Site 27 – Rock Glacier Site

The Rock Glacier site is a large colluvium slope on the lower slopes of Mount Rae and along the upslope side of Highway 40 approximately 2 km southbound of the parking area at the Elbow Pass trailhead. The colluvium slope is approximately 200 m high with portions having slope inclinations of up to approximately 40°. The bedrock slopes above the colluvium are steep and expose sandstone and weathered shale.

McAffee and Cruden (1996) presented the results of research on landslides at the Rock Glacier site during which hazards from rockfalls, toppling failures and rockslides were identified. A copy of an airphoto of the site from McAffee and Cruden (1996) is attached as Figure E8. This airphoto shows the proximity of the colluvium and bedrock slopes to Highway 40 and has been further annotated as noted in the following discussion.

Rockfall Hazard

Cruden and McAffee (1996) reported high frequency/low magnitude rockfalls from steep rock slopes at this site. This is consistent with the typical conditions at many slopes in the Highwood Pass area (Gardner, 1980). The rockfalls typically consisted of rocks with diameters ranging from a few centimeters to tens of centimeters. The approximate extent of the colluvium slope where the rockfall debris is deposited is marked on Figure E8. These rockfalls present little hazard to the highway because the existing ditch is of sufficient size to prevent rocks from rolling onto the road. However, McAffee and Cruden (1996) noted that if the upslope road ditch was to be taken as the downslope limit of rockfall runout, the rockfall shadow angle at this site is 31° whereas Evans and Hungr (1993) suggested a more conservative value of 27.5° as a preliminary value for estimating the extent of rockfall runout from colluvium slopes in the Canadian Cordillera. McAffee and Cruden (1996) also reported that there were boulders on the slope below the highway that may have been deposited by rockfall runout that pre-dated the existing highway and/or were carried downslope by avalanches.

Notwithstanding the boulders downslope of the highway and the apparent rockfall shadow angle of 31°, the rockfall hazard at the highway is judged to be low based on the lack of evidence or documented reports of rocks rolling onto the road at this site since the current highway was constructed. Also, if large rocks are carried down to the highway by avalanches this would occur when this segment of the highway is closed between December 1st and June 15th of each year and therefore present no risk to motorists.

Toppling and Rockslide Hazard

The hazard to the highway from the toppling failures along the exposed bedrock slopes is low because the areas directly impacted by the topples are a significant distance

upslope of the highway. However, flexural toppling of the underdip[1] bedrock slopes above the highway can theoretically lead to a rockslide hazard to the highway. The Rock Glacier site is the best example of such a potential hazard to the highway, however similar conditions could occur on other underdip slopes of weathered bedrock above the highway on the east side of the upper Pocaterra Creek valley. The mechanism and causes of flexural toppling are detailed in McAffee and Cruden (1996) and are summarized as follows:

- Frost action and "wedging" by debris into the open topple scarps causes progressive downslope rotation of the steeply dipping beds of weathered shale.

- As the rotation of the beds increases beyond a certain point, the beds can rupture at depth (roughly around the "hinge point" of the rotation). A series of adjacent rupture points can form into a continuous surface of rupture along which there is no cohesion and a rockslide can occur under certain conditions (e.g. steep slope angle, groundwater pressure).

Figure E8 includes a cross-section adapted from McAffee and Cruden (1996) that shows the results of a slope stability analysis for the Rock Glacier site where a potential rockslide with a volume of approximately 50,000 m^3 of material was identified. The possible source area for such a slide is marked on the airphoto on Figure E8. Such a rockslide could occur as a series of smaller movements with relatively little risk to the highway, however the hazard of a single, major rockslide event cannot be ruled out on the basis of:

- Other stability analyses performed by McAffee and Cruden (1996) that illustrate that the existing slope profile at the Rock Glacier site may be the result of a single, large rockslide.

- Some of the debris in the colluvium slope above the highway was identified as possibly being deposited by large rockslides.

In addition, if there are zones of alpine permafrost in underdip slopes of weathered shale in the area around the Rock Glacier site that degrade in the future due to climate change effects, the intensity of frost action in the active layer of these slopes could increase and therefore the possibility of flexural toppling could increase.

[1] See Figure C1 in Appendix C for a definition and illustration of this term.

