TERRAIN STABILITY ASSESSMENT

Big White Ski Resort
Backcountry &
Black Forest Chair Expansion

Whitefoot Creek

Okanagan-Shuswap Forest District

Prepared for:

Big White Ski Resort Ltd.

Prepared by:

consulting ltd.
sitkum
GEOTECHNICAL SERVICES

Project No. 18-1462

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December 13, 2018 SCL File No. 18-1462

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Vice President of Operations President, Brent Harley and Associates Inc.

Cc: Mr. Matt Bakker, B.A., MRM
Resort Planner, Brent Harley and Associates Inc.

Subject: **Terrain Stability Assessment of Big White Ski Resort Backcountry and Black Forest Chair Expansion**

1.0 INTRODUCTION

At the request of Mr. Brent Harley, President of Brent Harley and Associates Inc. (BHA), Sitkum Consulting Ltd. (SCL) has conducted a Terrain Stability Assessment (TSA) of the Big White Resort Backcountry and Black Forest Chair Expansion located within the Whitefoot Creek drainage ~56 km southeast of Kelowna, B.C. Access to the development is via Highway 33 and Big White Road (refer to Figure 1).

This assessment was requested based on portions of the development situated upslope and within terrain mapped as P (potentially unstable) by the available terrain survey intensity level D (TSIL D) terrain stability mapping (TSM) as well as downslope and downstream elements at risk as outlined below.

The scope of work, as confirmed with BHA, is to:

1. identify potential terrain stability concerns associated with the proposed development;
2. evaluate the potential spatial impacts relating to slope stability of the proposed development on downslope resources as identified below; and
3. make recommendations where appropriate to reduce the likelihood of landslides attributable to the proposed recreational development.

Based on an office review by Mr. Wayne Miller, P.Geo, Eng.L. of SCL prior to the field assessment, it was determined that the majority of the proposed Big White expansion is situated on benign terrain with a Very Low likelihood of slope instabilities (Figure 1). There are three terrain polygons mapped as potentially unstable (P) in the western portion of the development near the proposed southern ski lift and east of Trapping Creek. These areas are more likely to be classified as stable (Very Low likelihood of slope instability) due to the predominately flat to moderate gradient; there are isolated areas of irregular, steeper terrain within and immediately downslope of the P polygons that are short (<50 m) and consist of localized exposed bedrock and bedrock-controlled terrain. In addition, there are intervening slopes of <25% and ~150 m to 330 m in length prior to Trapping Creek. Based on information from Cabin Forestry Services (Cabin), the TRIM tributary streams to Trapping Creek are ephemeral with no visible channels (NVCs) or intermittent watercourses and are neither fish-bearing nor able to transport material to downslope/downstream fish habitat. Terrain characteristics have been confirmed by field crews of Cabin and from orthomosaic imagery and LiDAR mapping (Bare Earth, slope, contours). As a result, there is a Very Low likelihood of a landslide initiating in the mapped P terrain or the majority of the expansion area, and a Very Low likelihood of an impact to Trapping Creek in the unlikely event of a downslope landslide. Therefore no further assessment has been included in this report for these areas.

The focus of the assessment and report is on the area above Whitefoot Creek and downslope of the proposed eastern chairlift due to mapped potentially unstable terrain and gentle-over-steep (GoS) terrain determined as having a higher likelihood of landslides than Very Low. **Based on the discussions below, no changes to the proposed development boundaries and roads alignments assessed are anticipated.**

The considered elements at risk are fish habitat, domestic water, and human safety. There is assumed fish habitat in Whitefoot Creek (S2). Whitefoot Creek is located ~425 m to 575 m downslope/downstream of the development boundary. The nearest domestic water intake is point of diversion (POD) PD83325 License C126010 situated within the Kettle River, >70 km downstream from the most proximal point of impact into Whitefoot Creek. Due to the significant intervening distance and large water volumes within Whitefoot and Damfino Creeks, and particularly within the Kettle River, the partial risk to domestic water quality is considered Very Low and therefore no further risk analysis has been carried out. Human safety at downstream locations has been considered; however considering spatial and temporal probabilities, the exposure is sufficiently low that no further risk analysis has been presented.

Other potential downslope elements at risk which have not been specifically addressed by means of assigning risk ratings in this report include wildlife habitat, visual resources, timber value, and soil productivity.

2.0 METHODOLOGY

This TSA has been carried out in a method consistent with the *Guidelines for Terrain Stability Assessments in the Forest Sector* (ABCFP/APEGBC 2010). A partial risk analysis has been completed with specific definitions and an overview presented in Appendix A, along with a list of descriptive terms relating to soil drainage, soil texture and consistency, surface expression, and bedrock characteristics. Land Management Handbook 56, *Landslide Risk Case Studies in Forest Development Planning and Operations* (BC MoF 2004) can be referenced for additional background information on partial risk analysis.

The likelihood of landslide initiation has been estimated in a qualitative manner based on generally accepted geotechnical interpretations and assumptions, the experience of SCL, comparative observations of both natural and forest development-related landslides in the southern interior of B.C., and results from landslide attribute studies in the southern interior of B.C. (Jordan 2003). The landslide likelihood ratings are considered incremental to the existing state (natural or otherwise) as a result of the proposed development. **Where the assessed likelihood of a hazardous landslide attributable to the proposed development has been estimated at Very Low, no further risk analysis has been carried out. Unless otherwise**

stated, likelihood and risk ratings are based on the assumption that generally accepted good development and maintenance practices, along with careful drainage management have been implemented. Residual likelihood and risk ratings are based on the assumption that all recommendations presented in this report are implemented along with generally accepted good development and maintenance practices.

It is the responsibility of the land manager to understand and accept the rating definitions used in this analysis as they are not set by any regional or provincial standards. It is also the responsibility of the land manager to determine the acceptable, tolerable, or unacceptable levels of risk for the development in order to complete the risk assessment, and decide whether or not to proceed with the development based on that decision.

Worker and road user safety during and after operations relating to layout and design is addressed by Big White Ski Resort Ltd., along with work site safety standards and procedures. Worker and road user safety related to terrain stability is addressed in this assessment by means of identification of upslope hazards where they exist, and recommendations for construction of a stable road or trail prism where conventional practices may not be appropriate.

Figures 1 and 2 in Appendix B indicate water features based on LiDAR and Terrain Resource Information Management (TRIM) mapping, supplemented with additional information gathered by Cabin and SCL in the field.

