

Terrain Stability Assessment

**TA1918 Blocks CAR-153, 155, 160, 162, 176,
177, 178, 180**

Seller Creek – Collins Creek Area

Prepared for:

**British Columbia Timber Sales – Cariboo Chilcotin
Business Area**

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Table of Contents

1.0	Introduction	3
2.0	Rationale for the TSA.....	3
3.0	Methodology	3
4.0	Background Data and Fieldwork.....	4
5.0	General Site Description.....	5
6.0	Proposed Harvesting - Discussion, Results and Recommendations	8
6.1	CAR-153 & CAR-155	8
6.2	CAR-160 & CAR-162	9
6.3	CAR-176.....	10
6.4	CAR-177.....	11
6.5	CAR-178.....	11
6.6	CAR-180.....	12
7.0	Closure	24

List of Figures

Figure 1: Location Key Map	25
Figure 2: Clip of Map Legend to Accompany Harvest Plan Maps	26
Figure 3: Clip of the Harvest Plan Map provided by BCTS for Block CAR-153.....	27
Figure 4: Clip of the Harvest Plan Map provided by BCTS for Block CAR-155.....	28
Figure 5: Oblique GE Image of CAR-153 & CAR-155	29
Figure 6: Clip of the Harvest Plan Map provided by BCTS for Block CAR-162.....	30
Figure 7: Clip of the Harvest Plan Map provided by BCTS for Block CAR-162.....	31
Figure 8: Clip of the Harvest Plan Map provided by BCTS for Block CAR-176.....	32
Figure 9: Clip of the Harvest Plan Map provided by BCTS for Block CAR-177.....	33
Figure 10: Clip of the Harvest Plan Map provided by BCTS for Block CAR-178.....	34
Figure 11: Clip of the Harvest Plan Map provided by BCTS for Block CAR-180.....	35
Figure 12: Oblique GE Image of CAR-177, CAR-178 & CAR-180	36

List of Appendices

Appendix A: Landslide Risk Analysis Terminology	attached
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1.0 Introduction

As requested by Ian Robertson, RPF, of British Columbia Timber Sales – Cariboo Chilcotin Business Area (BCTS), Onsite Engineering Ltd. (OEL) has completed a Terrain Stability Assessment (TSA) for the proposed Timber Sale License TA1918 including Cutblocks CAR-153, 155, 160, 162, 176, 177, 178, and 180. The proposed development is located to the east of the Cariboo River near Seller Creek and Collins Creek, approximately 80km northeast of Williams Lake, BC. See Figure 1 for a location map.

As the block development has not been finalized at the time of the assessment (i.e. harvest boundary locations, road locations and harvest methods have not been finalized), the TSA was completed based on the recce maps provided by BCTS and is considered preliminary with the intent of guiding layout. **For the purposes of this report, the Work in Progress (WIP) boundary shown on the Block Recce Maps is the assumed harvest boundary.** If the final block boundary deviates significantly from the WIP boundary shown on the provided mapping, BCTS must inform OEL so the results and recommendations presented within this TSA report can be re-evaluated and updated as necessary. Depending on the extent of the boundary change, additional field assessments may be necessary.

This assessment focused on areas of concern within and downslope of the assessed cutblocks, as well as the proposed and existing roads. Areas of concern were identified by OEL during an overview assessment of the development that included a review of available terrain stability mapping, available airphotos, orthoimagery, and previous terrain reports for the area.

Known elements at potential risk from a landslide initiating within or downslope of the proposed development include:

1. Water quality and fisheries resources in the Cariboo River downstream and downslope of Blocks 153, 155, 160 & 162.
2. Water quality and fisheries resources in Seller Creek downslope of Blocks 176, 177, 178, and 180.
3. Access along the Black Bear Creek FSR downslope of Blocks 160, 162, 176, 177, 178, and 180.

If elements at risk other than those indicated above are identified by readers of this report, OEL should be notified to revise the partial risk assessment provided here.

Note: Risk to timber and soil resources within and downslope of the proposed development are not discussed as it can be assumed that the impact to these resources will always occur in any landslide. An estimate of the maximum area that could be impacted by a potential landslide is provided, and it should be assumed that all of the estimated area contains soil and timber resources, as well as any other identified elements at risk.

