preparation purposes. The absolute accuracy of UAV surveys typically exceed that of conventional surveying and often yields tolerances comparable with laser scanning. The use of UAV photogrammetry was ground-breaking when the survey was completed in 2014. This was the first use of photogrammetric DEM in Canada to model rock cuts and provide a rich and robust data set for rock fall analysis. The UAV photogrammetry provided a DEM, accurate to 5 cm for bare earth areas and a high-resolution digital image. The use of UAV to achieve this level of accuracy and detail was accomplished in a fraction of the time and expense that a conventional survey could achieve. The UAV also eliminated concerns for field worker safety and the potential to cause small rock falls during the field work. Each site was scanned and processed in approximately 7 days; it is expected that process times will decrease as the technology matures. The UAV photogrammetry was viewed using simple 3D software to guide the rock fall analysis. This survey method was pivotal in the characterization of inaccessible areas at each site, and was used in conjunction with historical LiDAR survey to complete the rock fall analysis. The accuracy of the model lead to a greater confidence in the outcome of the analysis and ultimately an optimization of the final design. The high-resolution photographs were also used in the tender package to help bidders visualize the site conditions from a perspective not possible with conventional aerial photography.

2.2 Rock Fall Analysis

The Crowsnest Lake site is subject to persistent rock fall from a mountain slope above a rock cut, as well as from a talus-filled gully. Various iterations of rock fall barriers were previously installed at the talus gully to mitigate the main rock fall source but were frequently damaged, required ongoing maintenance which was difficult due to worker safety concerns, the sheer volume of rock fall debris that accumulated and the occasional large block rock fall that destroyed elements of the barrier structures. Small gravel sized debris falls continually at the talus site accumulating as a high talus cone. Large rocks are able to roll along the talus cone with high velocity and impact forces that occasionally exceeded the barrier capacity. As a result the barrier often operated in a compromised condition which put highway users at risk. A quantitative risk assessment was done that determined the rock fall frequency, and a rock fall analysis was done to estimate the quantity of rock falls that might bypass a given mitigation scheme and ultimately reach the highway. The major rain event in June 2013 caused significant rock fall along the entire 400 m long rock cut so, for the flood mitigation program, the study area was extended to the entire rock cut. The risk of rock fall to cause a fatality was calculated for several mitigative options. The risk was compared to societal risk acceptance limits to determine which mitigative options could reduce the risk to acceptable levels.

The desired outcome for the analysis on the talus gully was to determine the risk due to very large but infrequent rock falls. By using a set of probabilities and rock fall cases Amec Foster Wheeler was able to complete a probabilistic iterative analysis to evaluate various mitigative measures and quantify the risk to an individual road user on an annual basis, correlated to the life cycle cost for each mitigative measure considered. Using the results of the analysis, Alberta Transportation was able to decide on an acceptable level of risk based on a defendable, robust and thorough analysis. That level of risk was used to choose appropriate and cost effective mitigative measures. In this case, the talus rock fall mitigation was a 5 m high, 7 m wide, and 35 m long geosynthetic reinforced soil mass with a wire basket assembly filled with rock. Strips of a recycled conveyor belt were used as impact cushioning on the uphill facing aspect of the structure. This type of rock fall barrier is a first for Alberta Transportation and only the second in Canada, the other being located in Boston Bar, BC.

