Golder Associates

TECHNICAL MEMORANDUM

DATE August 3, 2016

STANDING OFFER AGREEMENT 5P420-15-5004/001
CALL UP # 15
GOLDER DOCUMENT NO. 1659658_TM0001_Rev 0

TO Ryan Syme
Highway Engineering Services, Parks Canada

CC Selina Fong
McElhanney Consulting Services Ltd.

FROM Brock Simons **EMAIL** Brock_Simons@golder.com

GEOTECHNICAL SITE VISIT REPORT, MT BOSWORTH YOHO NATIONAL PARK

1.0 INTRODUCTION

McElhanney Consulting Services Ltd. (McElhanney) is coordinating an evaluation of avalanche mitigation options associated with Trans-Canada Highway, Mt. Bosworth, Yoho National Park, BC. Golder Associates Ltd. (Golder) was retained by Parks Canada Agency (PCA), by the departmental representative Highway Engineering Services (HES), to provide preliminary geotechnical services to assist with this mitigation program.

It is understood that Remote Avalanche Control Systems (RACS) are being considered for installation in proximity to three avalanche paths on the south flank of Mt. Bosworth approximately 13 km west of Lake Louise, Alberta. These avalanche paths are identified as slide paths 3, 4 and 5 in a report by McElhanney Consulting Services Ltd., dated February, 2013 and titled: Trans-Canada Highway, Avalanche Risk Management Mount Bosworth, Remote Avalanche Control System Study. Figure 1 shows the overall site plan.

The geotechnical services and reporting were carried out in general accordance with the scope of work provided in Golder's proposals dated June 14, 2016. The purpose of this preliminary geotechnical report is to assess the constructability of each avalanche system based on ground conditions, and to provide general geotechnical comments and recommendations for consideration during the design process. The environmental assessment aspects of the project and Basic Impact Analysis (BIA) are addressed in Golder's Phase II BIA, which is presented separately.

2.0 PROJECT UNDERSTANDING

2.1 Anticipated Works

It is understood that four avalanche mitigation works are currently being considered for the Bosworth site; Wyssen Tower, Avalanche Guard, Gazex Inertia Exploder and O'Bellx. The specific locations or specific types of installations are yet to be determined and the descriptions of the installations are provided below based on available product descriptions as well as product review information forwarded by McElhanney. The avalanche mitigation equipment locations are intended to be chosen so that the installations can reliably affect the explosion target zones (avalanche start zones) shown on Figure 2.

2.1.1 Wyssen Tower

Wyssen Tower is a secure explosive magazine system that is placed slightly above the avalanche start zone. The carrier is a tower (or a cantilever extending from a rock wall) designed to withstand snow creep, snow settlement, small rock falls, heavy riming, wind gusts, and other severe alpine conditions. Its design depends on the location. The foundations for the towers are small (approximately 1 m by 1 m) and, depending on the ground conditions, may be anchored directly to sound rock or may have a small, cast-in-place concrete base. Rock anchors or micro-piles are typically used as anchors.

2.1.2 Avalanche Guard

In the Avalanche Guard system, the magazine is located in a convenient, safe location up to 150 m from the avalanche start zone. The footprint of the base is small (less than a few metres square) and will be anchored to the ground using rock anchors or micro-piles. Anchor depths and extent of excavation for base preparation will depend on rock quality.

2.1.3 Gazex

The Gazex Inertia Exploder system is articulated at the base and rests on a mobile counterweight system that absorbs the upwards forces from the blast. The base area for this system is somewhat larger than the other systems considered and would likely consist of a cast-in-place concrete base anchored to the ground. Depending on installation location and rock quality, some ground preparation might be required to remove surficial loose materials prior to placing the base.

Each exploder has gas lines running to it from a shelter that is built above the slide path on even ground free of rock fall hazard. Each shelter can service multiple exploders and has a relatively small footprint.