2.0 Rationale for the TSA

This TSA was commissioned at the request of the coordinating forest professional for BCTS. During a review of the harvest plan mapping, it was determined that portions of the proposed forestry development are located proximal to terrain stability class (TSC) potentially unstable (P) or unstable (U) polygons. Due to the potential for landslide activity to occur as a result of harvesting and the potential to impact a high value resources, BCTS requested that OEL perform a TSA for the development.

The objective of this TSA is to undertake a partial risk assessment of the proposed development (areas of proposed timber harvest and road construction) and assess the potential for the initiation of landslides within or downslope of the development to reach elements at risk identified in Section 1.0. The TSA will also provide recommendations to reduce the hazard or risk to the identified elements at risk as required.

3.0 Methodology

This TSA has been prepared in accordance with generally accepted geotechnical practises in the British Columbia forest industry and in general conformance with the “Guideline for Professional Services in the Forest Sector – Terrain Stability Assessments”¹. General observations are made on the existing slope gradients,

¹ APEGBC/ABCFFP 2010.

shape, morphology and the general stability. Information on the subsurface soil, groundwater and bedrock conditions are gathered from hand-dug test holes, bedrock outcrops, root balls of fallen trees and the cutslopes on the existing roads in the surrounding area. A comparative-observational approach has been used to provide rationale for conclusions and recommendations. This approach relies on the examination of historical air photographs, field review of past forestry practices and the proposed development area, and professional judgement and experience to assess the likely response of the terrain to the proposed operations, based on the past response of similar terrain to previous forest developments.

The reader should be aware that the classification and identification of the type and condition of the geological units present are judgemental in nature. Variations (even over short distances) are inherent and are a function of natural processes. OEL does not represent or warrant that the conditions listed in the report are exact and the user should recognise that variations may exist. If sub-surface conditions encountered are significantly different than those identified, the conclusions and recommendations contained in this report should be reviewed by OEL, with amendments made as needed.

This report does not imply that a landslide will not occur following the proposed development. An estimate on the likelihood (or probability) of occurrence of a specific hazardous landslide (*i.e.* the $P(H)^2$) is given in relation to the proposed activities. The partial risk (*i.e.* the $P(HA)$) to the adjacent resources from the specific hazardous landslide has been assessed using methods described in the “Landslide Hazard and Risk Case Studies in the Forest Sector”³ document. Partial risk is the product of the probability of occurrence of a specific hazardous landslide (*i.e.* the $P(H)$) and the probability of that landslide reaching or otherwise affecting the site occupied by a specific element (*i.e.* the $P(S:H^4)$). Further explanation of the partial risk assessment, a matrix and a sample partial risk calculation are included in Appendix A.

Elements included in the partial risk analysis are those indicated on the mapping and materials provided by the client or coordinating registered professional for the proposed development and are listed in Section 1.0. Additional elements may exist. It is the responsibility of the coordinating registered professional to review our assessment of landslide likelihood, runout and magnitude and determine if any additional elements may be impacted.

Where recommendations are given to reduce the likelihood of landslide occurrence and/or mitigate the risk, the residual rating (where given) applies only if the recommendations from this report are followed. The acceptance of these recommendations indicates a willingness to manage the risks to the downslope and/or downstream resources (*i.e.* the elements at risk) associated with the occurrence of the specific hazardous landslide.

4.0 Background Data and Fieldwork

The following information was reviewed as part of this assessment:

- 1) Block Recce Maps for TA1918 Blocks 153, 155, 160, 162, 176, 177, 178, and 180 at a scale of 1:5,000 provided by BCTS. All maps dated either November 15, 16, or 17, 2021
- 2) Bedrock geology mapping – Mapping available online at iMapBC.
(<http://maps.gov.bc.ca/ess/sv/imapbc/>).
- 3) Land Management Handbook 56 – “Landslide Risk Case Studies in Forest Development Planning and Operations,” published by the BC Ministry of Forests Forest Science Program, 2004.
- 4) “Guidelines for Terrain Stability Assessments in the Forest Sector,” published by ABCFP/APEGBC, 2010.
- 5) Images and digital terrain model obtained from Google Earth, copyright of the province of BC 2021.
- 6) The following airphotos were also reviewed:

BC1264

No. 076-079

1950

² Probability of occurrence of a specific hazardous landslide.

³ Province of British Columbia, Ministry of Forests, 2004.

⁴ Spatial probability relates to the potential of a landslide to reach or otherwise affect the site occupied by an element.

