MCELHANNEY CONSULTING SERVICES LTD

MT. STEPHEN
REMOTE AVALANCHE CONTROL SYSTEMS

PRELIMINARY GEOTECHNICAL AND GEOHAZARDS ASSESSMENT

FINAL

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January 25, 2019
Project No.: 1572-002

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Dear Ms. Sanderson,

Re: Mt. Stephen Remote Avalanche Control Systems: Preliminary Geotechnical and Geohazards Assessment

Please find attached a copy of the above referenced report for your review and comment. It characterizes geotechnical foundations conditions and geological hazards for the proposed Remote Avalanche Control Systems at Mt. Stephen, Yoho National Park, southeast British Columbia.

Should you have any questions or concerns, please do not hesitate to contact the undersigned.

Yours sincerely,

BGC ENGINEERING INC.
per:

Sam Fougère, M.Sc., P.Geo.
Senior Engineering Geologist

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LIMITATIONS

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1.0 INTRODUCTION

McElhanney Consulting Services Ltd. (McElhanney) is coordinating an evaluation of avalanche mitigation options for Mt. Stephen, Yoho National Park, British Columbia. Avalanche start zones near the summit, mid ridge, col area, and ridges farther downslope are under consideration for remote avalanche control system (RACS) placement (Figure 1-1 Figure 1-2; Appendix A; Figure A1). The RACS are intended to reduce snow avalanche hazard at the Trans-Canada highway at the base of the slope through timely activation of controlled avalanches (Figure A1).

As part of the RACS design process, McElhanney retained BGC Engineering Inc. (BGC) to conduct a field-based preliminary geotechnical and geological hazard assessment of the proposed Mt. Stephen RACS sites. This report documents BGC's preliminary assessment of the proposed Mt. Stephen RACS sites, including field observations, rock mass characterization, geohazard potential, and preliminary geotechnical recommendations for RACS foundation design inputs.

This work was carried out at the request of McElhanney's Ms. Jaime Sanderson under terms and conditions outlined in BGC's August 31, 2018 proposal and McElhanney's September 4, 2018 sub-consultant agreement with BGC. Field review for this assessment was completed on September 5, 2018 by Mr. Sam Fougère, P.Geo. (BGC) with Ms. Jaime Sanderson, EIT (McElhanney), Mr. Chris Argue and Ms. Penny Goddard (Dynamic), Mr. Grant Statham and Mr. Trevor Kinley (Parks Canada Agency).

1.1. Scope of Work

The scope of work for the preliminary geotechnical and geohazards assessment of proposed RACS installation locations on Mt. Stephen included:

- Characterization of the general geotechnical foundation conditions in the area of the proposed RACS locations on Mt. Stephen. The exact physical location of the proposed RACSs is unknown. Exact locations will be determined by others in later design stages.
- Assessment for rock fall, landslide, or other geological hazards that could affect the RACS installation or worker safety from a geohazard perspective (excluding snow avalanche hazard).
- Estimation of rock mass properties that are suitable for preliminary use by others to guide design of RACS foundations and anchors (based on field observations only).
- Documentation.

The purpose of the work is to provide geotechnical and geohazard documentation for others to advance the RACS design on Mt. Stephen. Typical RACS require reinforced concrete foundations and anchorage to the underlying soils or bedrock.

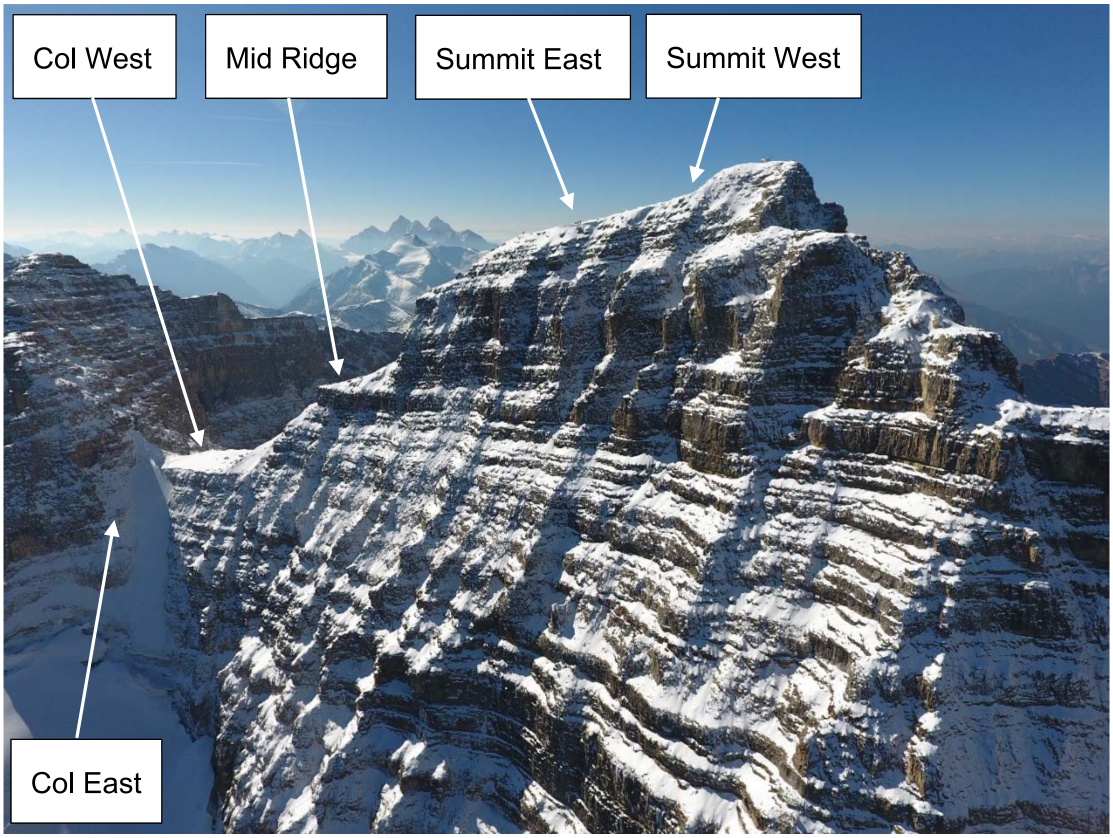

Figure 1-1 Looking to the southwest towards the proposed RACS locations on Mt. Stephen (UAV photograph September 5, 2018).