2.1.4 O'Bellx

O'Bellx is self-contained and does not require a separate shelter for gas storage or installation of pipes. Relative to the Gazex system, O'Bellx is easier to install, with simpler anchoring requirements and smaller foundations. However, the size of the denotation is substantially smaller, potentially requiring additional units to cover the same area controlled by a comparable Gazex system. The module weight is about 630 kg and must be installed in the start zone of the avalanche path. The system is anchored to a concrete sole plate by four GEWI bars or by a deadweight.

3.0 REVIEW METHODOLOGY

The understanding of the geological / geotechnical conditions at the Mt. Bosworth site is based on published geological information along with the results of a helicopter reconnaissance undertaken on June 23, 2016.

This report presents the results of this study and the available geological information is interpreted in the context of the proposed foundation installations and civil works, by providing general geotechnical comments that relate to the project development. Further, comments and recommendations for further investigation and/or construction review are provided.

The Bosworth Mountain avalanche zone consists of several potential avalanche paths though only slide paths 3, 4 and 5 are intended to be part of this mitigation program.

4.0 GEOLOGICAL INFORMATION

4.1 Bedrock Geology

Based on the British Columbia digital bedrock geology map (BCGS, 2015), the bedrock in the general vicinity of the avalanche start zones for the Mount Bosworth site is comprised of Middle Cambrian age sedimentary rock of the Eldon Formation, the Stephen Formation and the Cathedral Formation. The bedding orientations of these formations is relatively consistent in this area and strikes approximately NNW / SSE and dips moderately (20 to 25 degrees below horizontal) to the west.

The Eldon Formation is exposed at (and below) the mountain crest for Bosworth avalanche zones 3 and 4 and is recorded to be formed primarily of limestone noted to be massive (relatively thick bedded); micritic, grey, dolomite-mottled; with dolomitized equivalents. The Eldon Formation overlies the Stephen Formation.

The Stephen Formation is recorded to be interbedded grey to green shale and limestone, and is more thinly layered than the overlying and underlying formations. It is believed that this formation is evident on the mountain slope as a darker grey, usually cliff forming zone (apparent in the lower left corner of Photo 29). The Stephen Formation overlies the Cathedral Formation.

The Cathedral Formation forms the eastern half of the mountain crest within Bosworth avalanche zone 5. It is similar to the Eldon Formation and is also recorded to be formed primarily of limestone noted to be massive (relatively thick bedded); micritic, grey, dolomite-mottled; with dolomitized equivalents.

A near vertical fault is recorded within the study area. The fault strikes NNW / SSE with the surface trace of the fault more or less along the Bosworth avalanche track 5. The fault dips steeply to the west and the materials on the west side of the fault are recorded to be downthrown with respect to the east side.

4.2 Surficial Geology

The bedrock described in Section 4.1 is exposed over most of the areas around the explosion targets identified for slide paths 3, 4 and 5 (see Figure 2). Where exposed, the bedrock is expected to be significantly fractured due to freeze – thaw processes. The depth of this fracturing is not known but is expected to be at least a few metres and is also expected to diminish with depth below the surface.

Where the rock is not exposed at the surface, it is covered with thin, discontinuous wedges of colluvial material (mostly talus) derived from exposed bedrock higher on the slope. The colluvial material is expected to be generally coarse, with particle sizes ranging from several centimetres to generally less than 1.5 m. Significantly larger fragments of rock also exist on the slope and some locations also appear to have a silt / sand matrix within the coarse colluvial deposit. The thicknesses of the colluvial deposits are probably less than a few metres, but may be significantly thicker locally.

Photos for each of avalanche paths are presented in Appendix A. A heading at the top of each photo page identifies the avalanche path to which the photo refers.

4.3 Review of Remote Sensing Data

LiDAR data is not currently available for this site. Stereo air photos are available but were not reviewed for this work.

5.0 GEOTECHNICAL ENGINEERING CONSIDERATIONS

Based on the findings of the review of available published geological information, the conditions observed during the site reconnaissance and our understanding of the potential installations, the following general geotechnical engineering considerations are provided for the Bosworth avalanche area.