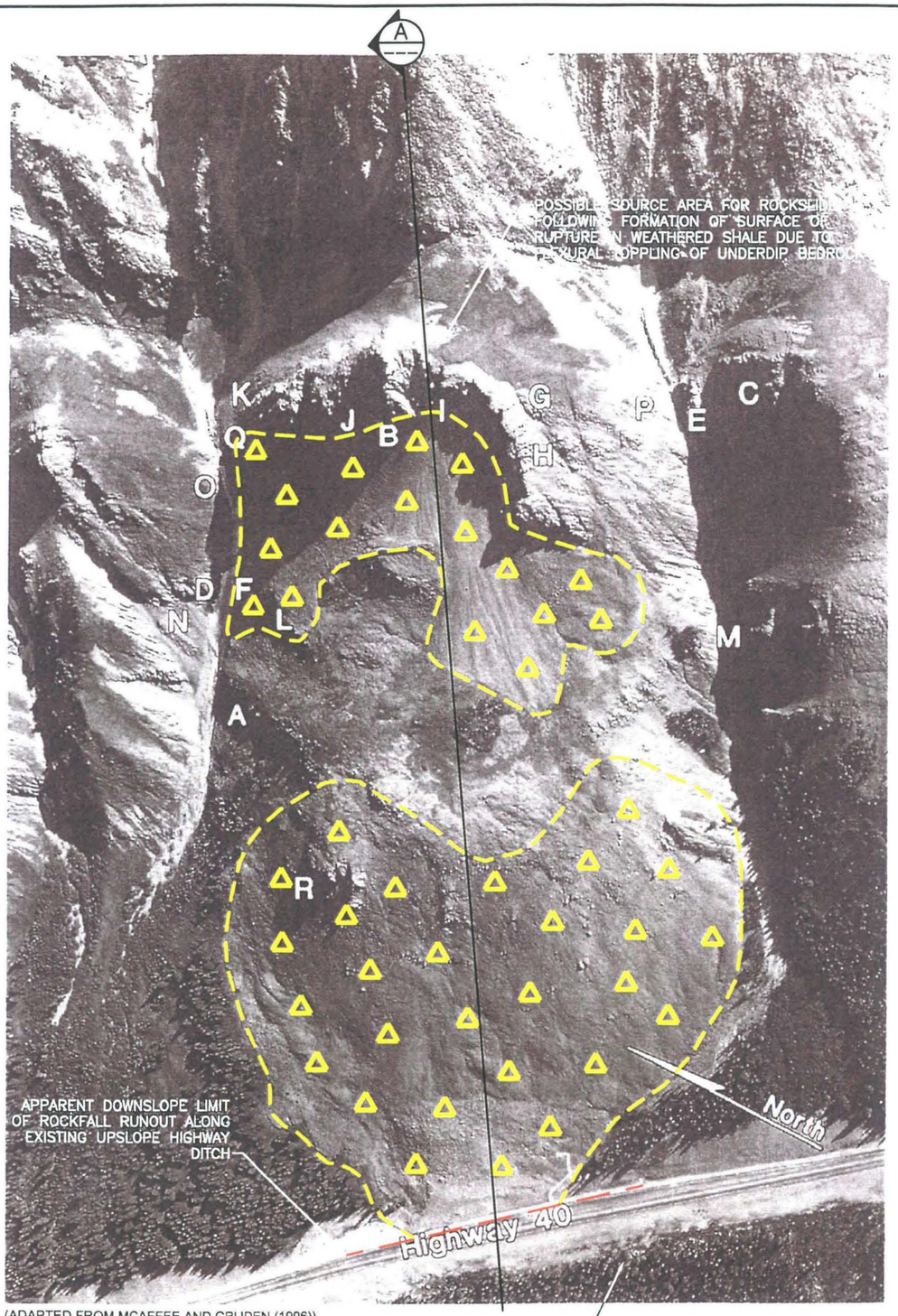
AMEC recommends the following Risk Level factors for the rockslide hazard at this site. The Risk Level factors are based on the rock fall frequency-severity matrix, but interpreted relative to the rockslide hazard.

- Probability Factor of 3 based on the low probability of rockslide occurrence.