1.2. Background

Snow avalanches initiating from Mt. Stephen have the potential to impact the Canadian Pacific Railway line and the Trans-Canada highway approximately 4.5 km northeast of Field, British Columbia. Parks Canada Agency (Parks) performs helicopter-based avalanche control to reduce the exposure to snow avalanche hazards to vehicle occupants on the highway. The high avalanche starting zones between 3,000 and 3,200 m elevation are challenging to reach during adverse weather conditions; thus, limiting the effectiveness of the avalanche control program.

Preliminary design of the RACS for Mt. Stephen is under consideration. Based on discussions with McElhanney and Parks, BGC understands that industry-typical RACS's will be proposed. RACS's have several advantages for avalanche control, including:

- Increased effectiveness of avalanche control (through remote access unaffected by weather considerations)
- Increased efficiency of the avalanche control program due to decrease staffing requirements
- Increased worker safety due to a reduction of worker exposure in high risk environments (i.e. reduced helicopter flying time in poor weather conditions).

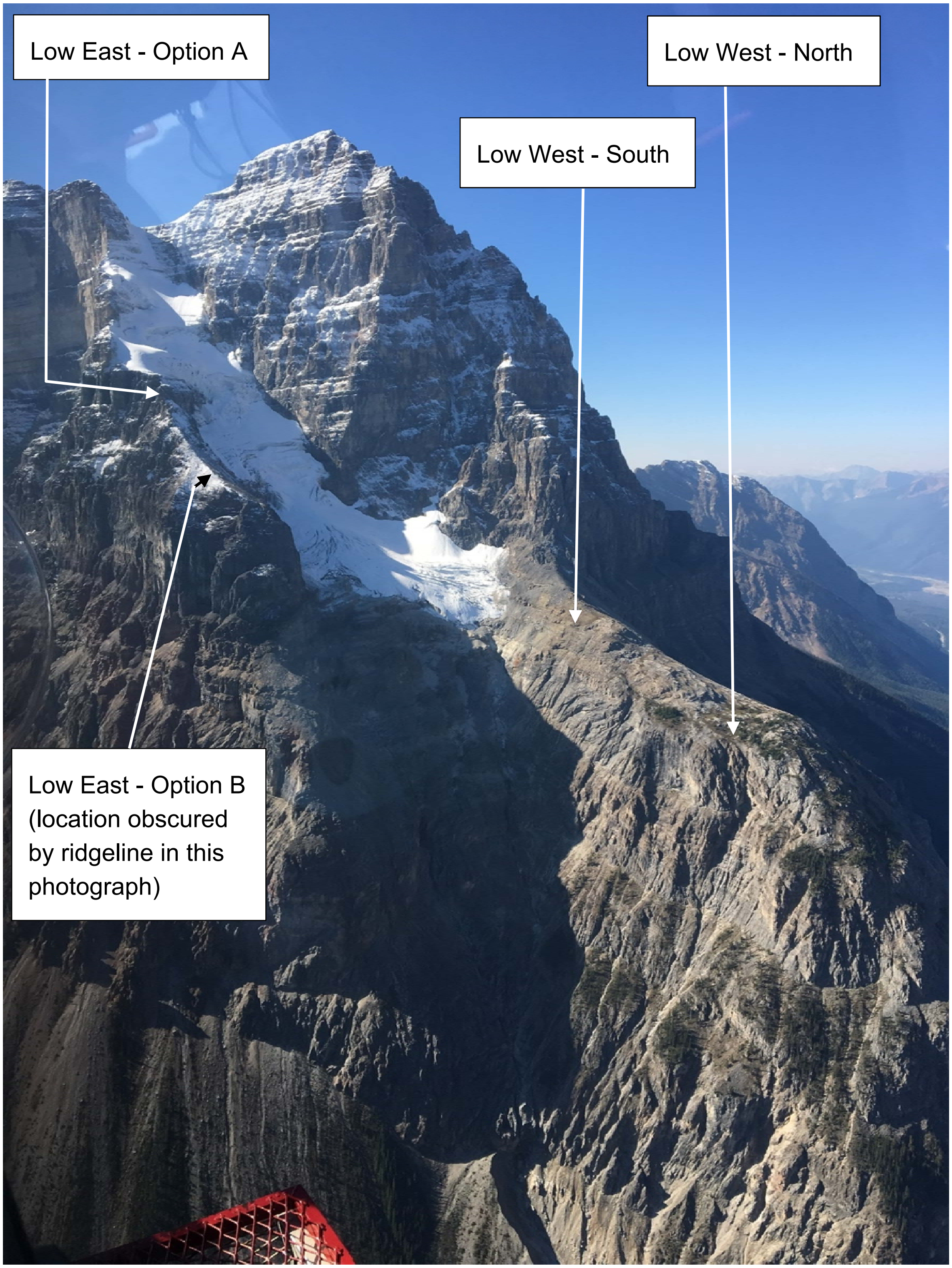

Figure 1-2 Mt. Stephen lower elevation proposed RACS locations (heli-photograph September 5, 2018).

2.0 SITE CHARACTERIZATION

2.1. Geology and Physical Setting

Regional geological mapping by the British Columbia Geological Survey (BCGS) maps the Mt. Stephen summit area as fault bound rock units of the Cambrian to Ordovician Rockies strata (BCGS 2005). Cui et al., 2017 map three units between Mt. Stephen's summit and the Trans-Canada highway at the base of the slope are respectively; the Stephen and Mount White formations, the Cathedral, Tanglefoot, Elko and Gordon formations, and the Gog Group (Figure 2-1). The proposed RACS are located in the area mapped by Cui et al, 2017 as the Stephen and Mount White Formation.

The Stephen and Mount White formation rocks are (Cui et al, 2017):

- Middle to Late Cambrian age (511 – 485.4 Ma)
- Shales derived from mudstone, siltstone, fine clastic sedimentary rocks.

The Cathedral, Tanglefoot, Elko, Gordon formation rocks are Cui et al, 2017):

- Middle to Late Cambrian age (511 – 485.4 Ma)
- Limestone, dolomite, and shales derived from limestone, slate, siltstone and argillite.

The Gog Group rocks are (Cui et al, 2017):

- Early Cambrian Age (541 – 511 Ma)
- Sandstones, quartzites and siltstones derived from quartzite and sedimentary rocks.

2.1.1. Physical Setting

Mt. Stephen's summit is located approximately 2 km south of the Trans-Canada highway and railway which are at the base of the slope. Mt. Stephen forms a prominent three-sided mountain profile with steep northeast, west and south aspect slopes (Figure A1). Mt. Stephen glacier trends northward from the col area and extends from about 3,000 m elevation to approximately 2,200 m elevation. The glacier is bounded to the west by Mt. Stephen before a broader north-south trending ridge commences at approximately 2,300 m elevation. The eastern side of Mt. Stephen glacier is bounded by a narrower ridgeline than extends northward from the col area.