The geotechnical comments and recommendations outlined below are based on limited information and are preliminary in nature.

- No overall slope stability issues have been identified that would preclude building the proposed structures at this site.
- Reasonable bearing conditions for spread footing support of the proposed installations appears to be generally available in the vicinity of the proposed explosion target zones as well as other areas where RACS might be installed. As discussed below, however, the near surface materials are fractured and relatively loose and some removal of this material is recommended to prepare foundation areas prior to placement of footings. Given the mountain slope situation for these installations, it will likely prove impractical to excavate sufficiently at most footing locations to provide adequate, reliable support for the proposed structures solely through the footing bearing surface. As a consequence, it is recommended that drilled anchors or drilled micro-piles be incorporated into all but non-critical foundations.
- Although the bedrock is not considered to be frost susceptible, the surficial zone is likely to be fractured due to freeze/thaw processes. Chosen foundation sites on bedrock will likely still require some preparation to remove loose material. Anchor depths and the extent of excavation will depend on the sites chosen and the tolerance of the installation for seasonal movement and multi-year accumulations of that movement.
- The colluvial materials may locally contain enough silt / sand sized material to be frost susceptible, however, these materials are still expected to provide adequate foundation support for the proposed structures, subject to the following comments:
  - Some removal of surficial, loose materials and open-work coarse rock will be required to adequately prepare foundation areas. Careful site selection can minimize this need.
  - The prepared subgrade should be reviewed by qualified geotechnical personnel to confirm that reasonably competent foundation material has been reached that meets the design needs of the foundation and the installation it supports.
- The use of rock anchors as a component of the proposed foundations is considered to be geotechnically feasible. It is anticipated that the intact bedrock could be characterized as ‘medium strong’ to ‘strong’ (R3 - R4) and would generally be expected to have a uniaxial, unconfined compressive strength ranging from about 25 MPa to 100 MPa (Zhang 2005). The rock is expected to be variable both vertically and horizontally and layers of weaker rock (R2; unconfined compressive strength ranging from 5 MPa to 25 MPa) may be encountered in individual anchor holes. As noted below, the bedrock near the surface is expected to be significantly fractured and should not be included as a part of the anchor design. For design assumption purposes, the upper 1.5 m of in-place, but significantly fractured bedrock should not be included as part of the resisting zone for the anchors.
- For anchors placed within colluvial materials, the anchors should be designed assuming that the colluvial materials can be considered to be a compact to dense, cohesionless material. For anchors placed in such conditions, the upper 3 m of the anchors should not be included as part of the resisting zone.

- Most of the target explosion locations are within areas that are subject to active rockfall. Based on the helicopter reconnaissance, it doesn't appear practical to thoroughly scale the slopes above explosion target locations 3-2, 4-1, 4-2, 5-1 and 5-2 (Figure 2). Scaling of loose material should be undertaken above these sites wherever practical, though significant rockfall hazard will likely continue to exist at those locations. This continuing hazard should be considered in site selection, development of safe work procedures and long term operation and maintenance of the installations.
- Explosion target location 3-1 is likely of lower hazard for rockfall since it is closer to the mountain crest. Explosion target location 5-3 may also be relatively lower hazard risk of rockfall since it is located in an area of shallower slope conditions. It appears to be practical to scale potential rockfall hazards that could affect these two worksites and such scaling should be carried out.

6.0 FUTURE WORK

It is understood that the detailed design and location choices for the proposed facilities will be established as part of the successful contractor's design. It is recommended that the detailed drawing submissions be reviewed by the geotechnical engineer.

Further, it is recommended that geotechnical site review of the foundation preparation work be undertaken at the time of construction.

7.0 CLOSURE

We trust that this report provides the information that you require at this time. Please do not hesitate to contact the undersigned if you have any questions or need clarification. Golder appreciates the opportunity to be of service on this project.

Yours truly,

GOLDER ASSOCIATES LTD.