BC1265	No. 014-017, 048-051, 076-077, 099-103	1950
BC2380	No. 016-023, 036-046, 058-070	1957
BC5269	No. 188-191, 244-247, 257-261	1967
BC5270	No. 210-212	1967
BC7682	No. 181-182, 209-210, 253-254	1974
BCC82026	No. 157-158, 177-178	1982
BCC1008	No. 114-115	1989
BCC96149	No. 100-103, 109-110, 181-188	1996
BCC97217	No. 224-225	1997
BCC03041	No. 092-100, 135-144	2003
BCC03043	No. 012-013	2003

Fieldwork was completed on July 18-20, 2022 by Justin Walch, GIT, and Justin Tamas, P. Geo., of OEL. Fieldwork consisted of foot traverses of potential areas of concern with respect to terrain stability in the proposed cutblocks and downslope areas. Conditions at the time of the assessments were cool with periods of rain and hail with no major limitations to visibility.

Conventions Followed

Soil classifications use terminology defined in the Unified Soil Classification System (USCS).

Slope gradient classification and landform descriptions follow the convention defined in the publication Terrain Classification System for British Columbia B.C. Ministry of Environment 1997.

Gentle: 5-27%
Moderate: 28-49%
Moderately Steep: 50-70%
Steep: > 70%

5.0 General Site Description

Physiographic Description

The proposed development covered in this report includes eight proposed cutblocks on variable slope aspects to the east of the Cariboo River. Four cutblocks are located in the Seller Creek valley, two are located in the Collins Creek catchment area, and two are located on face-unit slopes directly upslope of the Cariboo River. More broadly, the proposed development is located within the Quesnel Highlands Physiographic Region of BC, characterized by upland areas, remnant of a highly dissected plateau of moderate relief. The landscape becomes progressively more dissected moving eastward as the highland rises from approximately 1,500 m above sea level (asl) on the west side to over 1,900 m asl on the east side (Holland, 1976)⁵. Relief is substantial with the Cariboo River located at 748 m asl, while the local height of land at the peak of Badger Peak to the east and north of the development is located at 1795 m asl. The proposed development is located at an elevation between roughly 840 and 1480 m asl.

Geology and Soils

The bedrock underlying the proposed development area consists of a combination of two separate geologic units. The dominant bedrock unit underlying the majority of the development is Middle to Upper Triassic-aged undivided sedimentary rocks of the Nicola Group which includes sandstone, siltstone, shale, slate and phyllite, bioclastic limestone, minor felsic tuff, tuffaceous argillite, and basalt breccia. The second bedrock unit, underlying the northeast extents of CAR-155, is Carboniferous to Permian-aged serpentinite ultramafic rocks of the Slide Mountain Group from the Crooked Amphibolite Formation which includes serpentinite, sheared ultramafic rocks, amphibolite, and talc schist. The bedrock observed in the field was in broad agreement with

⁵ Holland, S.S., Landforms of British Columbia, A Physiographic Outline, Bulletin 48, 1976; BC Department of Mines and Resources. Victoria, B.C.

the mapped geology as lithologies surrounding Collins Creek and the Cariboo River reflected weakly fissile shale to slate rocks with minor amounts of schist found in the Seller Creek valley.

The soils observed in the Seller Creek valley and the mid to upper slopes of the Cariboo River valley sidewall consist of compact to dense silt leading till with some sand and gravel. Terraces along the lower valley sidewall adjacent to the Cariboo River are composed of deep deposits of glacio-fluvial sand and gravel with layers of fine textured glaciolacustrine soils.

Climate

Proposed cutblocks CAR-176, 177, 178, and 180 are located in the Engelmann Spruce – Subalpine Fir (ESSF) wk1 biogeoclimatic ecosystem classification (BEC) zone, typified by cool, short summers and long, cold winters with abundant annual precipitation⁶. Proposed blocks 155 and 153 are located in the Interior Cedar-Hemlock (ICH) wk4 BEC zone, characterized by cool winters and warm, dry summers with moderate precipitation. The closest weather station with sufficient long term data to determine climatic averages is located in Barkerville at an elevation of 1283 m a.s.l, approximately 38 km north of the proposed development. For the period of 1981-2010 this station recorded an average annual precipitation of 1021.7 mm with 560.3 mm falling as rain. Extreme daily precipitation was 71.1 mm/24 hr and average annual snowfall was 461.4 cm.