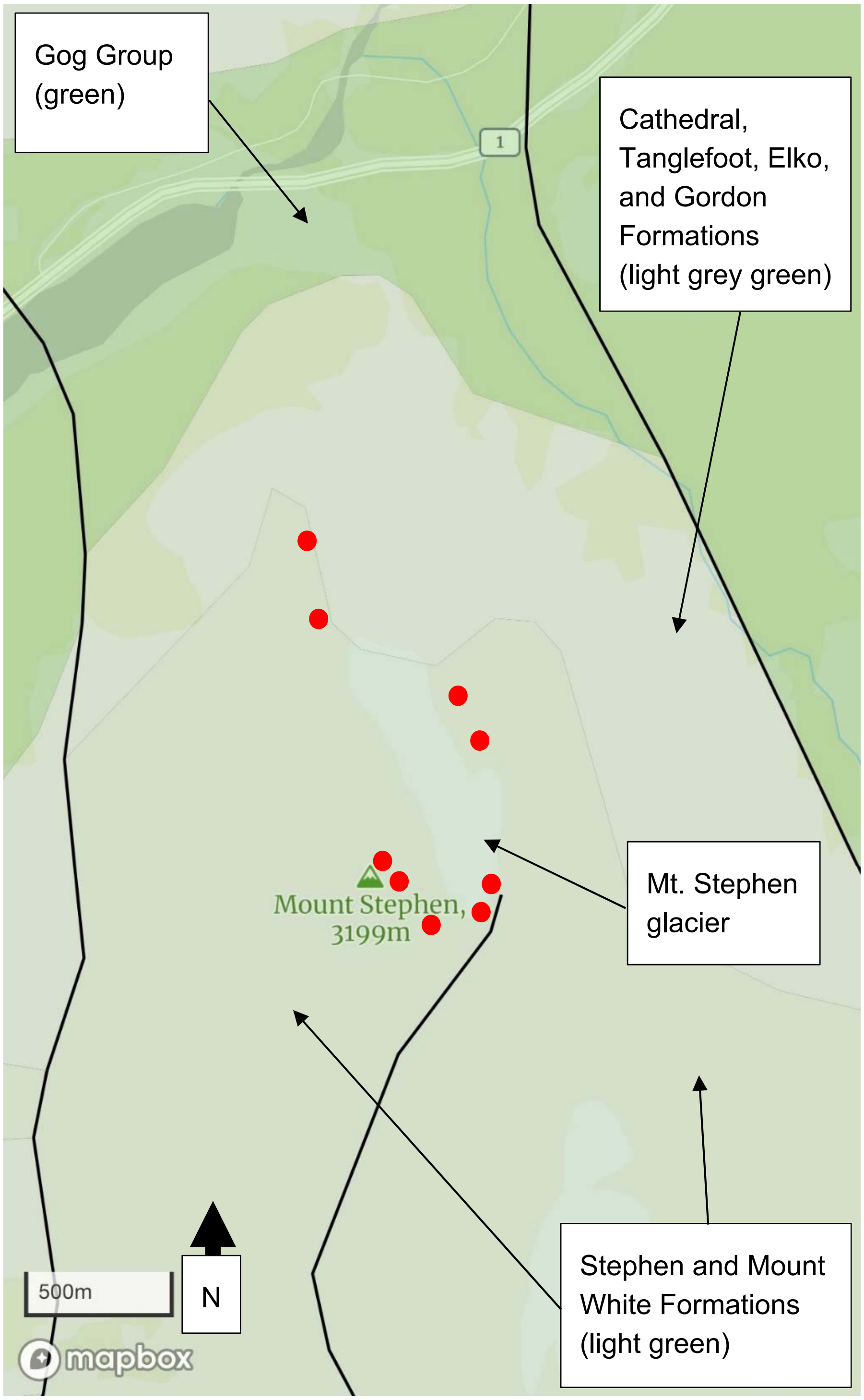

Figure 2-1 Mt. Stephen geology map (image from Rockd.org based on Cui et al, 2017). The black lines trending in the northern direction are mapped as regional scale normal faults. Red dots are the approximate location of the proposed RACS – see Figure A1 for RACS locations.

2.2. Slope Assessment

On September 5, 2018 several potential RACS locations were reviewed on Mt. Stephen by alpine guide assisted foot traverse, UAV, and helicopter-based flyover (Figure A1; Figure 1-1 and Figure 1-2):

- Summit West – 3,170 m asl (30 cm snow cover)
- Summit East – 3,160 m asl (30 cm snow cover)
- Col West – 3,000 m asl (20 cm snow cover)
- Low West – North – 2,130 m asl (snow free)
- Low West – South – 2,200 m asl (snow free).

Two additional sites were reviewed from helicopter-based flyover only (Figure A1):

- Low East – Option A (patchy snow cover – depth unknown)
- Low East – Option B (patchy snow cover – depth unknown)

The two remaining locations shown on Figure A1, Mid Ridge and Col East, were not reviewed during the site visit.

2.3. Rock and Geohazards Characterization

2.3.1. Rock Characterization

The rock encountered on the traverse of five sites has been characterized as a single unit. Rock mass character is described based on ISRM (1981) nomenclature.

The typical rock mass encountered at Mt. Stephen has been characterized as a 'strong' (R4, 50 to 100 MPa Uniaxial Compressive Strength estimate), fresh to slightly weathered (W1 – W2), bedded (variable thickness, ~2 mm to >2,000 mm), fine to medium grained (0.002 mm – 2 mm) light to dark grey metamorphosed calcareous siltstone and fine sandstone or limestone (metamorphosed limestone or carbonate rich sedimentary rock) with black and grey lichen cover. The Geological Strength Index (GSI) for the rock was estimated as GSI 65 to 75 based on the blocky rock structure (see next section) and the rough, fresh to slightly weathered, bedding and joint surfaces (Hoek and Marinos, 2000). Dilation of the rock mass was observed at several locations and several instances of smaller (<10 m^3) rock topples, rock falls or rock slides were also observed on Mt. Stephen's northeast aspect slope. The extent of dilation of the rock mass appears to reduce with depth. Rock strength appears to increase with depth as rock weathering and rock dilation decreases; this weathering profile results in fresher rock with depth.