Doug Pelly, P.Eng.
Senior Geotechnical Engineer

Robert Armstrong, M.Sc., P.Eng.
Senior Geotechnical Engineer

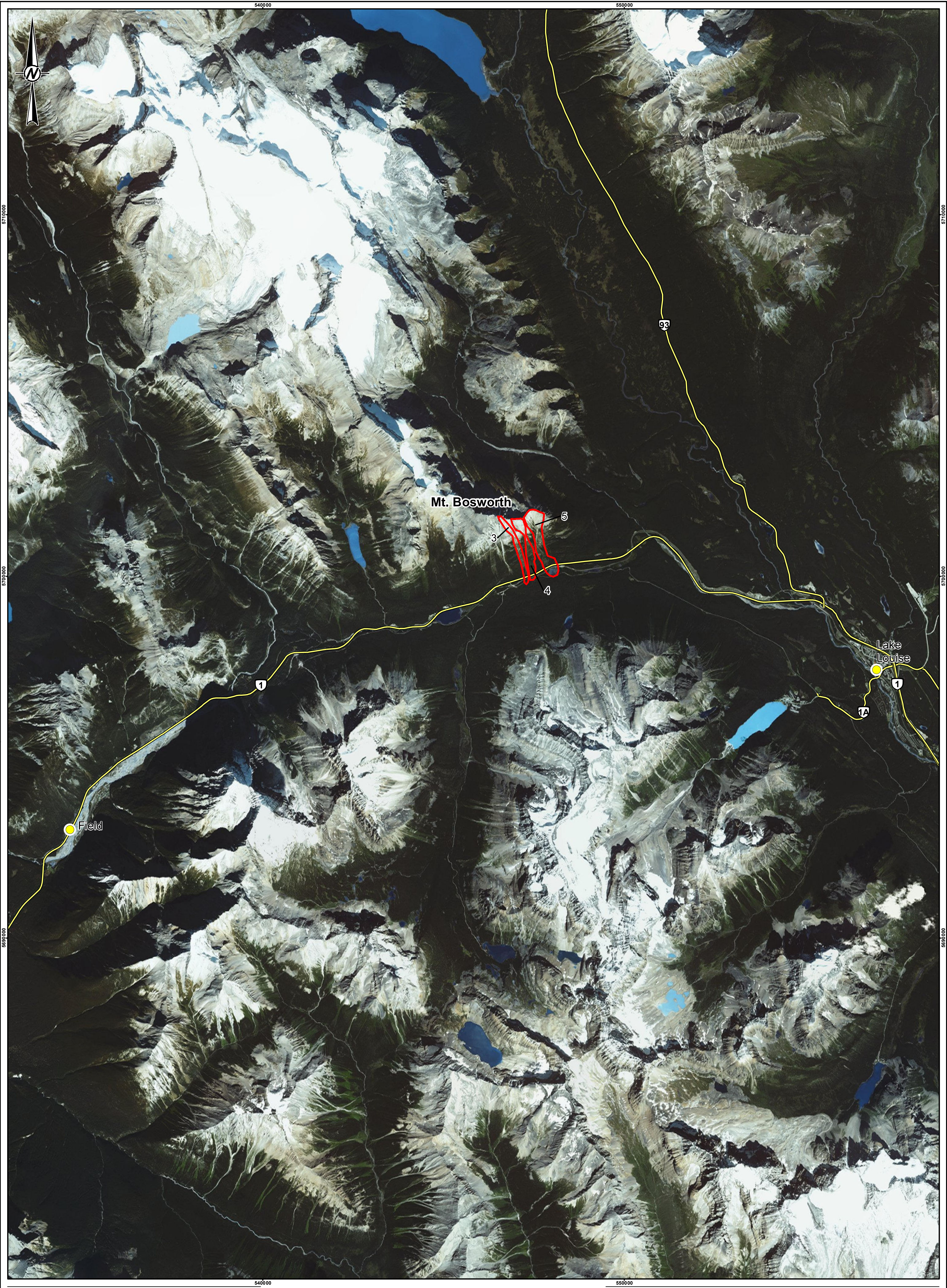
MS/DP/BS/RCA/sb

Attachments: Figure 1: Overview of Project Area
Figure 2: Target Explosion Locations
Appendix A: Photos

https://capws.golder.com/sites/1659658pcayohonpcu15mtbosworth/geotechnical assessment/geotechnical assessment - site recon/rev 0/1659658_tm0001_bosworth site recon_rev 0.docx