ClimateBC is a climate model that uses data from western North America to predict climate characteristics for locations distant from weather stations, such as the proposed development. Using data for the ten-year period between 2001 and 2010, the model predicts the annual precipitation to be 750 mm, with 399 mm in the form of rain, at an elevation of 1,124 m a.s.l (ClimateBC, 52.669, -121.430). This climatic regime tends to result in maximum moisture inputs to the ground during spring snowmelt and convective summer rainfall events that lead to increased soil moisture and an increased frequency of slope instability. Future climate projections for the proposed development area show that over the next 20-50 year period, annual precipitation is expected to increase to 819 mm and rainfall to slightly increase to 456 mm (13GCMs_ensemble_ssp126_2041-2070.gcm).

Existing Development and Potential Instability

A substantial amount of forestry related development has taken place in the study area throughout the 1970s and 80s. There is an extensive road network in the area with numerous smaller service roads branching off the Black Bear Creek FSR that is located along the lower valley sidewall adjacent to the southeast side of the Cariboo River. Numerous cutblocks have been harvested using ground based methods on the gentle to moderately steep terrain between the Cariboo River and the mountains of the Quesnel highland that are in various stages of regeneration.

Large scale clear cut forestry development in the study area began in the early 1970s. The Black Bear Creek FSR had been constructed and harvesting on the south side of the Cariboo River on the lower slopes of the hillside is visible.

The airphotos taken in 1989 show that the Black Bear Creek FSR had been extended down the south side of Seller Creek to reach the area surrounding proposed block CAR-176; additionally, the area on the sidewall surrounding proposed cutblock CAR-176 is heavily harvested with the addition of an extensive network of forestry roads and trails present on the hillside. Large cutblocks and extensive trail networks utilized to facilitate harvesting within the blocks continue to appear throughout the hillside surrounding the proposed development in the Seller Creek area until the mid-1990s. In the 1996 airphotos, the area surrounding proposed cutblocks CAR-177, 178, and 180 is harvested and Black Bear Creek FSR is extended roughly 4 km further up-chain to reach timbered slopes above CAR-180. The vast majority of the legacy roads and trails in the study area remain intact and have been unmaintained since the last major period of harvesting in the mid 1990s.

Due to the moderately steep and steep gradient terrain present within/downslope of the proposed development, landslides could potentially initiate as a result of harvesting and/or road construction. Our observations while completing numerous TSAs, as well as a review of relevant documents of numerous forest

⁶ BC Ministry of Forests and Range Forest Science Program, 2006; Map of Biogeoclimatic Zone of British Columbia.

developments and development-related landslides in the interior of BC, suggest that significant forest development related landslides are generally caused by drainage redirected by forestry roads and trails onto moderately steep to steep slopes (In one study for the Arrow and Kootenay Lake Forest Districts it was found that about 95% of development-related landslides are due to roads or skid trails). Smaller landslides can be caused by drainage redirected onto over-steepened road fills on similar slopes. Landslides on gentle to moderate slopes harvested by ground-based methods or traversed by balanced bench roads are almost unknown. Landslides caused by tree removal and root strength loss following cable harvesting on moderately steep to steep slopes are rare. The few landslides known to have occurred following cable harvesting appear to be related to some ground disturbance on wet, marginally stable sites.

Managing forestry related terrain stability hazards primarily requires controlling road and trail drainage that could affect steeper, potentially unstable slopes, and secondarily preventing excessive ground disturbance in steeper, wetter harvesting areas.

The incidence of natural or development related landslide activity in the upper reaches of Collins Creek and the vast majority of the Seller Creek valley appears to be relatively low despite a high density of unmaintained roads and trails in the existing cutblocks. In the 2003 airphotos a surficial slide, Slide-A, is visible to the east of CAR-180 which initiated in the fill slope of a road and ran out onto gentle terrain in the upper timbered extents of CAR-180. Slide-A is characterized by a 180 m runout length, 10 m width, and 1 m depth for a total estimated volume of 1800 m³. A second minor slide, Slide-B, is visible in the 2003 airphotos in a previously harvested block to the west of proposed cutblock CAR-178 and downslope of CAR-177 which ran out in-block on the Black Bear Creek FSR, with no impact to Seller Creek. Slide-B was triggered just upslope of the Black Bear Creek FSR and is defined by a 25 m runout length, 5 m width, and 1 m depth for a total volume of 125 m³ (Figure 12). Slides A and B are a good example of the typical magnitude of the development related slope failures that have occurred in the study area as a result of past harvesting operations