2.3.2. Rock Structure

The rock mass contains three primary rock discontinuity sets, including shallow southeast dipping (0 to 15 degrees) bedding planes and two sub-vertical orthogonal joint sets (Table 2-1). Rock structure measurements were estimated visually and confirmed by compass measurements of the primary discontinuity sets. The rock structure assessment data is preliminary and does not represent a statistically determined average from several hundred measurements. Spacing of the bedding planes varies from millimetre scale to 2 m or greater. The bedding plane and dominant joint sets are consistently observed over several hundred metres of Mt. Stephen's mountain face (Figure 1-1 and Figure 1-2; Appendix B, Photograph B1).

Table 2-1 Mt. Stephen principal rock discontinuities summary table.

Discontinuity Type	Discontinuity Orientation (°)		Spacing (m)	Persistence (m)
	Dip	Dip Direction[1]		
Bedding	5-15	145 (±10°)	~0.002 - >2	>10
Joint Set 1	75-90	080 (±10°)	~0.002 - >20	>10
Joint Set 2	90 (±10°)	020-200 (±10°)[2]	~0.002 - >20	>10

1. Corrected for magnetic declination of 15 degrees East.
2. Bearing of Joint Set 2 plane – dipping sub-vertical striking towards 020 or 200 depending on dip orientation

Joint set intersections form Mt. Stephen's faces resulting in saw-tooth slope faces. For example, Mt. Stephen's steep northeast aspect face that has approximately 500 m vertical elevation and 500 m horizontal width is formed by several intersections of the dominant rock structure (Figure 1-1 and Figure 1-2). Sections of the rock mass release laterally along these intersecting joint sets once the sub-horizontal bedding is undermined. Mt. Stephen's west and southerly aspect slopes are formed by the same joint set and bedding structure intersections; except with different slope face orientations creating different rock mass release directions.

2.3.3. Geohazards

The primary non-avalanche geohazards observed at the proposed Mt. Stephen's RACS locations are rock fall from above the proposed locations, or undermining of the slope below the proposed locations through ongoing incremental dilation and subsequent failure of the rock mass supporting the RACS. Geohazards for the individual proposed locations will be addressed in their respective summary sections.

2.4. Summit West

The approximate location of the proposed Summit West RACS location is illustrated in Figure 1-1 and Photographs B1 to B4. The proposed location is east of Mt. Stephen's summit near the crest (from the crest to approximately 10 m down slope distance) of the large northeast aspect slope above Mt. Stephen glacier. Snow cover obscured topography between steeper rock outcrops formed by the bedding, Joint Set 1, and Joint Set 2 (Photograph B5 to B8).

The snow-covered slope angle between the steeper sub-vertical steps of the Joint Set 1 and 2 intersecting faces is approximately 35 to 45 degrees for approximately 15 m slope distance before steepening to sub-vertical slopes to the glacier below. The steeper sections of rock faces are dilated and likely contribute to small talus slopes below each vertical rock steps. Depth of rock dilation and the depth of talus is unknown because it was obscured by snow cover. While obscured by snow cover, the slope profile and vertical rock faces visible through the snow cover suggests talus thickness is less than 1 m thick, and likely less than 0.5 m. This could be confirmed in snow free slope conditions.

The proposed area for the Summit West RACS has limited slope length upslope, with an overall slope angle at approximately 35 to 45 degrees (Photograph B6 and B7). Rock fall releases upslope of the proposed RACS location, of sufficient volume to damage a RACS foundation, while possible, are not considered likely because the slope angle and short slope length above the proposed RACS location both act to limit rock fall velocity.

2.5. Summit East

Rock slope observations for the proposed Summit East RACS area are similar to the Summit West RACS area (Photograph B9 and B10). The exact location of the Summit East RACS along the ridgeline is still to be determined, however, based on a review of site conditions, the foundations conditions and geohazard exposure is considered similar along the Summit East ridgeline. The area proposed a RACS is between the slope crest and approximately 15 m down slope distance. In the northwest section of that area a cornice appears to have formed that is not observed in the southeast section of the area along the ridgeline. The cornice development appears to coincide with a steeper rock slope section below the slope crest. Farther to the southeast within the proposed RACS area along the ridgeline the slope is less steep and there appears to be loose rock at the surface or small debris or talus piles. While obscured by snow cover, the slope profile and vertical rock faces visible through the snow cover suggests talus thickness is less than 1 m thickness. This could be confirmed in snow free slope conditions. As with the Summit West locations, depth of rock dilation is unknown.

The proposed Summit East RACS locations have limited slope length upslope of their proposed location, with an overall slope angle at approximately 35 to 45 degrees. Rock fall releases upslope of the proposed RACS location, of sufficient volume to damage a RACS foundation, while possible, are not considered likely because the slope angle and short slope length above the proposed RACS location both act to limit rock fall velocity.

2.6. Col West

At the base of the ridge line that extends from the summit of Mt. Stephen to the southeast is a bedding-controlled surface that forms a broad 80 to 100 m long, 50 to 60 m wide col (Photograph B11 to B15). The col surface dips to the south east at about 6 degrees. The proposed area for the Col West RACS is at the mid-point between the two ridges that bound the col area. The final location of the RACS is proposed to be at the crest of the col slope, or a few metres (0 to 5 m vertically) downslope of the crest towards the glacier (see Photograph B14 to B15). Slopes to the north of the col surface fall toward the Mt. Stephen glacier at an angle between 55 to 60 degrees (Photograph B16). The rock mass is dilated at least in the accessible upper 1.5 m (vertical height) of this slope (Photograph B17 and B18).

Development of a talus slope was not observed on the central section of the col. Rock fall boulders originating from the ridgeline to the west of the col, or saddle, have developed a talus slope on the top surface of the col with some outlying boulders running out onto the col surface. Some boulders have runout approximately 25 m from the base of the talus slope along the col surface. Rock fall boulders originating from the ridgeline to the southeast of the col may also be present but were not visible due to snow cover.

The rock mass on the southeast slope above of the col appeared fractured and deformed (visual observations from a distance) and may form part of the fault zone mapped by Cui et al. (2017) (Figure 2-1) (Photograph B19). If large rock fall events, or a rock slide, release from this slope to the southeast of the col, the col slope profile would likely divert rock fall and slide masses north or south of the col (i.e. they spill over laterally). The proposed Col West RAC position near the centre of the col appears favourable because of its maximum distance from each rock fall source zone. Also, the likelihood of rock fall events reaching the proposed RACS location from the slope southeast of the col are limited by the favourable topography. The central col section is approximately 4 m higher (vertical) than the southeast col margin.