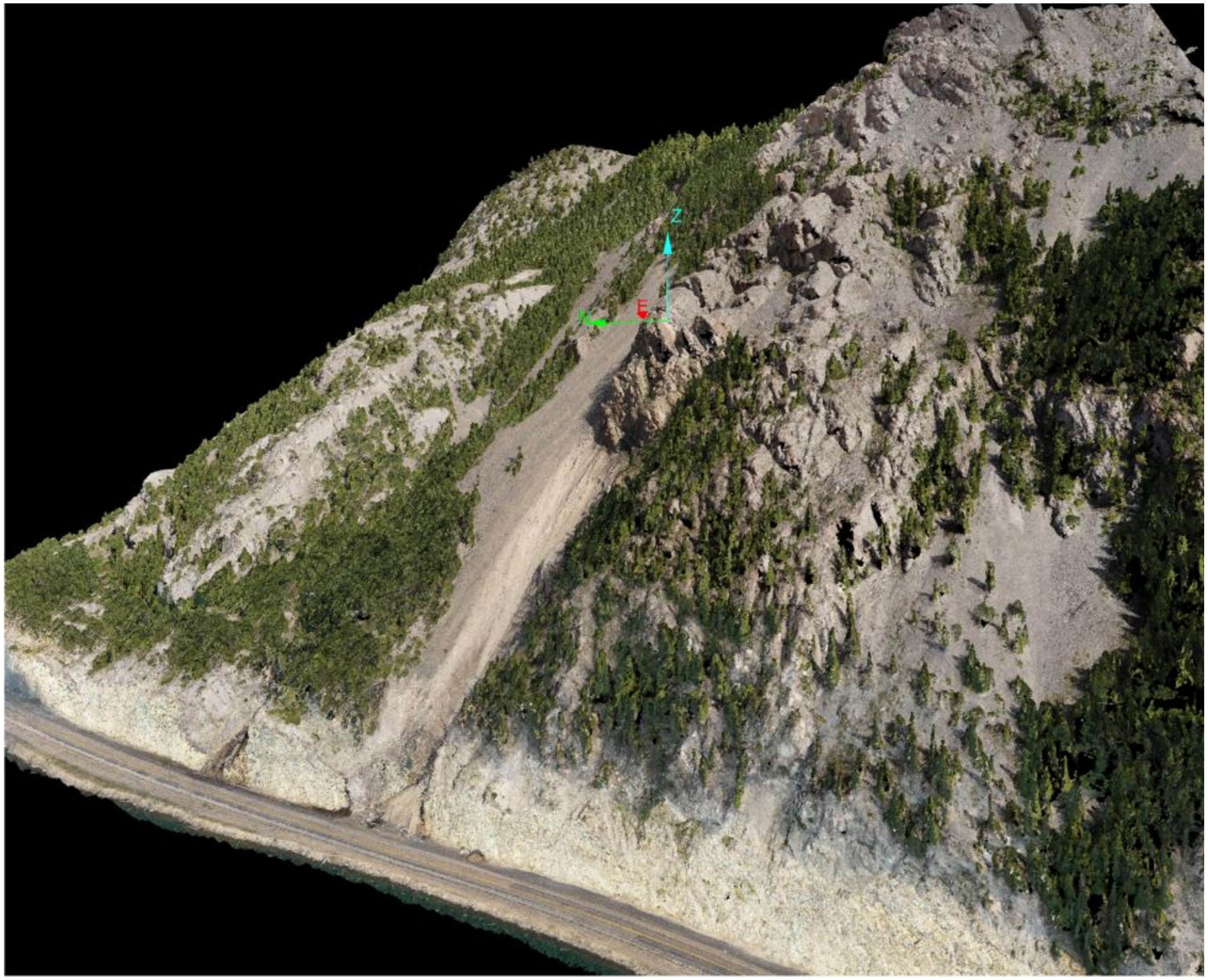
The remaining rock cut at the Crowsnest Lake site as well as those at the Galatea and Mt. Baldy Sites were evaluated using RocFall© software which modeled the percentage of rock fall that is likely to end on the road surface in a driving lane. Based on this information, Amec Foster Wheeler partitioned the rock cuts into risk intensity zones that identified the areas of rock cut where a mitigative measure was required. Alberta Transportation chose a draped wire mesh system to mitigate the rock fall from the cut slopes at each site. The purpose of the draped mesh is to contain rock fall between the cut slope and the mesh and deposit it in the ditch with minimal bounce and no travel into a driving lane. This system is based on the 2012 British Columbia Ministry of Transportation and Infrastructure (BC MoT) specifications and is routinely used in BC but had never been used by Alberta Transportation.

2.3 Wildlife Analysis

In addition to the use of a mitigation measure that was new to Alberta Transportation, there was a need to accommodate movement of Rocky Mountain Bighorn Sheep across the rock faces at both the Galatea and Mt. Baldy sites. To accomplish this, Amec Foster Wheeler completed a wildlife study using motion-activated video cameras to capture the preferred sheep routes across each rock cut. There were three (3) cameras installed at Mt. Baldy and four (4) cameras installed at Galatea between June 2017 and July 2015. There were seven (7) routes identified at Mt. Baldy, four (4) of which would be affected by the installation of slope mesh. At Galatea, four (4) routes were identified, all would be affected by mesh installation. These paths represent the most common travel paths and essential escape routes used by the sheep. Based on this study and with input from Alberta Parks and Environment, sheep path locations were chosen and the draped mesh pattern was adjusted to accommodate the paths. A post-construction monitoring program is underway to confirm that the paths are being used and to identify locations where adjustments are required. To the applicants knowledge this is the first time a study of this nature has been used for this purpose in Canada.

Figures

Figure 1



Crowsnest site as rendered with data acquired by UAV survey. In the center of the picture, the talus filled gully is visible. In the foreground, the face of the rock cut is shown.

Figure 2

Galatea site as rendered with data acquired by UAV survey. This picture accentuates the level of detail and depth of information gathered by the UAV. This rendering can be turned 360° to view the through-cut from all angels.

Figure 3

Screen capture from wildlife study video footage at the Galatea site. Sheep are seen on the right-side of the picture negotiating the rock cut slope.

Figure 4

Screen capture of wildlife monitoring post construction at the Galatea site in the same location as Figure. 2. The arrow is pointing to the slope mesh installation and sheep can be seen continuing to negotiate the rock cut slope.

Figure 5

Screen capture from wildlife study video footage at the Mt. Baldy site. Sheep are seen on the left-side of the picture negotiating the rock cut slope.

Figure 6

Screen capture of wildlife monitoring post construction at the Mt. Baldy site in the same location as Figure. 4. The arrow is pointing to the slope mesh installation and sheep can be seen continuing to negotiate the rock cut slope.