2.1 Office Assessment

Prior to and/or following the field assessment, the following information was reviewed by SCL:

- SCL Report: Terrain Stability Assessment CP 395 Blocks 1, 2, 3 & 4 and Associated Roads, Whitefoot and Damfino Creeks, Project 15-1107, December 2015;
- 1:14,210 scale Cabin Forestry Lift Layout Ortho Map, August 2018;
- 1:5000 scale Overview Development Map, September 2018;
- 1:5000 scale Overview LiDAR Bare Earth Map, September 2018;
- 1:5000 scale Overview LiDAR Slope Map, September 2018;
- 1:5000 scale Overview Map with Location Inset, November 2018;
- 1:2500 scale TSA and Traverse Route Map, November 2018;
- Google Earth (GE) orthomosaic imagery; and
- iMapBC, BC Water Licence Query, Habitat Wizard, and ClimateBC_Map web applications.

2.2 Field Assessment

Mr. Olindo R. Chiocca, P.Eng. of SCL along with Ms. Heather Moore, Ski Patrol Centre Manager of Big White Ski Resort, completed a field assessment of the proposed development on September 20, 2018. At the time of the assessment the weather was cloudy and cool with temperatures up to 12°C. The previous 20 days recorded 2.1 mm of precipitation.[1] The total field traverse time by SCL was ~5 hours.

1 Environment Canada Historical weather data for Rock Creek, B.C., September 2018

Field positions were established based on preliminary field flagging, handheld GPS (iPad mini) and recognizable land features (creeks, slope breaks, etc.). Refer to Figure 2 for the approximate traverse routes.

2.3 Limitations

Field assessments are a result of surface and near surface investigations of the surficial geology, soil drainage, and geomorphologic processes. Shallow soil pits, existing road and trail cuts and overturned root wads were examined; no deeper subsurface investigation was completed. Subsurface conditions are inferred from observations and interpretations of surface characteristics and conditions encountered during excavation may vary.

Interpretations of surface flow patterns were made by careful observations of the forest floor, vegetative indicators, and surface configuration, as is typical for geotechnical assessments. These interpretations take into account the experience of the authors observing local conditions of similar terrain in the region during periods of high runoff.

Stereo air photo pairs were not reviewed as a part of this assessment. This is not considered a significant limitation due to the quality of the orthomosaic imagery reviewed, the limited size of the development area in addition to the extent of fieldwork, and the author and reviewers familiarity with the terrain in the area.

3.0 BACKGROUND INFORMATION

The following sections include background information and general details about the project area and present relevant information on terrain stability that provides the basis for the partial risk ratings presented within this TSA report.

3.1 Regional Terrain Stability Considerations

Landslides within the region occur both naturally and as a result of forest development. Landslide attribute studies completed in the region (Jordan, 2003) report an increase in landslide occurrence where forest development exists. Slope steepness, terrain type, and the presence of natural landslides are identified in Jordan's studies as significant terrain variables when looking at development-related landslides. In general, landslide frequency was found to be much lower than average in areas with slopes less than 20° (35% gradient) and increase with slope steepness to a maximum in the 35° to 40° category (70% to 84% gradient), with a decrease in the >40° category (likely due to the presence of steep yet stable bedrock slopes in this category). Landslide frequency was found to be greater in gullied terrain in comparison with non-gullied. Glaciofluvial and kame deposits were found to have the greatest landslide frequency of all the surficial material types, with thick morainal materials being second.

In the southern interior of B.C., roads have been shown to be a much more significant factor than harvesting for landslides attributable to forest development, with over 95% of development-related landslides attributable to roads and skid trails (Jordan 2001). Landslides caused by roads are primarily due to drainage diversions or unstable fill slopes, with cut slope failures being less common overall. As a result of improved road construction methods and standards, fill slope failures are much less common on newer roads, with drainage now being the most frequent cause (Jordan 2001, Jordan 2003, Jordan et al. 2010).

With generally accepted good construction practices and favourable surficial material properties (e.g. free-draining, non-cohesive), road prism landslides following conventional sidecast fill construction in the region are virtually non-existent on side slope gradients less than 45%, and uncommon on side slope gradients between 45% and 60%. Road prism landslides are more likely to occur on slopes exceeding 60% to 65%. It is important to understand that these estimates are approximate and critical slope angles vary depending on site specific conditions, including drainage and surficial material properties. In most cases, the likelihood of road prism landslides can be reduced through modified construction methods and drainage management appropriate to specific site conditions.

Downslope drainage-related landslides and gentle-over-steep (GoS) landslides are an important consideration in the region, with many drainage-related landslides initiating at some distance (several to several hundred metres) downslope of a road or trail (Grainger 2002, Jordan 2003, Jordan et al. 2010). These drainage-related landslides most commonly occur at a slope break to steeper terrain with slopes at the headscarp typically greater than 60%, but occasionally as low as 45% (Jordan 2001). They also more commonly occur on gullied terrain, and where weathered surficial materials are relatively thin overlying an impermeable layer such as bedrock or dense basal till, as opposed to where downslope materials are thicker and permeable (Grainger 2002). Drainage-related or GoS landslides occur more frequently where there is greater potential for concentrated and redirected drainage along the road and are most often preventable with a high level of effective drainage control including seasonal deactivation measures.

The above findings are generally consistent with observations of the author and reviewer over the last 20+ years of assessing terrain stability in the region and provide supporting rational for the landslide likelihood and partial risk ratings presented in this report.

3.2 General Physiography

The proposed development of Big White Mountain is situated ~45 km to the southwest of Kelowna B.C. Big White is the highest mountain of the Okanagan Highland and Beaverdell Range. The general physiography of the region consists of rolling topography with rounded ridge crests and moderate valley sides up to 2300 metres with steep gully sidewalls along tributary creeks. Local ridge top and summit elevations are generally between 1800 m and 2300 m, with local relief on the order of 600 m to 700 m. Refer to GE Image 1 below and Figure 1.

3.3 Site Location – General

The assessed portion of the proposed development is located on the lower slopes of the Whitefoot Creek (S2) face with elevations ranging from 1620 m to 1900 m. Drainage is directly towards Whitefoot Creek or its S5-1 tributary stream. The area has a history of forest development with existing roads and harvesting adjacent to the proposed development. Refer to Figures 1 and 2, and Image 1 below.

According to information provided by iMapBC, the majority of the proposed development is situated within the Monashee variant of the Dry Cold subzone of the Engelmann Spruce Subalpine Fir biogeoclimatic zone (ESSFdc1). However most of the assessed area downslope of the development lies within the Moist Hot subzone (ESSFmh). The referenced climate model data indicates the mean annual precipitation across the development area is approximately 738 mm.

The referenced geological mapping indicates the local bedrock is predominantly underlain by Mesozoic aged igneous rocks which include granodioritic intrusive rocks of the Okanagan Batholith. In general this is consistent with field observations.