2.7. Low West Options

Both of the proposed Low West RACS locations were reviewed on foot in the field and during a helicopter-based flyover (Figure A1). The Low West – North and South Options are located on a north-south trending ridge line to the west of Mt. Stephen glacier (Photograph B20 and B21). At the proposed RACS locations the rock mass is controlled by the previously discussed sub-horizontal bedding, Joint Set 2 that trends perpendicular to the ridgeline, and Joint Set 1 that forms the ridge slope face.

2.7.1. Low West – North

The proposed location for the Low West – North RACS is towards the distal end of the north-south trending ridgeline extending from Mt. Stephen (Photograph B22 to B28). The ridgeline above the proposed RACS location is benched with intermittent steeper bluffs and small talus slopes forming on the bedding-controlled step out features. The proposed RACS location is approximately 5 to 10 m vertical distance below the slope crest.

At this location the eastern face of the ridge steps to the west northwest approximately 50 m resulting in the narrowing of the ridgeline (Figure 1-2). This step has resulted in a series of dilated ridge spurs that appear to be toppling, or failing through undercutting of basal rock support, and falling into the valley below. At this location joint spacing along Joint Set 2 appears narrower than typical. Several larger (> 5 m^3) rock fall events expose lighter coloured rock where lichen cover has not established. Fault zones were also observed along Joint Set 1 at this location.

Rock fall, rock topples and rock slides below the foundation elevation (considered 0 to 5 m below the ridge crest) that could undermine or intersect the proposed RACS foundation are considered very likely (Photograph B23, B26 and B27). This slope appears to be actively deforming, and shows evidence of recent rock fall, topple and slide activity.

The proposed Low West – North RACS location has limited rock fall exposure because the rockfall source zone is limited to the few metres of slope between the ridge crest and the proposed RACS location. Rock fall releases upslope of the proposed RACS location, of sufficient volume to damage a RACS foundation, while possible, are not considered likely because the slope angle and short slope length above the proposed RACS location both act to limit rock fall velocity. Approximately 500 m of ridge line separates this proposed RACS location from any rock fall hazard originating from the steeper sections of Mt. Stephen. Up slope rock fall events impacting the tower are considered unlikely at this site.

2.7.2. Low West – South

Below the broad north-south trending ridgeline the slope descends to the east towards Mt. Stephen's glacier (Photograph B29 and B30). The upper slope profile is benched with intermittent steeper bluffs and small talus slopes forming on the bedding-controlled step out features (Photograph B29 to B33). Rock at the surface appears dilated in the outer 0.5 to 1 m (or so) of the ground surface. This observation is consistent with observations of the rock mass from an old mining excavation located farther downslope that shows rock mass dilation decreasing with depth from the ground surface (Photograph B35 to B36).

The proposed RACS location is at least 250 m beyond the base of the steeper ridgeline extending north from Mt. Stephen and approximately 5 to 10 m vertical height below the slope crest of the overall north-south trending ridge. No rock fall debris was observed on the broad ridgeline above the proposed RACS location that was interpreted as originating from the steeper slopes of Mt. Stephen above. Rock fall originating from the steeper Mt. Stephen slopes is not expected to impact this site. The likelihood of rock fall that originates from between the RACS location and the slope crest impacting the proposed RACS system is expected to be mitigated by check scaling during construction to provide safe site access.

2.8. Low East Options

Neither of the proposed Low East RACS locations were reviewed on foot in the field (Figure 1-2). Both locations were reviewed briefly during a helicopter-based flyover. The Low East Option A and B locations are positioned on a north-south trending ridge line to the east of Mt. Stephen glacier.

2.8.1. Low East – Option A

The proposed location for the Low East Option A RACS is approximately 2,610 m asl on the crest of a narrow ridgeline situated above the mid reaches of Mt. Stephen glacier (Photograph B37). On the east side of this ridge the surface trace of a very high persistence fault plane that trends approximately north-south and dips towards the west is observed (Photograph B38). The rock mass along this ridge line appears to be deformed and a series of narrow steep ridgelines are exposed on the eastern slopes. These slopes appear to be actively raveling.

The ridgeline location of the RACS may receive rock fall originating from the peak to the east of Mt. Stephen, however, the north-south trending ridgeline is expected to divert rock fall towards the glacier or the valley to the east. Therefore, rock fall events hitting the RACS location are considered unlikely. Slope failures below the foundation elevation in the fractured rock mass could undermine the proposed RACS. Also, depending on rock mass dilation, foundation anchor drilling and grouting may be challenging.

2.8.2. Low East – Option B

The proposed location for the Low East Option B RACS is approximately 2,480 m asl approximately 20 m (vertical distance) downslope of a broad ridgeline (Photograph D39). Option B is located upslope of the distal reaches of Mt. Stephen glacier. The proposed RACS location is in the middle of a talus deposit with intermittent fractured bedrock outcrops. The depth of talus is unknown. Construction of the RACS foundations may be challenging for anchor installation and foundation preparation at this location if the loose talus proves too deep to excavate to achieve a rock foundation for the RACS, and intermittent rock outcrops are not suitable for the RACS foundation.

Rock fall originating from the fractured bedrock outcrops of remobilization of the talus slope material is considered unlikely. There are no other rock fall source areas immediately upslope of this proposed location. From a geohazard risk perspective the site is favourable.

2.9. Mid Ridge and Col East

Site reconnaissance of the proposed RACS locations by McElhanney and Parks indicated that the proposed Mid Ridge and Col East site options were unnecessary from an avalanche initiation perspective. The Mid Ridge and Col East sites were not assessed by BGC.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1. Conclusions

Geotechnical and geohazard conditions of the proposed RACS foundation areas on Mt. Stephen were assessed as part of this study above the Trans-Canada highway, Yoho National Park.

The rock encountered on the traverse of five of the originally proposed nine RACS sites has been characterized as a strong calcareous siltstone/fine sandstone or limestone unit. Pervasive bedding structure and joint sets that are orthogonal to bedding and each other control the rock mass structure and help shape the larger and smaller scale slope topography. At each location evidence of near surface rock mass dilation was observed. Rock strength appears to increase with depth as rock weathering and rock dilation decrease. The depth of rock disturbed by dilation and weathering is uncertain. Evidence of rock topples, rock falls or rock slides were observed on Mt. Stephen at several locations. These geohazards could affect some of the proposed RACS locations through debris impacting them from above, or undermining of their foundations from below.