- Consequence Factor of 2 based on a scenario where a large rockslide originates around 2300 to 2500 m elevation above the highway (see the cross-section on Figure E8) and has a similar runout distance to the possible previous rockslide deposits identified slightly upslope of the highway. Debris from such a rockslide could encroach onto the highway and require heavy equipment to clean up, however the road would likely not be completely blocked.

Therefore, the recommended Risk Level for this site is 6.

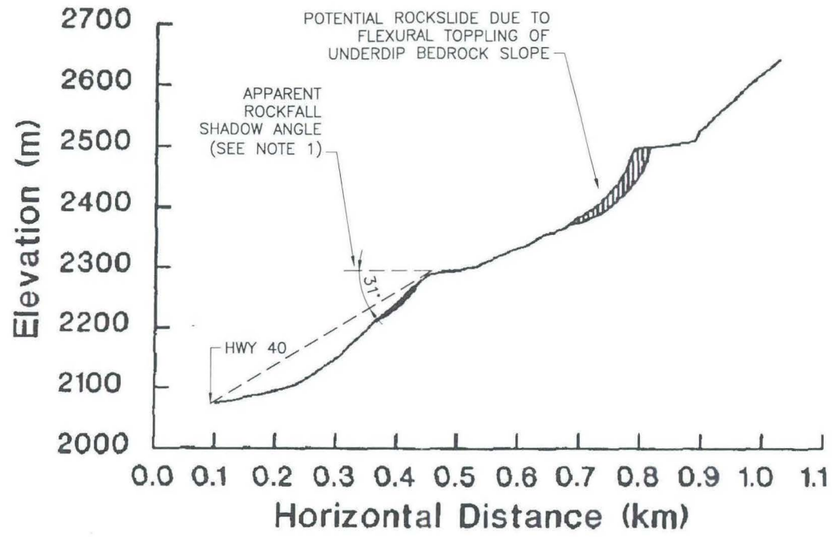
Additional work to clarify the Probability and Consequence Factors is likely not justified given the relatively low recommended Risk Level for this site in comparison to other sites along the highway corridor that have higher recommended Risk Levels that can be managed and reduced with relatively straightforward measures. However, there are satellite-based methods for the monitoring of ground movement that may be applicable to the potential rockslide hazard at this site and could possibly help to further characterize the slope stability conditions at this site and clarify the Risk Level relative to a large rockslide. AMEC understands that the Alberta Geological Survey (AGS) is considering the application of such methods to slope instability sites in Alberta. The Rock Glacier site may be a good candidate site for this work. AMEC recommends that the AGS be contacted to review the Rock Glacier site for this purpose.



(ADAPTED FROM MCAFFEE AND CRUDEN (1996))

SCALE
1: 5000
0 50 100 m

BOULDERS NOTED DOWNSLOPE OF HIGHWAY – APPARENT ROCKFALL RUNOUT PREDATING THE HIGHWAY (REPORTED IN MCAFFEE AND CRUDEN (1996))



(ADAPTED FROM MCAFFEE AND CRUDEN (1996))

A SECTION

LEGEND:

A — TOPPLING SITES IDENTIFIED IN MCAFFEE AND CRUDEN (1996)

APPROXIMATE EXTENT OF COLLUVIUM FROM HIGH FREQUENCY/LOW MAGNITUDE ROCKFALLS (ONGOING PROCESS). ALSO INCLUDES POSSIBLE ROCKSLIDE DEPOSITS FROM FLEXURAL TOPPLING AREA FURTHER UPSLOPE.

NOTES:

1. APPARENT ROCKFALL SHADOW ANGLE TO UPSLOPE EDGE OF HIGHWAY IS 31°. MCAFFEE AND CRUDEN (1996) NOTED BOULDERS DOWNSLOPE OF HIGHWAY 40 THAT MAY INDICATE A ROCKFALL SHADOW CLOSER TO 27.5° AS SUGGESTED IN EVANS AND HUNGER (1993).

amec Earth & Environmental

CLIENT: Alberta Infrastructure and Transportation

PROJECT: HWY 40/HWY 541 GEOHAZARDS REVIEW

TITLE: ROCK GLACIER SITE

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
DECEMBER 2005	CG25211	25211N03.dwg	FIGURE E8	A