In contrast, the landslide incidence on the escarpment bordering the Cariboo River and the lower reaches of its major tributaries is relatively high. Although there are a number of development related landslides visible on the available imagery, a large proportion of the landslides appear to be primarily the result of down-cutting (toe-of-slope erosion) by the Cariboo River and its larger tributaries through deep deposits of poorly consolidated glaciofluvial/lacustrine materials. Most of the contemporary landslide features are translational events on the order of 10-100m wide, several meters deep, and 50-150m long.

To a lesser extent, the escarpment has also hosted several slow moving rotational slumps several hundred meters in width and length. At-least one of the slumps downslope of CAR-155 has re-mobilized in the last ~70 years. The last major period of movement appears to pre-date forestry development in the catchment upslope. The slide is discussed in greater detail in Section 6.1 as it relates to the partial risk analysis for the proposed development.

Additional Considerations

As a result of natural erosional processes imposed by the Cariboo River and its tributaries, landslide activity on the escarpment is expected to continue regardless of forestry development upslope; however, the magnitude and frequency could be exacerbated by harvesting and road building operations through the alteration of natural drainage patterns, timber removal, or a combination of the two. With respect to the hydrologic impacts of timber removal it is important to consider not only the projected equivalent clear-cut area (ECA) in a given catchment but also how each cutblock in the catchment is weighted differently depending on its elevation.

A study conducted by UBC Department of Forest Resources Management evaluating peak flow sensitivity to clear-cut harvesting at different elevation bands in snowmelt dominated mountainous catchments found that increasing harvest levels in the upper 80-40% of the basin resulted in significant impacts on annual maximum flows. For the Redfish Creek catchment area in south-eastern BC, the hydrologic modelling showed instantaneous increases of 22% for a 22.4% basin cut. “The upper 40% of the Redfish catchment is alpine/sub-alpine in character, lessening the effect of timber harvesting on peak stream flows. Logging impacts in basins without an alpine zone may be proportionally greater. Furthermore, terrain characterized by plateaus, a

significant portion of the total basin area will fall within a narrow elevation range and peak flows will be particularly sensitive to harvesting in these areas of gentle slopes, because snowmelt is simultaneous across the entire zone”⁷.

6.0 Proposed Harvesting - Discussion, Results and Recommendations

It is our understanding that the licensee or logging contractor will adhere to industry accepted standards and/or practices and applicable legislation for this development. This means that natural hillslope runoff patterns will be maintained by minimizing excessive site disturbance and through prompt rehabilitation of all temporary roads and bladed trails upon completion of harvesting. Rehabilitation must ensure that natural hillslope runoff patterns are maintained and runoff is not overly accelerated or concentrated. Our assessment of post harvesting landslide likelihood is based on this condition.

6.1 CAR-153 & CAR-155

General Observations and Discussion

Blocks CAR-153 and 155 are 70.1 ha, and 35.2 ha in size (respectively) and are located on northwest aspect slopes planned for clearcut harvesting using a combination of conventional ground and cable based methods. The falling boundaries of CAR153 are defined by CAR-155 to the north, the existing non-status TA1918-CAR153-04 Road to the west, Collins Creek to the south, and a recently logged cutblock to the east. The falling boundaries of CAR-155 are defined by a plantation to the north and east of the development, CAR-153 to the south, and the Cariboo River located to the west.

The primary access into the development is provided by an extensive network of proposed and existing roads with timber being hauled adversely back up to the Black Bear FSR to the east. The CAR-155 Rehab Road-1 descends off of the Black Bear FSR and enters the northeast corner of CAR-155. Numerous proposed roads are planned within the block descending into the lower slopes and tying into the existing non-status TA1918-CAR153-04 Road downslope.

Cariboo River flows within a deeply dissected valley bottom at the base of a steep escarpment below the cutblock (valley type IV, and stream class F based on the Rosgen Stream Classification System⁸). The reach below the development is typically 50 m wide with an average channel gradient of 1%. Active stream bank erosion is apparent along isolated areas of the escarpment, though the majority of the slope is timbered.