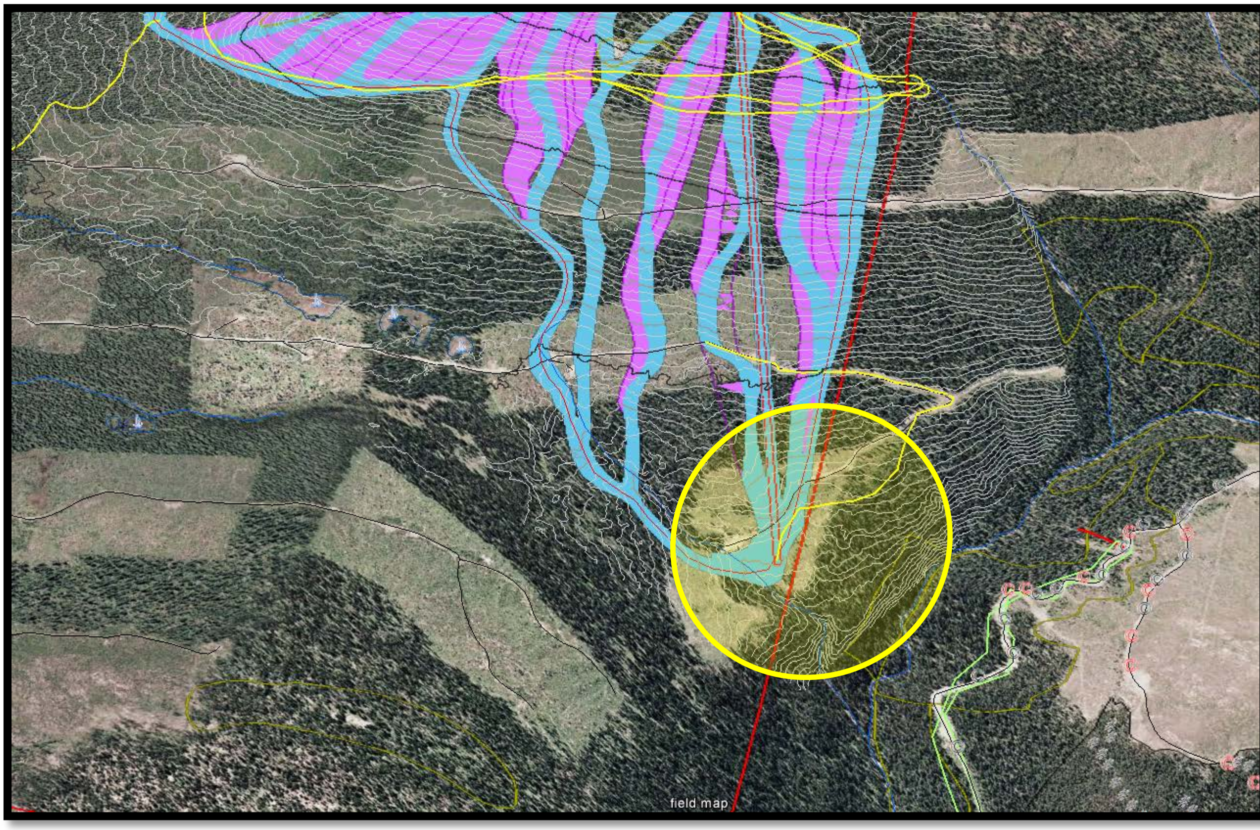

Image 1: Orthomosaic view of proposed development area looking to the west.
Area of concern outlined in yellow.

4.0 OBSERVATIONS AND INTERPRETATIONS

The following section presents the observations and interpretations as well as the partial risk analysis relating to the proposed development.

4.1 Field Assessed Portion of Big White Expansion

Terrain from the northeast tip of the development and downslope was traversed by SCL including the gully sidewall of Whitefoot Creek, terrain in the vicinity of the proposed access road Cabin Option 1, existing Spur 2 road, and the tributary stream of Whitefoot Creek (labelled S5-1). Cabin Option 1 includes several roads of which only one was assessed in the field and is referred to as Spur 1 for the purposes of this report. The location of Spur 1 is derived from LiDAR and the alignment was not laid out at the time of the field assessment. The alignment's location was provided by Cabin and estimated in the field by SCL based on georeferenced mapping. Whitefoot Creek is located ~425 m to 575 m downslope/downstream of the development boundary. Refer to Figures 1 and 2, and Image 2 below.

Terrain downslope of existing Spur 2 and prior to the slope break into the Whitefoot Creek gully consists of slightly irregular broken slopes with lateral swales, gullies and local high points. Slope gradients are flat to moderate and typically <25% with infrequent isolated areas up to 45% which are generally <25 m in slope length. A significant portion of this area has been previously harvested.

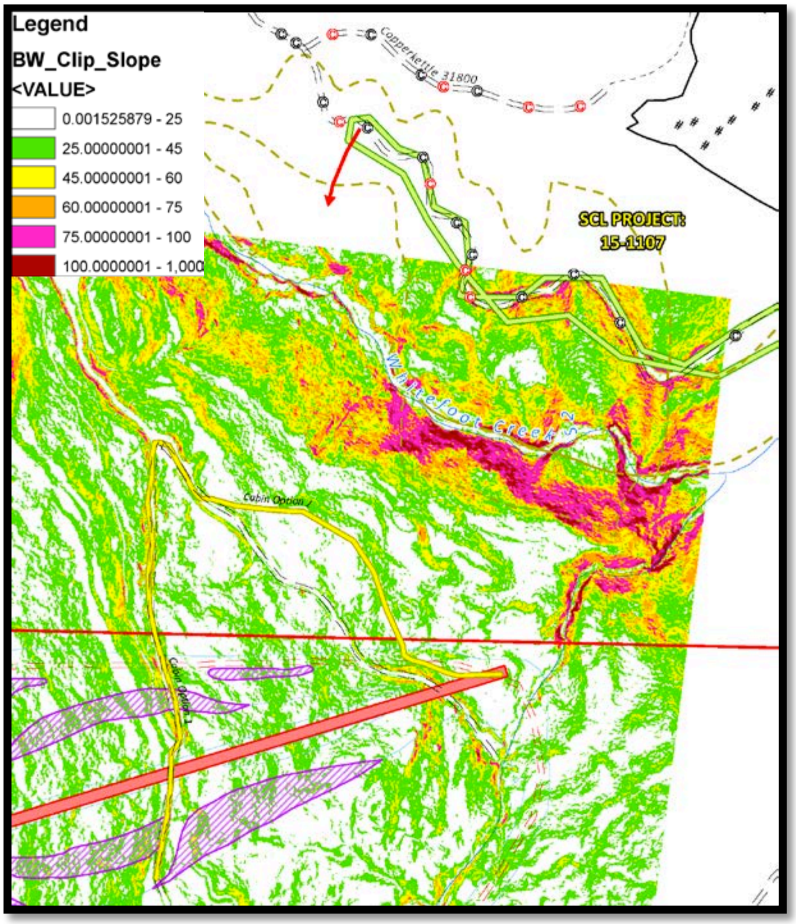

Image 2: LiDAR slope map of terrain the northeast tip of the proposed development and downslope which was traversed by SCL.