Table 3-1 summarizes BGC's assessment of the proposed RACS areas by assessment category. Installation of RACS's at the following locations appears feasible from a geotechnical and geohazards perspective:

- Summit West, Summit East, Col West, Low West - South

The rock mass at each of these locations is dilated to an unknown depth, but the dilations appears to reduce with depth. Excavation of loose debris, embedment of the foundation by removing the heavily dilated rock mass, and confirmation of anchor capacities would be required. The excavation depth required to remove this material is unknown, and each site would be unique, however removal of the loose debris and heavily dilated rock mass is likely less than 2 m (vertical height). Dilated rock mass that is not removed could affect the ability to drill anchors (circulation loss, drill mis-alignment across cracks), and could affect the ability to fully grout the anchors.

Geohazards at these locations appear limited to rock fall from the slopes immediately upslope of the proposed foundation location (slope heights between 0 to 10 m). Rock scaling for safe work access would likely mitigate this hazard. Undermining of the foundations at these locations does not appear likely but this should be confirmed as part of more precise siting of the RACS.

Installation of RACS's at the following locations appears less feasible from a geotechnical and geohazards perspective without extensive slope or foundation mitigation work:

- Low West – North, Low East – Option A, Low East – Option B

Foundation conditions and geohazards at the Mid Ridge and Col East potential RACS sites were not assessed as BGC understands these are not receiving further consideration.

3.2. Recommendations

Based on the field assessment observations BGC recommends the following to finalize the RACS design:

- Confirmation of the type of RACS that will be installed to allow recommendations for allowable foundation bearing pressure, and rock anchor bond strength for use in RACS ground anchor design.
- Once RACS type and general locations are finalized from a snow avalanche operational perspective by McElhanney and Parks complete a field review by a qualified geotechnical engineer to finalize RACS foundation locations in snow free conditions. The purpose of this field review is to select precise locations of RACS (i.e. review of specific locations to the nearest metre rather than review of an area of potential locations) considering:
  - Constraints of the selected RACS for it to be effective
  - Depth of rock dilation at each location
  - A minimum foundation set back of 1 m (horizontal) of the concrete foundation pad from the slope crest on the foundation bench to achieve a minimum of 2.0 m horizontal intact rock width (not talus or dilated rock) at an anchor depth of 3.5 m (assuming a 75-degree rock slope face)
  - That the local area of the RACS foundation is not subject to foundation failure along rock structure.
- Use of the following design parameters and construction requirements for preliminary RACS foundation design purposes. These are based on the visual rock strength estimates assessed in the field and topographic constraints:
  - An allowable bearing pressure on rock of 1,000 kPa (CFEM 2006).
  - Removal of soil cover, loose talus, or dilated rock mass, at all foundation and anchorage points; field observations suggest the thickness of material will be less than 2 m, this needs to be confirmed in the field. Place all anchors, and foundations in bedrock and confirm anchor capacities with one or two tests per RACS location.
  - Working bond zone stress of 500 kPa (Wyllie and Mah, 2007) for rock anchors. Minimum bond zone lengths and anchor lengths to meet the RACS providers specifications, as a minimum, or longer based on Parks foundation factor of safety requirements.

Assuming that scaling of loose debris and dilated rock upslope of the proposed RACS locations to reduce rock fall hazard from the slopes immediately upslope from the proposed foundations will be required during construction.

Table 3-1. Summary of estimated rock scaling effort, rock fall protection requirements, and foundation conditions for the proposed Mt. Stephen RACS's.

Proposed Location	Scaling Effort for Construction Access and Long-Term	Rock Fall Protection Required for Contractor Safety	Rock, or Soil Cover and Approximate Thickness (m)	Bedrock Near Surface Suitable for Concrete Foundations	Suitable for Rock Anchors	Preliminary Feasible as a RACS Location from Geotechnical and Geohazards Perspective
Summit West	Check-scaling; additional localized effort	Determine following initial scaling effort; unlikely	Rock, talus (< 2)	Yes	Yes	Yes
Summit East	Check-scaling	Determine following initial scaling effort; unlikely	Rock, talus (< 2)	Yes	Yes	Yes
Mid Ridge and Col East	Not assessed					
Col West	Check-scaling	Unlikely; assess with rock scalers	Rock	Yes	Yes	Yes
Low East – Option A	Check-scaling; additional localized effort	Determine following initial scaling effort; unlikely	Rock, talus (< 2)	Probably	Yes	No (undermining of slope considered likely)
Low East – Option B	Check-scaling; extensive localized effort to reach bedrock surface	Determine following initial scaling effort; unlikely	Talus (> 1)	Depth to rock unknown	No	No (anchor drilling challenges, foundation preparation issues)
Low West – North	Not considered applicable – unstable slope	Extensive rock slope stabilization required to buttress slope.	Rock, talus (< 2)	Yes	Yes	No (undermining of slope considered likely without extensive slope stabilization and buttressing)
Low West – South	Check-scaling; additional localized effort	Unlikely; assess with rock scalers	Rock, talus and soil	Yes	Yes	Yes

4.0 CLOSURE

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING INC.
per:

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SF/AS/map/admin

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APPENDIX A
OVERVIEW DRAWING

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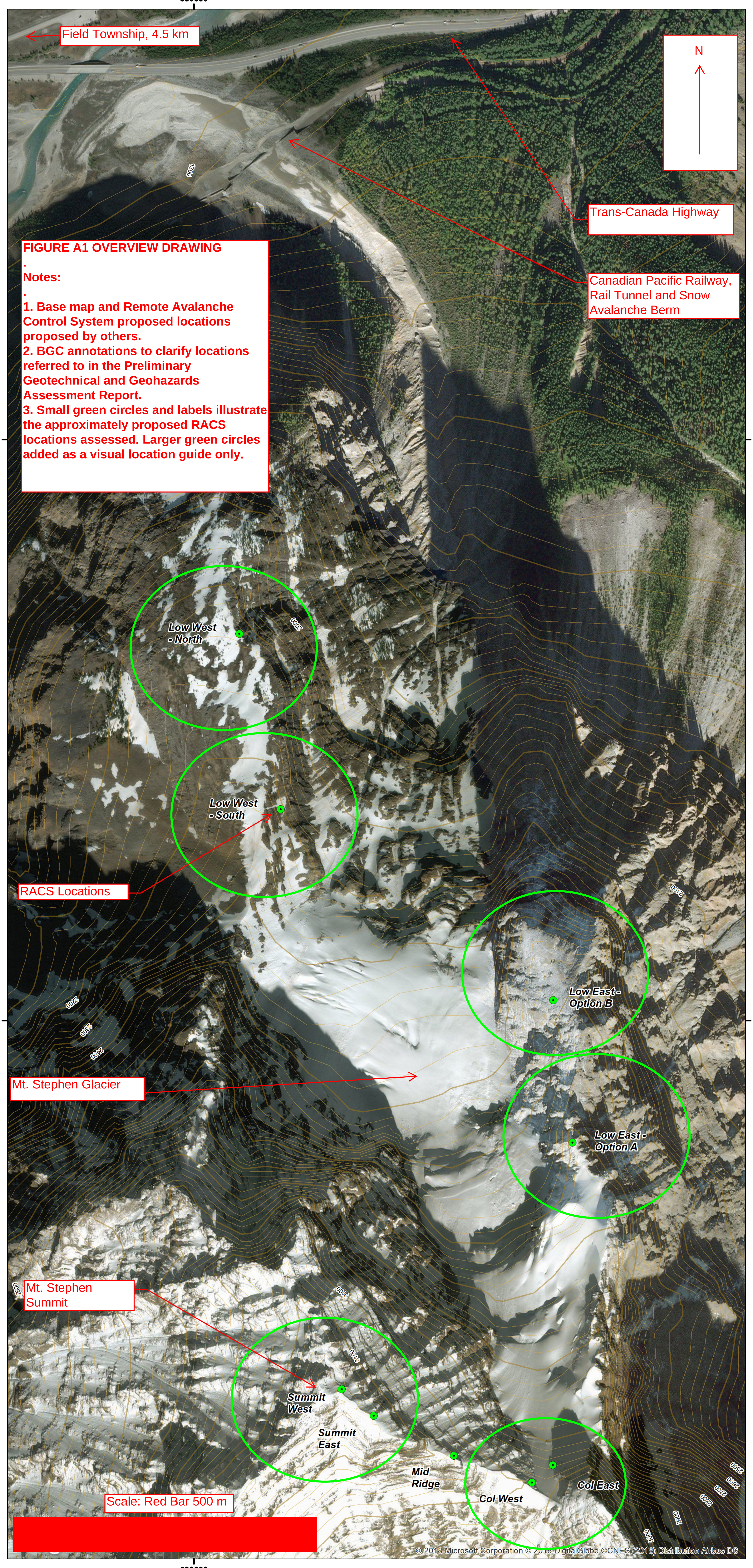

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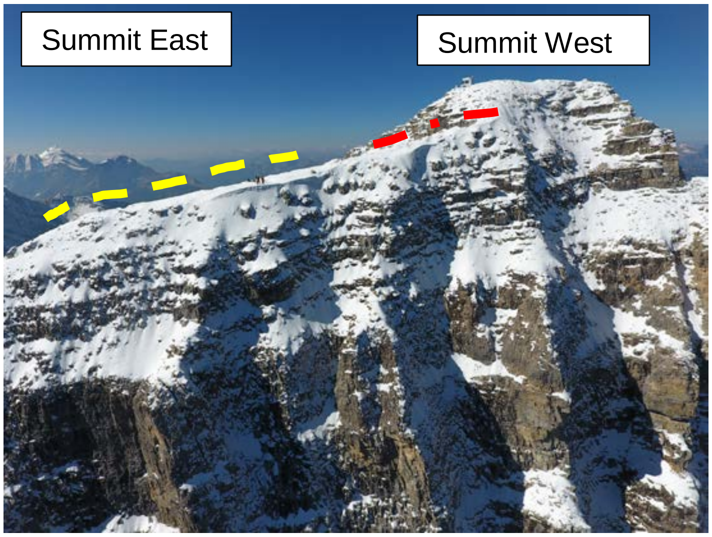
APPENDIX B
ANNOTATED PHOTOGRAPHS



Photograph B1.
Summit East and West Locations

Looking to the southwest at potential summit RACS locations along the eastern side of the ridgeline illustrated by the yellow dashed line (Summit East).

Potential Summit West locations illustrated by the red dot dash line.

Photograph B2.
Summit East and West Locations

Looking west at potential summit RACS locations along the eastern side of the ridgeline illustrated by the yellow dashed line (Summit East).

Potential Summit West locations illustrated by the red dot dash line.

Photograph B3.
Summit East and West Locations

Looking south at potential summit RACS locations along the eastern side of the ridgeline illustrated by the yellow dashed line (Summit East) and the red dot dash line (Summit West).

Photograph B4.
Summit East and West Locations

Looking northeast at the southwest side of the potential summit RACS locations along the eastern side of the ridgeline (locations obsured by ridgeline). Summit East and West locations illustrated by yellow and red arrows, respectively.

Photograph B5.
Summit West Location

Looking southwest at potential Summit West RACS locations illustrated by the red dot dash line.

Photograph B6.
Summit East and West Locations

Looking northwest along the ridgeline from Summit East towards Summit West and Mt. Stephen summit and alpine structure.

Photograph B7.
Summit West Location

Looking northwest from the crest of the ridgeline towards Mt. Stephen's summit and alpine structure.

Photograph B8.
Summit East Ridgeline Rock Outcrop

Frost shattered rock outcrop at the crest of the slope on the Summit East Ridgeline.

Photograph B9.
Summit East Location

Looking northwest along potential Summit East RACS locations.

Joint Set 1 illustrated by white arrow.

Joint Set 2 orientation illustrated by dashed white arrow (joint set face not visible in photograph).

Photograph B10.
Summit East Location

Looking northeast from the crest of the ridgeline towards Mt. Stephen glacier (obscured from view). Typical down slope view from the ridgeline crest shown in Photograph B9 (slope distance approximately 15 m).

Photograph B11.
Col East and West Overview

Looking south towards the potential Col RACS locations (white arrow illustrates approximate Col West location, blue arrow for Col East).

Photograph B12.
Col West

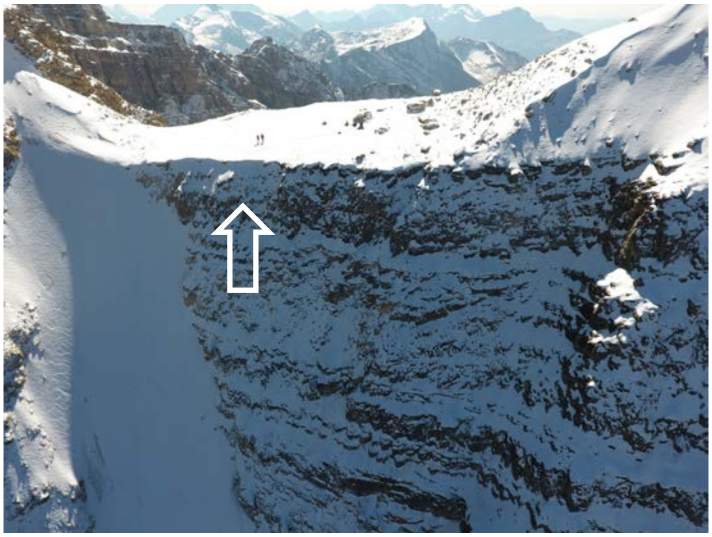
Looking north towards the potential Col RACS locations (obscured by ridgeline).