Regional terrain stability mapping identifies several TSC-P polygons (potentially unstable) located downslope of the development along the Cariboo River and Collins Creek escarpments. One TSC-U polygon (unstable) is designated around an area of active slope erosion on the Cariboo River escarpment due west of CAR-153. An additional TSC-P polygon is located in the northern portion of CAR-155. The field assessment for this area primarily targeted these polygons.

For discussion purposes, the terrain within and adjacent to CAR-153 & 155 has been divided into 9 areas, designated as Areas A to I. See Table 6.1 for a full description of the terrain, partial risk assessment, and subsequent recommendations for each of these areas. A map of the proposed cutblocks with each of the areas outlined is provided in Figures 3 and 4.

Discussion of Terrain Instability

The vast majority of the terrain encompassed by the proposed development (Areas A-F) contain few contemporary indicators of instability. With standard trail rehabilitation, road deactivation and maintenance of natural drainage patterns, the likelihood of post-harvest instability is expected to be kept at a tolerable level. The majority of the terrain stability concerns identified in the field or during the airphoto review are located downslope of the proposed development along the Cariboo River escarpment (Areas G & H, See Figure 5). In

⁷ Whitaker, A., Y. Alila, J. Beckers, and D. Toews, Evaluating peak flow sensitivity to clear-cutting in different elevation bands of a snowmelt-dominated mountainous catchment, *Water Resour. Res.*, 38(9), 1172, doi:10.1029/2001WR000514, 2002.

⁸ Watershed Academy Web - Fundamentals of Rosgen Stream Classification System, <https://cfpub.epa.gov/watertrain>

Area G the majority of the contemporary landslide features were observed near the toe of the slope (active slump and erosional failure indicated on Figure 5). Soils typically consist of deep deposits of loose glaciofluvial sand and gravel underlain by thin deposits of soft silt and clay lacustrine soils. Much of the surface drainage intercepted by the face unit of the hillside within the proposed block area readily infiltrates into the sand and gravel layers but likely becomes restricted at depth by the lacustrine sediments allowing flows to run horizontally and emerge in the mid to lower slope of the escarpment. While the majority of the slope movement is a function of ongoing bank erosion along the Cariboo River, seepage emergence likely exacerbates the magnitude and frequency of these events.

In Area H the slope movement indicators were observed at the crest of the escarpment (see Figure 5). Roughly 30-40m upslope from the slope crest is a prominent tension crack running along contour for approximately 130m, blending into the escarpment along the northern edge. A poorly confined NCD flows into the tension crack for 50-100m before infiltrating into the sub surface. The mature Douglas Fir vets growing in the area are severely re-curved. Based on the weathered appearance of the tension crack and a lack of fresh soil exposures the last major period of movement is estimated to be several decades ago. Airphoto review of the site suggests it may have occurred between 1950 and 1957 as there are several small surficial exposures visible during this time along the northern portion of Area G and one in the headwall of the 1-S6 draw along the southern side of Area H.

The period of slope movement pre-dates forestry development in the catchment upslope and may be linked to the diversion of the NCD that flows into the tension crack. The most likely source of the NCD is from a nearby S6 stream (1-S6) that flows 20-30m to the south of the NCD through CAR-155. It is likely that at one point the NCD re-converged with the S6 upstream of to the escarpment.

It is unclear if harvesting in the catchment of 1-S6 upslope has significantly contributed to slope movement within Area H since forestry development began in the mid-1970s. The catchment area of 1-S6 is approximately 110 ha in total. Approximately 75 ha has been logged, with 56 ha logged in the span of 12 years between 1976 and 1988, and 19 ha logged in 2021. There has likely been a significant amount of hydrologic recovery in many of the logged areas from the 70-80s which may offset the harvesting that has been conducted in 2021 (19ha) and what is being proposed in CAR-155 (8.5ha).

There is a degree of uncertainty as to how the escarpment has responded to past harvesting operations upslope, and how it will respond following harvesting in CAR-153 and CAR-155. Conservatively, partial cutting is recommended for all of CAR-153 & CAR-155 due to terrain concerns downslope on the escarpment (Areas G & H in Table 6.1). **30% timber retention is recommended in CAR-153. 50% timber retention is recommended in CAR-155. If these retention objectives are not considered feasible in certain areas of the development, those areas must be excluded from harvesting.** A full list of the recommendations for CAR 153 and CAR 155 are provided in Table 6.1.