Surficial material consists of a predominantly well drained to moderately well drained till comprised of a gravelly sand with a trace of silt, cobbles and boulders, and a coarse fragment content (CFC) of 35%. Localized areas of what appeared to be exposed bedrock were observed along the road cut of Spur 2. This may indicate bedrock-controlled terrain; however these observations were rare and could also represent large partially buried boulders.

In some areas, surface runoff from the development is unlikely to drain uninterrupted directly northeast towards Whitefoot Creek. This is due to irregular terrain consisting of numerous cross-slope (lateral) drainage features and localized high points. An isolated area (bog) of imperfectly drained to very poorly drained soils was observed in flat terrain (<10%) just downslope of Spur 2 between two non-classified drainages (NCDs). The bog consists of shallow standing water and mud within a local depression. One of the NCDs is situated within a broad swale with a ~1.2 m wide mud and gravel channel with a gradient of 25%. The other NCD has a ~0.3 m wide channel and empties into the bog area.

Proposed Spur 1 alignment is situated along uniform to slightly irregular, flat to moderate slopes with gradients that range from 0% to 45%, but are typically 5% to 25%. Based on terrain in the immediate vicinity and LiDAR mapping, the steeper sections are infrequent and short (<25 m). Surficial material is generally well drained, but areas of imperfect to poor drainage were observed adjacent to the alignment in some areas, as mentioned above. Spur 1 follows a portion of existing Spur 2 and therefore may be a realignment and upgrade of the existing road access.

Existing Spur 2 accesses the northern end of the development. The road surface is ~4 m to 5 m wide, slightly overgrown with brush and is generally insloped or outsloped. There was a functioning ditchline as well as numerous cross-ditches/waterbars. Some of the cross-ditches/waterbars are shallow and worn, and many are not deep enough to effectively drain the ditch. The proposed future use for this road was unknown at the time of the assessment by SCL. Based on its location along the lower slopes at the north end of the development, Spur 2 controls the volume and direction of surface runoff from the development towards downslope terrain, which is described below.

The south gully sidewall of Whitefoot Creek consists of slightly irregular to irregular with some incised gullies and a convex downslope configuration. Terrain immediately upslope of the gully is generally ~20% to 45% breaking to 65% to 85%, thus creating a GoS terrain scenario in some instances. Based on LiDAR, the gully sidewall is typically steep to very steep (>75% gradients) downslope to the creek, with the exception of in the vicinity of the confluence with Stream S5-1 and ~150 m to the west where Whitefoot Creek has a sharp curve. These two areas have flat to moderate gradient intervening slopes of ~15 m to 80 m prior and adjacent to Whitefoot Creek.

Image 3: Stream S5-1 at 1630 m in elevation.

To the east at ~1630 m in elevation, Stream S5-1 is situated within a well-defined gully with sidewalls 5 m to 7 m long and slope gradients of 55%. The channel consists of gravel, cobbles and boulders with a step pool morphology, some woody debris and a channel gradient of 15% (Image 3). Downstream, LiDAR indicates that the gully becomes more incised and the channel gradient increases with loss of elevation transitioning to ~25% to 50% below 1580 m in elevation downstream to the confluence with Whitefoot Creek. A short NCD with a 10% gradient and confined within a gully was observed at 1610 m elevation to the north of Stream S5-1; it is unknown if it has continuity to the stream. Based on the terrain configuration, the adjacent drainage divide to the west, and the location of the development, it is unlikely that a development-related debris slide would impact the lower reaches of Stream S5-1, which could be susceptible to a debris flow if impacted by a debris slide.

Whitefoot Creek is confined within a broad, well-defined gully with moderate to very steep sidewalls. Based on TRIM mapping, the channel gradient averages 10% for the approximately 6 km downstream to the confluence with Damfino Creek. Based on the channel gradient of Whitefoot Creek, it is unlikely that a debris slide impacting the creek would develop into a debris flow or that a debris flow within Stream S5-1 would continue downstream along its channel.

Instabilities:

Based on the referenced SCL Report 15-1107 dated December 9, 2015, two debris slides were observed along the north gully sidewall of Whitefoot Creek (Figure 1). The first slide headscarp was noted ~190 m downslope of the junction of Copperkettle FSR and Copperkettle 30300 on an imperfectly drained slope of 70%. This slide was estimated to be >70 years old, ~60 m long and likely impacted Whitefoot Creek. The second slide was located… '*immediately downslope of the culvert at Hub 66 of existing Copperkettle FSR. The cause was likely road drainage related* *but could not be confirmed as the road appears to have been relocated since the slide occurred. This slide is approximately 100 m long and did not impact Whitefoot Creek directly. A GE review indicates that yet another slide may have occurred a further 600 m up Copperkettle FSR and 60 m below the road which does appear to have deposited material in Whitefoot Creek. This slide was not confirmed in the field.'*

There also appears to be possible undercutting along the slope toe of the south gully sidewall by Whitefoot Creek, as observed on Google Earth orthomosaic imagery.

Based on the 2015 SCL report, soil and terrain conditions along the north gully sidewall are similar to those observed by SCL in 2018 along the south sidewall and may have similar sensitivities to redirected and/or concentrated water increasing the potential for downslope instabilities.

4.1.1 Landslide Hazard and Partial Risk Analysis

Within the region, landslides attributable to development on similar terrain are rare when good practices are employed including careful drainage management. Taking into account the observations presented above, along with the regional terrain stability considerations presented in Section 3.1, **the likelihood of a drainage-related downslope landslide is estimated as Low to Very Low. The likelihood is estimated as Low on the moderately steep to very steep gully sidewall of Whitefoot Creek.** Although there is a history of landslides within this gully, the likelihood is estimated as Low due to the overall well drained soils, few watercourses, and the limited potential for redirected and/or concentrated drainage onto the gully sidewall as a result of the irregular upslope terrain with cross-slope drainage features which create a hydrological disconnect in many areas. The remainder of the assessed development area is estimated to have a Very Low likelihood of a drainage-related downslope landslide. This is due to a lack of significant drainage features within the area, predominately gentle sloped, irregular terrain, and a limited potential for significant runoff interception or water redirection.

Assuming that all recommendations presented in this report along with generally accepted good development and maintenance practices are implemented, **the residual likelihood of a downslope drainage-related landslide is estimated to be Very Low**.

In the unlikely event of a downslope drainage-related landslide, it would likely be a small to medium sized (500 m^3 to 1000 m^3) debris slide that could impact Whitefoot Creek, a fish-bearing watercourse. This is a result of the relatively short intervening distance (<100 m) of moderately steep to steep terrain along the Whitefoot Creek gully sidewall. A debris slide impacting the creek is unlikely to continue downstream as a debris flow due to channel gradients averaging <10%.