Figure 6

The Mt. Baldy site looking north-east prior to construction.

Figure 7

The Galatea site looking south-east prior to construction.

Figure 8

View of the rock cut at Galatea post construction. The mesh is barely visible from the road, making it less distracting to the travelling public.

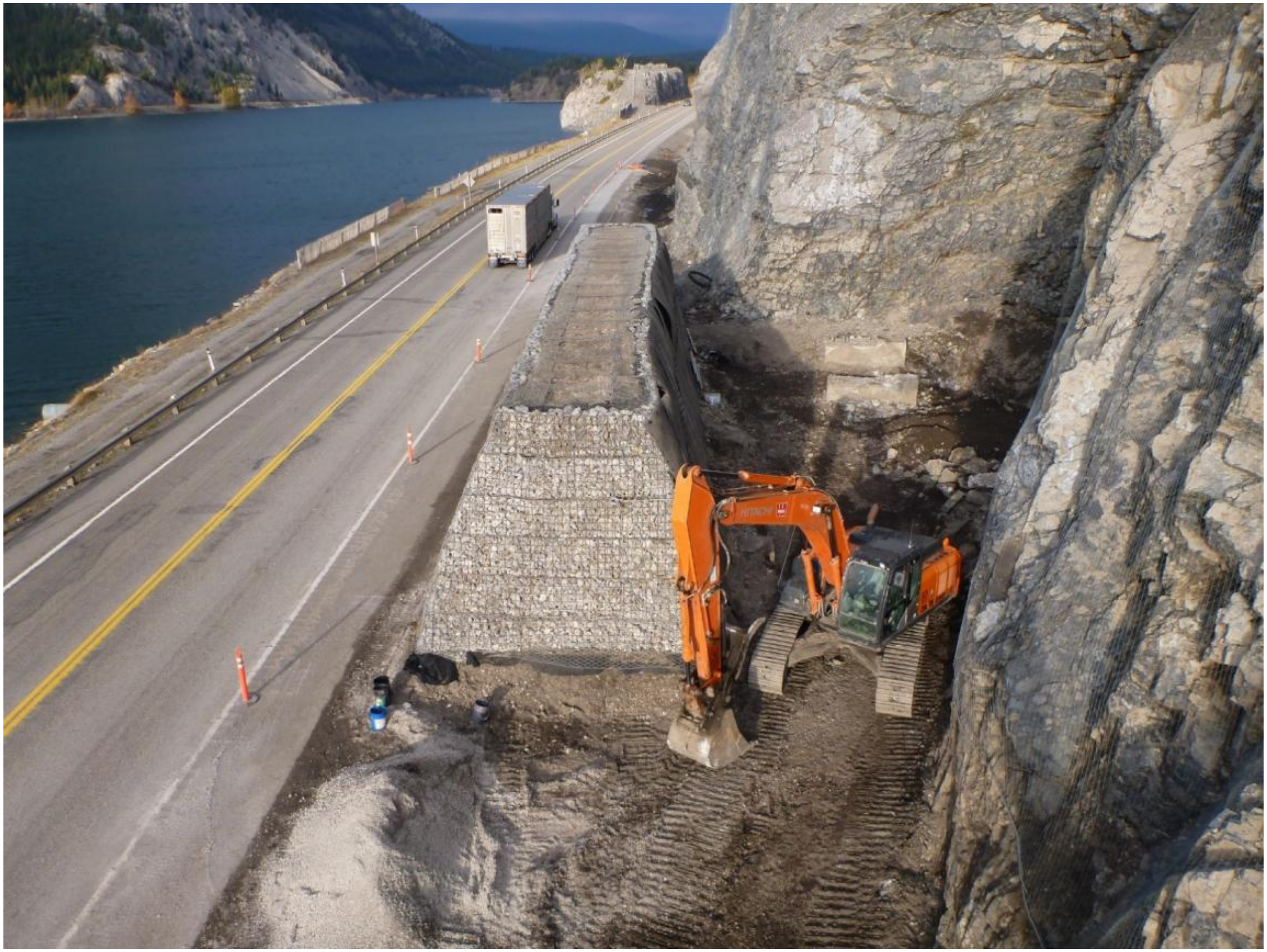
Figure 9

View of Mt. Baldy rock cut site post construction. The mesh is only visible because of the anchoring cable at the bottom of the installation. The High Tension Cable Barrier (HTCB) is being used to hang slope mesh that lines the ditch to contain rock fall where gaps in the slope mesh are present to allow bighorn sheep access. There are gaps in the mesh in the ditches to also promote bighorn sheep access.

Figure 10

Crowsnest lake talus filled gully pre-construction. Visible in the foreground is a previously installed rock fall barrier. The resulting high talus cone can be seen behind the fence filling up the ditch.

Figure 11



View from above showing the Geosynthetic Confined Soil (GCS) wall. This 5 m high, 7 m wide, and 35 m long geosynthetic-reinforced soil mass is a wire basket assembly filled with rock.

Figure 12

The completed GCS wall with strips of recycled conveyor belt used as impact cushioning on the uphill facing aspect of the structure