Photograph B13.
Col West

Overview from above the Col area with white arrow locating proposed RACS position (approximate). North to the top of the photograph (white arrow illustrates approximate Col West location, blue arrow for Col East).

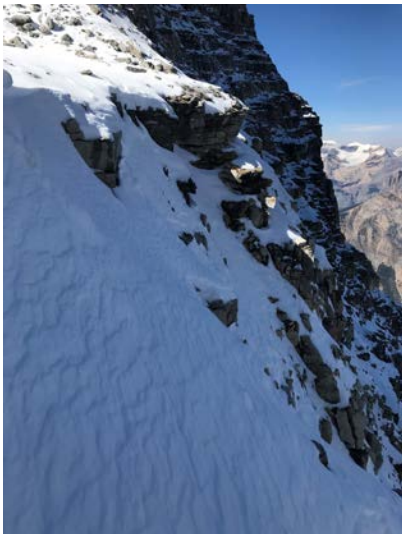
Photograph B14.
Col West

Looking south towards the proposed Col West RACS location – proposed location above the arrow head.



Photograph B15.
Col West

Looking south towards the proposed Col West RACS location – proposed location above the arrow head.



Photograph B16.
Col West

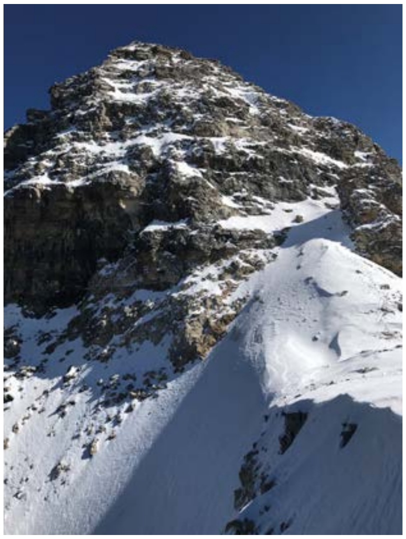
Looking northwest along the crest of the Col from the approximate Col West location.

Photograph B17.
Col West

Dilated bedding joint in the rock mass approximately 1 m below the slope crest near the proposed Col West location (dilation approximately 50 – 60 mm).

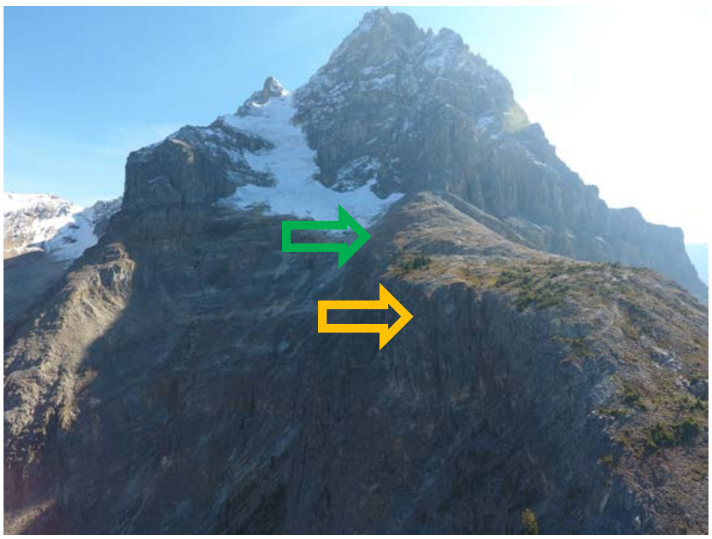
Photograph B18.
Col West

Dilated bedding joint in the rock mass approximately 1.2 to 1.5 m below the slope crest near the proposed Col West location (dilation approximately 10 – 20 mm).



Photograph B19.
Col West

Looking southeast along the crest of the Col from the approximate location of the proposed Col West RACS.



Photograph B20.
Low West – South and North

Overview photograph looking south towards Mt. Stephen. Green arrow Low West – South location, yellow arrow Low West – North location.

Photograph B21.
Low West – South and North

Overview photograph looking west towards the two Low West locations. Green circle Low West – South location, yellow arrow Low West – North location.

Photograph B22.
Low West – North

Overview photograph looking north towards the Low West – North location (inside orange dash).

Photograph B23.
Low West – North

Overview photograph looking down the slope at the Low West – North location (approximately inside orange dash).

Photograph B24.
Low West – North

Overview photograph looking north to northwest from the Low West – North location.

Photograph B25.
Low West – North

Overview photograph looking to the southwest towards the Low West – North location (approximately inside orange dash).

Photograph B26.
Low West – North

Closely spaced joints and toppling rock slope sections in small ridge spurs (white arrows). Light tan coloured area is a recent slope failure back scarp (inside white dash).

Photograph B27.
Low West – North

Closely spaced joints and toppling rock slope sections in small ridge spurs. Light tan coloured area is a recent slope failure back scarp (inside white dash) (same as Photograph B26).

Photograph B28.
Low West – North

Looking northwards towards closely spaced sub-vertical joints of Joint Set 1 (between arrows).

Photograph B29.
Low West – South

Overview of the Low West – South location looking towards the southwest.

Photograph B30.
Low West – South

Overview of the Low West – South location looking towards the west.

Photograph B31.
Low West – South

Rigde above the proposed RACS location.

Photograph B32.
Low West – South

Typical rock slope conditions.

Photograph B33.
Low West – South

Typical rock slope conditions of steeper rock outcrop slopes and shallower talus slope angles.

Photograph B34.
Low West – South

Typical talus material at Low West – South (tape 20 cm length).

Photograph B35.
Low West – North

Old mine workings between Low West – North and South locations on the ridge line.

Photograph B36.
Low West – North

Old mine workings.

Photograph B37.
Low East – Option A

Looking east at an overview of the Low East – Option A site location (illustrated by white arrow).

Photograph B38.
Low East – Option A

Looking southwest towards the eastern side of the east glacier ridge. Low East – Option A RACS location illustrated by white arrow (location partially obscured by ridgeline). Fault plane location illustrated by white dash line – fault plane immediately above this line.

Photograph B39.
Low East – Option B

Looking to the southeast at the Low East – Option B RACS location (illustrated by white arrow).