Taking the above factors into consideration, **the partial risk fish habitat in Whitefoot Creek from a direct impact by a debris slide or the secondary effect of suspended sediment is estimated as Low to Very Low (equivalent to the likelihood of a landslide).** The adverse effects of these events could last for a period of days to months, depending on the landslide characteristics, soil texture, and volume of material introduced into Whitefoot Creek. The presence of coarser material in some areas along the gully sidewalls may result in lesser amounts of fines deposited into the creek. Adverse effects could reoccur to a lesser degree during periods of high runoff for a few years following the event as a result of erosion of the landslide surface. **The residual partial risk to fish habitat in Whitefoot Creek is estimated as Very Low.**

5.0 RECOMMENDATIONS

These recommendations are intended to reduce the likelihood of landslide initiation and adverse effects to downstream water quality resulting from the proposed development. The focus of the recommendations is on drainage control and reducing the likelihood of accelerated, concentrated, or redirected runoff which could cause downslope instability. The recommendations are intended to reinforce or supplement good development practices in order to maintain the risk ratings as presented above.

5.1 General Operational Recommendations

1. **Clearing and construction activities associated with the ski hill expansion should be modified or suspended when there is abundant hill slope runoff occurring at the site,** which is likely to occur during times such as spring break-up or from prolonged heavy precipitation. This is intended to reduce the likelihood of concentrated or redirected drainage as well as erosion and sediment delivery. **All proposed and existing road and trail drainage systems** should be maintained and kept clear of debris during and subsequent to harvesting operations, including at and downslope of cross-drain discharge locations.

2. **Machine use should be limited** to areas where excessive scour, rutting, or compaction is avoidable. This would generally restrict machine use from areas of moderately steep or steeper slopes as well as any localized areas of wet, soft, or very loose soils. Some modified machine use (e.g. hoe-chucking) may be possible in these areas if excessive disturbance is avoidable.

3. **All natural drainage patterns** (including all NCDs and S6 streams as well as dry swales and gullies) should be maintained and left free of excess debris (slash or soil) that could result in a redirection of seasonal surface runoff.

5.2 Specific Recommendations

Existing Spur 2:

If the existing road ***<u>is not to</u>*** be used for accessing the development during construction or during the ski hill's seasonal operations:

1. Pull back and fully recontour the road to the natural state of the surrounding terrain; or
2. Improve and maintain all the cross-ditches by increasing their depth to ensure that they capture water within the ditch and discharge it downslope. Armour the downslope outlets of the cross-ditches.

If the existing road ***<u>is to be</u>*** used for accessing the development during construction or during the ski hill's seasonal operations:

1. Grade and crown the road 2%;
2. Remove all existing cross-ditches and replace with appropriately sized and spaced culverts as recommended by a qualified professional[2] in order to reduce the risk of water

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2 A qualified professional may include a Registered Forest Technologist or Registered Professional Forester with experience in road drainage layout or a Professional Geoscientist or Professional Engineer.

concentration downslope. Culverts locations should coincide with existing cross-ditch locations in order to use and maintain established drainage paths.

Proposed Cabin Option 1 Road (Spur 1):

1. If constructed, install frequently spaced and adequately sized culverts along the proposed road alignment as recommended by a qualified professional[2] in order to reduce the risk of water concentration downslope. The proposed culverts should align with the upslope cross-ditches or culverts located along Spur 2.
2. Particular attention should be paid to avoid redirecting water towards the steeper gully sidewall of Whitefoot Creek. Although the intervening terrain within this area is predominantly gentle, the isolated areas of sensitive, imperfect to poorly drained soil may result in machine rutting and water concentration.

5.3 Maintenance and Deactivation Considerations

The following maintenance and deactivation activities are recommended for the proposed and existing roads associated with the development:

1. **Permanent road and trail maintenance inspections** should be carried out consistent with generally accepted good maintenance practices and at minimum annually. Drainage structures should be inspected during the spring freshet to ensure they are operating as intended.

2. **Seasonal deactivation** is required for permanent roads and trails which will be used for future access in the development area. Deactivation should occur following operations or during shutdown periods in order to control erosion and sediment delivery to the fish streams, as well as to back-up road drainage systems at watercourse crossings. Measures should include cross-ditches and waterbars.

3. **Temporary access roads and trails** used for clearing or construction purposes should be fully rehabilitated[3]. Seasonal deactivation measures are recommended for all non-rehabilitated temporary access roads and trails during periods of non-industrial use, including overwintering. Measures should include back-up cross-ditches for all culvert locations and intermediate waterbars as appropriate. **A**dditional precautions such as pulling back all watercourse crossings and/or potentially unstable fill slopes may also be appropriate in order to limit the potential for redirected runoff.

5.4 Field Reviews

If site conditions encountered vary significantly from those described in this TSA (e.g., unexpected and significant seepage, unexpected material textures encountered in excavations, etc.), or if any stability or erosional concerns become apparent during operations, then a qualified registered professional should be consulted to confirm if an immediate field review is warranted. Timely mitigation of problem sites can significantly reduce potential adverse effects.

Sufficient development supervision should be carried out by an experienced and qualified harvesting and road construction supervisor to ensure generally accepted good development and maintenance practices are implemented along with all recommendations presented in this report.

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3 **Full rehabilitation** implies decompaction, recontouring, constructing waterbars on the recontoured surface where appropriate, and seeding with an appropriate seed mix, or replanting.

6.0 CLOSURE

The discussions and recommendations presented above are based on a visual field assessment and additional information, which was reviewed at the time of the assessment. This report has been prepared for the use by Brent Harley and Associates Inc., which includes distribution as required for purposes for which the assessment was commissioned. The assessment has been carried out in accordance with generally accepted geotechnical practice. Geotechnical judgment has been applied in developing the recommendations in this report. No other warranty is made, either expressed or implied.

SCL trusts that the information presented above meets your current requirements. If you have any questions, or require further information, please do not hesitate to contact the undersigned.

Respectfully submitted,

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Appendix A

Risk Analysis
&
Soil, Slope, and Rock Classification

Definitions and Overview

Risk Analysis Definitions and Overview

The following sections provide important definitions for terminology used in this report, and are based on definitions presented in Land Management Handbook 56 - Landslide Risk Case Studies in Forest Development Planning and Operations (Wise et al. 2004) (LMH-56).

Hazard: a source of potential harm, or a situation with the potential for causing harm, to a specified *element at risk*. With respect to landslide risk analysis, the landslide itself is the hazard.

Likelihood of occurrence: the qualitative estimate of probability (P), or the chance for an event to occur.