FIGURES

Figure 1: Overview of Project Area
Figure 2: Target Explosion Locations



LEGEND

- POPULATED PLACE
- HIGHWAY
- SLIDE PATH

0 2 4

1:100,000 KILOMETRES

REFERENCE(S)

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3. BC HIGHWAY AND POPULATED PLACE DATA OBTAINED FROM IHS ENERGY INC.
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DATUM: NAD 83 P ROJECTION: UTM ZONE 11

CLIENT
PARKS CANADA

PROJECT
TRANS-CANADA HIGHWAY AVALANCHE MITIGATION – YOHO NATIONAL PARK

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-08-02
DESIGNED	MS
PREPARED	SS
REVIEWED	RCA
APPROVED	VBS

TITLE
OVERVIEW OF PROJECT AREA

PROJECT NO.	CONTROL	REV.	FIGURE
1659658	2000	0	1

PATH: I:\CLIENTS\PARKS_CANADA\1659658\Mapping\MXD\General\Fig2_MtBosworth_TargetExplosionLocation_Rev0.mxd PRINTED ON: 2016-08-02 AT: 4:54:24 PM

LEGEND

- TARGET EXPLOSION LOCATIONS
- TRANS-CANADA HIGHWAY KILOMETRE POST WITHIN YOHO NATIONAL PARK
- RAILROAD
- TRANS-CANADA HIGHWAY (TCH)
- WATERCOURSE
- SLIDE PATH
- WATERBODY

0 400 800

1:12,000 METRES

CLIENT
PARKS CANADA

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-08-02
DESIGNED	MS
PREPARED	SS
REVIEWED	RCA
APPROVED	VBS

NOTE
TARGET EXPLOSION LOCATIONS ARE DIGITIZED FROM A PDF DOCUMENT AND ARE APPROXIMATE.

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DATUM: NAD 83 P ROJECTION: UTM ZONE 11

PROJECT
TRANS-CANADA HIGHWAY AVALANCHE MITIGATION – YOHO NATIONAL PARK

TITLE
TARGET EXPLOSION LOCATIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1659658	2000	0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

APPENDIX A
Photos

GENERAL SITE PHOTOS

Photo 1: Mount Bosworth

Photo 2: Mount Bosworth slide paths 3, 4, and 5 (west to east)

Photo 3: Mount Bosworth looking north west

Photo 4: Facing south at Trans-Canada Highway from crest of avalanche slide paths