Elements at risk (elements): a thing of value that is known to be at risk. Elements at risk may include human life, public and private property, transportation system/corridor, utility and utility corridor, domestic or community water quality and supply, fish habitat, wildlife habitat and migration, visual resource in a scenic area, timber value, and soil productivity (adapted from B.C. MoF, 2002).

Hazard analysis, P(H): an estimation of the probability of a specific hazardous event. With respect to landslide hazard analysis, it refers to the probability or likelihood of occurrence for a specific hazardous landslide.

Spatial probability, P(S:H)*:* relates to the potential for an event to reach or have a spatial effect on the location of a considered element, and mathematically can range from a value of 0 (certain not to reach the element) to 1 (certain to reach the element).

Temporal probability, P(T:S)*:* relates to the potential for a mobile element to be at the affected location, if the considered event occurs. If the element is of a fixed location and is always present (such as permanent infrastructure) then the temporal probability is numerically equal to 1, with a value of less than 1 applicable for mobile elements depending on the proportion of time exposed.

Consequence, C: the effect on a specified *element at risk*. With respect to landslide risk analysis, the consequence is the change, loss, or damage to the considered element caused by the landslide. Consequence takes into account the vulnerability as well as spatial and temporal probabilities of an event affecting an element.

Vulnerability, V: a measure of the robustness of an *element at risk* and its relative exposure to a hazard.

Partial risk analysis, P(HA): the product of the probability of occurrence and the probability of a spatial effect, taking into account both spatial and temporal probabilities. With respect to landslide risk analysis, it is the product of the probability for a specific hazardous landslide and the probability of that landslide reaching or otherwise affecting a considered element. It can also be referred to as <u>the probability of a specific hazardous affecting landslide</u>. Partial risk does not take into account the vulnerability of the element at risk, or the consequence of the event.

Specific risk analysis, R(S): the risk of loss or damage to an element. With respect to landslide risk analysis, it is the risk of loss or damage to a specific element resulting from a specific hazardous affecting landslide. Specific risk takes into consideration the vulnerability of the element at risk and consequence of the event.

Specific Value of Risk, R(SV): the worth of loss, or damage to a specific element, excluding human life, resulting from a specific hazardous affecting event.

In general terms, risk is defined as the product of probability of occurrence and consequence (R=PXC). In the consideration of consequence to a specific element at risk, the vulnerability or robustness of the specific element must be understood. The vulnerability of specific elements is generally best assessed by specialists (e.g. biologists, foresters, utility engineers) with a greater knowledge of the element than the terrain stability professional may have.

As a result, it is generally appropriate for a terrain stability professional to carry out a *partial risk analysis,* in which the likelihood of a specific hazardous landslide is determined, and whether or not a specific element at risk could be spatially affected by the hazardous landslide; however, the vulnerability of the specific element, including an estimation of consequence, is not considered (Wise et al. 2004; LMH 56).

The following tables further outline the terms and ratings presented in this report. Table 1 provides the qualitative descriptions for the relative likelihood of occurrence ratings for a considered event, and the related approximate quantitative probability ranges. While there is an inherent degree of uncertainty in estimating the probability of a specific landslide, and it is a subjective interpretation that is dependent on numerous factors, these relationships can give some physical meaning to the qualitative terms applied.

Table 1: Qualitative description of the likelihood of occurrence, and related quantitative probability ranges[1]

Likelihood of Occurrence	Qualitative Description	Annual probability of occurrence[4]	Probability of occurrence over a 20 year term
Very High (VH)	An event is imminent or likely to occur frequently; well within the lifetime of a typical resource road[2] or soon after logging[3].	>0.05 (>1/20)	>0.65
High (H)	An event can happen or is probable within the lifetime of a typical resource road[2] or soon after logging[3].	0.01 - 0.05 (1/100 - 1/20)	0.18 - 0.64
Moderate (M)	An event is not likely, but possible within the lifetime of a typical resource road[2] or soon after logging[3].	0.002 - 0.01 (1/500 - 1/100)	0.04 - 0.18
Low (L)	An event is unlikely to occur (remote possibility) within the lifetime of a typical resource road[2] or soon after logging[3].	0.0004 - 0.002 (1/2500 – 1/500)	0.01 - 0.04
Very Low (VL)	The likelihood of an event occurring is extremely remote to nil within the lifetime of a typical resource road[2] or soon after logging[3].	<0.0004 (<1/2500)	<0.01

1) Modified from Wise et al (2004), Table 2, pg 14; and B.C. MoF (2002), Appendix 10.2., and refers to a 1 km segment of road or a specified area of development.
2) Assumes a 20 year+ design life.
3) Time period between logging and establishment of a new-growth forest (generally on the order of 20 to 30 years).
4) Annual probability of occurrence does not consider the design life of the road.

These rating definitions are used for a considered event, and can apply to the likelihood of a specific hazardous landslide occurring [P(H)] as well as to the likelihood of a specific hazardous affecting landslide [P(HA)], or partial risk. This rating system can also be used to describe the likelihood for other events such as stream channel avulsion, soil erosion, or redirected runoff.

Table 2: Example of magnitude ratings and ranges of landslide area and volume

Magnitude Rating	Quantitative Range	
	Area affected (ha)*	Minimum Volume involved (m^3)**
Very Large	>5	50,000
Large	0.5-5	5,000-50,000
Medium	0.05-0.5	500-5,000
Small	0.005-0.05	50-500
Very Small	<0.005	< 50

*1 ha = 10,000 m^2

**Based on planimetric area and assumed depth/thickness of 1 m.

As partial risk, P(HA), is defined as the probability of a specific hazardous affecting landslide, it is derived from the product of the probability of a specific hazardous landslide [P(H)], the probability of that landslide reaching an element [P(S:H)], and the probability of the element being present at the time of event [P(T:S)]. This can be expressed mathematically as:

Partial Risk, P(HA) = P(H) X P(S:H) X P(T:S)

In the case where there is assumed certainty that the landslide would reach the element, and that the element would always be present, then P(S:H) and P(T:S) would both be numerically equal to 1 and the partial risk would be equal to the probability of the specific hazardous landslide occurring [P(HA) = P(H)]. Alternatively, if an element is always present [P(T:S) = 1], but it is not certain that the landslide would reach or otherwise affect the site of the element, [P(S:H) <1], then the partial risk rating may be reduced from the probability of the hazardous landslide occurring depending on the situation and level of certainty.

With this methodology the partial risk rating can be equal to or less than the likelihood of the hazardous landslide occurring in the first place, but will not be increased as can result from some qualitative matrix multiplication. Understanding how risk ratings are derived is important when management decisions may be based on the outcome, or when ratings may be compared between different developments or assessments.

In some cases, land managers may choose to complete a specific risk or specific value of risk analysis by incorporating additional vulnerability [V(L:T)], consequence [C], or worth [E] information with input from the appropriate specialists as required (refer to LMH 56 for additional information on specific risk).

Note: It is the responsibility of the land manager to understand and accept the rating definitions used in the analysis as they are arbitrary and not set by any regional or provincial standards. It is also the responsibility of the land manager to determine the acceptable, tolerable, or unacceptable levels of risk (partial, specific, or specific value of risk) for the development in question.

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Soil, Slope, and Rock Classification

Course Grained Soils [1] (Cohesionless):

Density	Field Test
Very Loose	Easily excavated with a spade
Loose	Some resistance to spade
Compact	Considerable resistance to space
Dense	Requires pick for excavation
Very Dense	High resistance to pick

Fine Grained Soils [1] (Cohesive):

Consistency	Field Test
Very Soft	Easily excavated with a spade
Soft	Easily penetrated by thumb
Firm	Readily penetrated by thumb
Stiff	Readily indented by thumb
Very Stiff	Penetrated by thumbnail
Hard	Difficult to indent with thumb

Rock Strength [1]:

Strength	Field Identification
Extremely Weak	Indented by thumbnail
Very Weak	Crumbles under firm blow of hammer; can be peeled with a pocket knife
Weak	Can be peeled by pocket knife (difficult): shallow indents from firm blow of hammer point
Medium Strong	Cannot be scraped or peeled with knife; fractures with single blow of hammer.
Strong	Requires more than one blow of hammer to fracture
Very Strong	Requires many blows of hammer to fracture
Extremely Strong	Can only be chipped by hammer

Spacing of Discontinuities in Rock [1]:

Spacing	Spacing Width (m)
Extremely Close	<0.02
Very Close	0.02 – 0.06
Close	0.06 – 0.20
Moderately Close	0.2 – 0.6
Wide	0.6 – 2.0
Very Wide	2.0 – 6.0
Extremely Wide	>6.0

Soil Description[1,4]:

Noun	Gravel, sand, silt, clay	> 50%
"and"	Silt and gravel, etc	> 35%
Adjective	Gravely, sandy, silty, etc.	20-35%
"Some"	Some sand, some silt, etc.	10-20%
"Trace"	Trace sand, trace silt, etc	1-10%

Soil Thickness[2,3]:

Thickness	
Blanket	>1.0 m
Veneer	<1.0 m

Soil Drainage[5](adapted):

Rapidly drained	Water is removed from the soil rapidly in relation to supply.
Well drained	Water is removed from the soil readily but not rapidly.
Moderately Well drained	Water is removed from the soil somewhat slowly in relation to supply.
Imperfectly drained	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Some mottling is common.
Poorly drained	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Soils are generally mottled and/or gleyed.
Very Poorly drained	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Typically associated with wetlands.

Slope Gradient:

Slope Gradient	Percent (%) Range	Degree Range
Flat	<5	<3
Gentle	5-26	3-15
Moderate	26-50	16-26
Moderately Steep	50-70	27-35
Steep	70-90	35-42
Very Steep	90	>42

Surface Configuration [2] (modified):

Surface Configuration	Relief (metres)
Uniform	<1.0
Slightly Irregular	1.0 – 2.0
Irregular	2.0 – 4.0
Very Irregular	>4.0

:

Slope Shape [3] (modified) and Features

Based on the overall shape of the slope between distinct slope breaks; includes ***concave, convex and straight*** and ***benched*** shapes.
Gullies[6] (modified): sidewalls >3m high (measured along the fall line); sidewall gradients >50%; channel gradients typically >20% (may be less for some sections); may or may not contain an active stream channel.
Swales: any linear depressions in the landscape that do not meet the gully criteria above; generally shallower with lower channel and sidewall gradients; may or may not contain an active stream channel.

Qualitative landslide magnitude ratings[7]

Magnitude Rating	Typical Area affected (ha)	Typical Volume Involved (m^3)
Very Large	>5	50,000
Large	0.5 - 5	5,000 – 50,000
Medium	0.05 – 0.5	500 – 5,000
Small	0.005 – 0.05	50 - 500
Very Small	<0.005	<50

REFERENCES:

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2. Ministry of Forests, A Guide for Management of Landslide Prone Terrain in the Pacific Northwest, 2nd Edition, *Land Management Handbook #18,* 1994.
3. Ministry of Environment, Terrain Classification for British Columbia, Revised Edition, *Manual # 10, 1998*
4. Ministry of Forests, Forest Road Engineering Guidebook, 2nd Ed., 2002.
5. Ministry of Environment Lands and Parks and Ministry of Forests, Field Manual for Describing Terrestrial Ecosystems, LMH#25, 1998.
6. Ministry of Forests, Gully Assessment Procedures Guidebook 1995
7. Ministry of Forests, Landslide Risk Case Studies in Forest Development Planning and Operations, LMH#56, 2004.

Appendix B

Figures

LOCATION: BIG WHITE SKI RESORT

MAPSHEET OPENING NO: 82E076

UTM ZONE: 11 362,751E 5,510,404N NAD 83

DATA SOURCE (S): TRIM-BASE; CABIN- BIG WHITE SKI RESORT DATA

LEGEND

- BLOCK BOUNDARY: EXISTING
- CONTOUR: INDEX / INTERMEDIATE
- EXISTING ROAD: PAVED / SECONDARY
- ROAD BRIDGE: EXISTING / PROPOSED
- PROPOSED ROAD:
  - PROJECT ACCESS ROAD
  - LiDAR Road Options (CABIN AND BHA)
- PROPOSED TRAIL: FORWARDING / BACKSPAR / DESIGNATED SKID / GUYBACK
- EXISTING TRAIL
- ROAD HUB / FALLING CORNER / TOWER SETTING
- SPOIL SITE: EXISTING / PROPOSED
- SKID BRIDGE: EXISTING / PROPOSED
- LINES: PIPE / TRANSMISSION / RAILWAY / FENCE
- STRUCTURE / GATE / MINE SHAFT
- PROVINCIAL PARK / REC. SITE / WILDLIFE
- CULVERT: EXISTING / PROPOSED CLIENT / PROPOSED SCL
- TEMP. CROSSING: EXISTING / PROPOSED
- CROSS-DITCH: EXISTING / PROPOSED
- WATERBAR: EXISTING / PROPOSED
- ROCK OUTCROP / BOULDERS / LARGE BOULDER
- GULLY / SWALE / SLOPE PERCENT (19%)
- SLOPE BREAK / RIDGE / TALUS
- STREAM / DIVERTED / DRAINAGE DIVIDE
- NON-CLASSIFIED DRAINAGE / DIVERTED
- STREAM CLASS / REACH BREAK (S1-S6, NCD)
- LAKE / POND/ WATER LICENCE INTAKE
- SEEP / SWAMP / BOG
- HEADSCARP / LANDSLIDE
- AVALANCHE PATH / POTENTIAL AVALANCHE PATH
- SLUMP / TENSION CRACK
- TERRAIN STABILITY MAPPING POLYGONS:
- LEVEL C / D: STABLE I, II, III / S POTENTIALLY UNSTABLE IV / P UNSTABLE: V/U
- EXISTING COMMERCIAL RECREATION AREA REGISTERED
- EXISTING CHAIRLIFTS
- PROPOSED POWERLINE RIGHT-OF-WAY
- SKI TRAILS FOR SM
- CHAIRLIFT RIGHT-OF-WAY
- PROPOSED GLADING
- PRIVATE LOT