SLIDE 3 PHOTOS

Photo 5: Slide path 3, upper part

Photo 6: Slide path 3, middle part

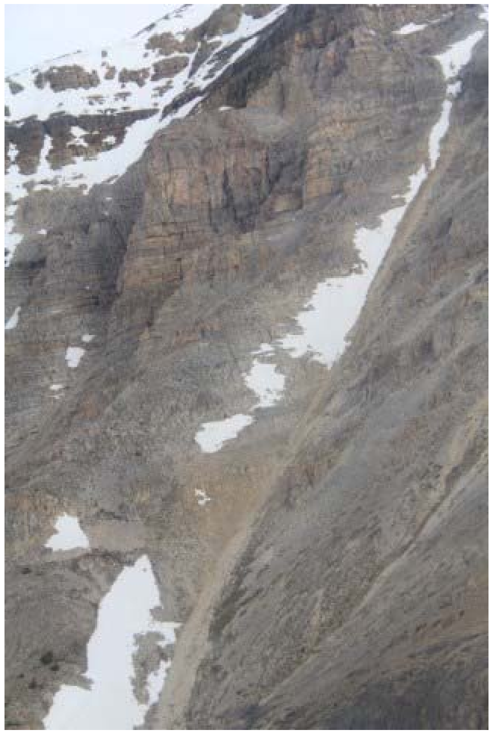

Photo 7: Slide path 3, middle part

Photo 8: Slide path 3, upper part

Photo 9: Slide path 3, middle part

Photo 10: Slide path 3 – loose surficial material at crest

Photo 11: Slide path 3 – fractured and loose surficial material at crest

Photo 12: Slide path 3 – fractured and loose surficial material at crest

Photo 13: Slide path 3 – Potential helicopter landing zone at the crest, just west of slide path 3.

Photo 14: Slide path 3 – Same as previous photo, broader view

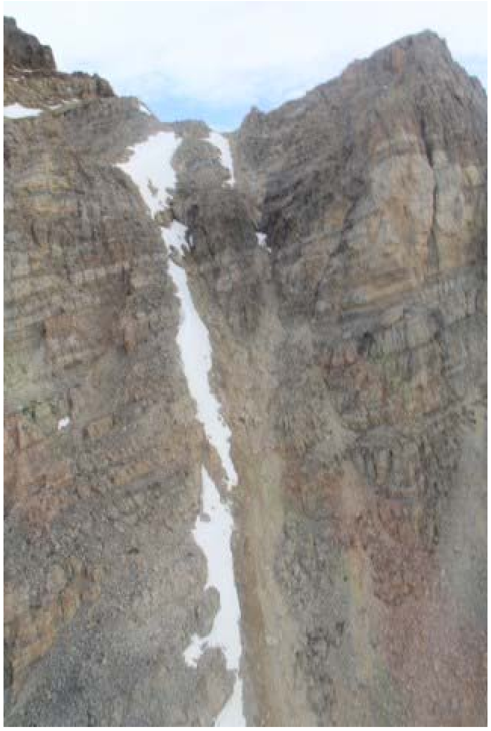

Photo 15: Slide path 3

Photo 16: Slide path 3

Photo 17: Slide path 3 – loose surficial material

Photo 18: Slide path 3 – Potential helicopter landing location (center of photo), west of slide path 3

Photo 19: Slide path 3 – Same as previous photo, broader view

SLIDE 4 PHOTOS

Photo 20: Slide path 4

Photo 21: Slide path 4

Photo 22: Slide path 4

Photo 23: Slide path 4 – loose surficial materials

Photo 24: Slide path 4 – loose surficial materials appear to include a silt/sand matrix

Photo 25: Slide path 4

Photo 26: Slide path 4

Photo 27: Slide path 4 – loose surficial materials appear to include a silt/sand matrix

Photo 28: Slide path 4 – loose surficial materials appear to include a silt/sand matrix

Photo 29: Slide path 4, Stephen Formation (dark grey) forms cliff at lower left

Photo 30: Slide path 4

Photo 31: Slide path 4

Photo 32: Slide path 4 – loose surficial materials, and whitebark pine.

Photo 33: Slide path 4 – loose surficial materials

Photo 34: Slide path 4 – Potential helicopter landing pad

Photo 35: Slide path 4 – Same area as previous photo, broader view. Potential landing pad in upper left corner of photo

Photo 36: Slide path 4 –loose surficial materials

SLIDE 5 PHOTOS

Photo 37: Slide path 5

Photo 38: Slide path 5 – looking east at Trans-Canada Highway

Photo 39: Slide path 5

Photo 40: Slide path 5

Photo 41: Slide path 5 – loose surficial materials

Photo 42: Slide path 5

Photo 43: Slide path 5 – helicopter landing site at crest

Photo 44: Slide path 5 – loose surficial materials

Photo 45: Slide path 5 – loose surficial materials

Photo 46: Slide path 5 – loose surficial materials

Photo 47: Slide path 5 – looking south at Trans-Canada Highway

Photo 48: Slide path 5 – loose surficial materials

Photo 49: Slide path 5 – Same area as previous photo, closer view