SCALE: 0 50 100 150 200 250 300 Meters

1:5,000

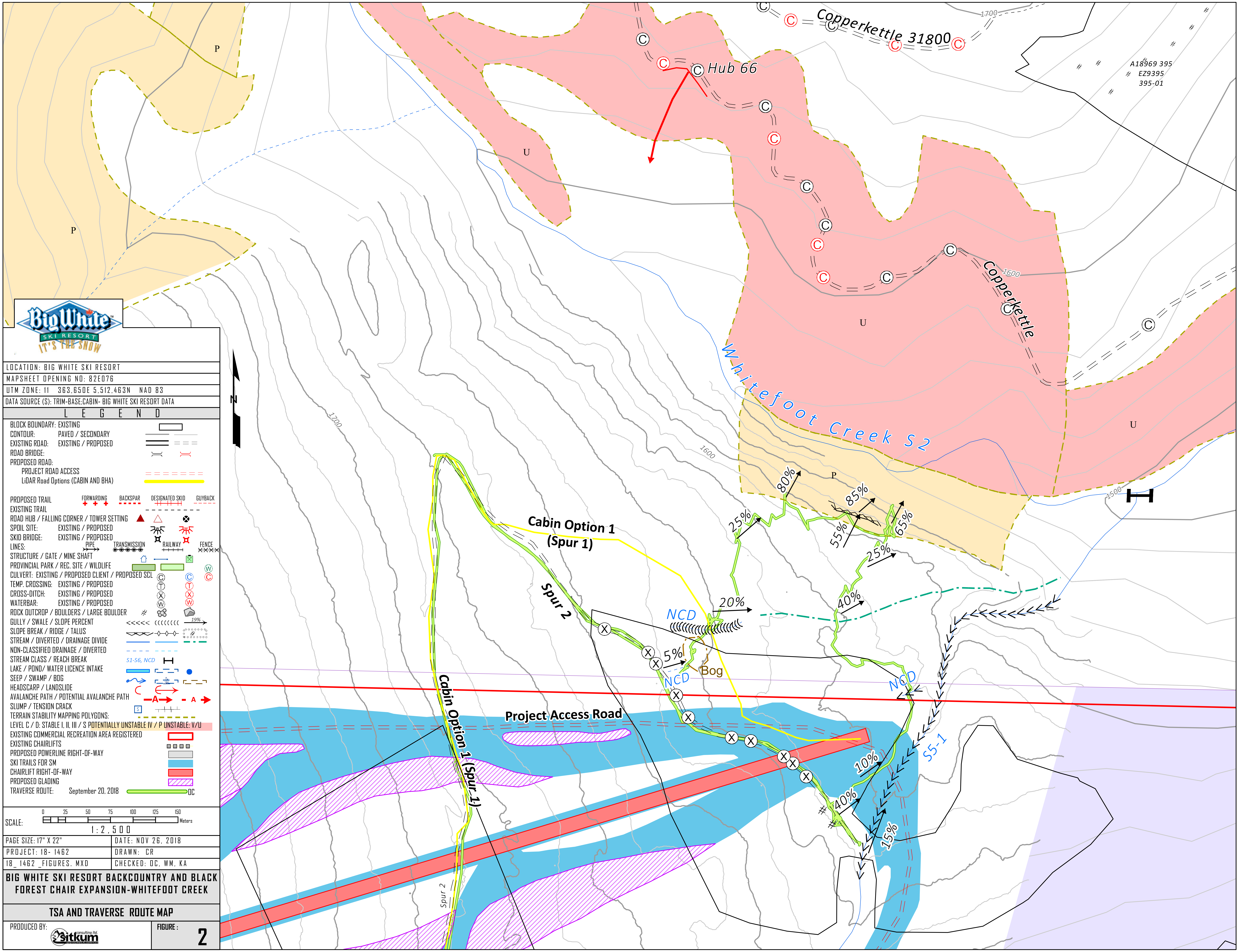
PAGE SIZE: ANSI E 33"X44"	DATE: NOV 26, 2018
PROJECT: 18- 1462	DRAWN: CR
18_1462_FIGURES.MXD	CHECKED: DC, WM, KA

BIG WHITE SKI RESORT BACKCOUNTRY AND BLACK FOREST CHAIR EXPANSION-WHITEFOOT CREEK

OVERVIEW MAP

PRODUCED BY: Sitkum consulting ltd.

FIGURE: 1



Copperkettle 31800
Hub 66
Copperkettle
A18969 395
EZ9395
395-01
Whitefoot Creek S2
Cabin Option 1
(Spur 1)
Spur 2
Cabin Option 1 (Spur 1)
Project Access Road
NCD
Bog
S5-1
80%
85%
55%
65%
25%
20%
40%
5%
10%
15%
1700
1600
1500
P
U
N
LOCATION: BIG WHITE SKI RESORT
MAPSHEET OPENING NO: 82E076
UTM ZONE: 11 363,650E 5,512,463N NAD 83
DATA SOURCE (S): TRIM-BASE;CABIN- BIG WHITE SKI RESORT DATA
LEGEND
BLOCK BOUNDARY: EXISTING
CONTOUR: PAVED / SECONDARY
EXISTING ROAD: EXISTING / PROPOSED
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LEVEL C / D: STABLE I, II, III / S POTENTIALLY UNSTABLE IV / P UNSTABLE: V/U
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PROPOSED POWERLINE RIGHT-OF-WAY
SKI TRAILS FOR SM
CHAIRLIFT RIGHT-OF-WAY
PROPOSED GLADING
TRAVERSE ROUTE: September 20, 2018 OC
SCALE: 0 25 50 75 100 125 150 Meters
1:2,500
PAGE SIZE: 17" X 22"
DATE: NOV 26, 2018
PROJECT: 18- 1462
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18_1462_FIGURES.MXD
CHECKED: OC, WM, KA
BIG WHITE SKI RESORT BACKCOUNTRY AND BLACK FOREST CHAIR EXPANSION-WHITEFOOT CREEK
TSA AND TRAVERSE ROUTE MAP
PRODUCED BY:
FIGURE : 2