6.2 CAR-160 & CAR-162

General Observations and Discussion

CAR-160 & 162 consists of four harvesting patches with a total area of 57.3 ha (gross) planned for clearcut harvesting using conventional ground based methods. It is located on north and east facing slopes adjacent to Collins Creek. Most of the falling boundaries are defined by 40-50 year old plantations. Access to the cutblock is provided by the existing CAR-160 Rehab Road-1 on the southwest side of Collins Creek and the existing CAR-162 Rehab Road-1 on the northwest side of Collins Creek. Several additional spurs are also proposed (CAR-160-01, -02 and CAR-162-01, -02, -03, -04, and -05).

Field assessments targeted the moderate to steep gradient terrain located downslope of the northern portion of the development which includes a TSC-P polygon located in a well confined reach of the Collins Creek draw in Area C (See Table 6.2, Figure 6). This TSC polygon is associated with moderately steep to steep gradient sidewall slopes of the Collins Creek stream draw.

Collins Creek is a small tributary of the Cariboo River. The upper reach of the stream adjacent to the proposed development has an average gradient of 15%, increasing to 18% in the gullied reach below the Black Bear FSR, and >20% near its confluence with the river. At this time it is OEL's understanding that the stream is not fish bearing. Approximately 43% of the catchment has been logged, the majority was conducted before 1985. No evidence of channel instability could be discerned from the historic airphotos in the reach immediately downslope of CAR-160 & 162 following harvesting; however, one fill slope failure is visible on a legacy road in the lower reach adjacent to the Cariboo River (near CAR-153). The magnitude and areal extent of the event is estimated as 3000m³ and 0.3ha. The event became entrained in the channel and travelled 120m directly into the Cariboo River.

No signs of contemporary slope instability were observed in the proposed development or immediately downslope during field assessments. The incidence of development related landslides following past harvesting operations conducted on similar terrain nearby is low; however, the northern portion of the development is largely imperfect to poorly drained and features a number of small flow paths presenting a concern for a gentle-over-steep (GOS) type of landslide on the steeper slopes below the proposed block (Areas C and D).

For discussion purposes, the terrain within and adjacent to CAR-160 & 162 has been divided into 5 areas, designated as Areas A to E. See Table 6.2 for a full description of the terrain, partial risk assessment, and subsequent recommendations. A map of the proposed cutblocks is provided in Figures 6 and 7.

6.3 CAR-176

General Observations and Discussion

Block CAR-176 is a 15.8 ha (gross) cutblock planned for clearcut harvesting using a combination of conventional ground and cable based methods. The block is located on northeast aspect slopes above Seller Creek, approximately 6.9 km upstream of its confluence with the Cariboo River. The falling boundaries of the cutblock are defined by previously harvested cutblocks to the northeast and south. Access to the cutblock is provided by the existing Black Bear Creek FSR, the CAR-176-Rehab Road and the proposed TA1918-CAR-176-01 Road.

Field assessments targeted a TSC-P polygon located downslope of the Black Bear Creek FSR, overlapping the lower southeast cutblock unit. The polygon is associated with the moderately steep to steep gradient sidewall slopes of Seller Creek.

Seller Creek is located 100-300m downslope of the proposed block and is classified as fish bearing. The average channel gradient below the harvest area is 5%. Connectivity between the cutblock and the creek is moderate in the southeast and high downstream toward the northwest.

No signs of contemporary slope instability were observed in the proposed development or downslope during field assessments. The incidence of development related landslides following past harvesting operations conducted on similar terrain nearby is low. Terrain in the proposed cutblock is predominantly moderately well drained with few indicators of shallow sub-surface flow; however, there is a minor concern for seasonal runoff paths or the large S6 channel in the southern part of the development to be disrupted by roads, bladed trails, or soil ruts created by harvesting machinery which could have stability implications for the terrain downslope (Area B).

For discussion purposes, the terrain within and adjacent to CAR-176 has been divided into 2 areas, designated as Areas A and B. See Table 6.3 for a full description of the terrain, partial risk assessment, and subsequent recommendations. A map of the proposed cutblock is provided in Figure 8.

6.4 CAR-177

General Observations and Discussion

Block CAR-177 is a 13.1 ha (gross) cutblock planned for clearcut harvesting using conventional ground based methods. The falling boundaries of the cutblock are broadly defined by two previously harvested areas to the east and west. Access to the cutblock is provided by the existing CAR-177 Rehab Road-1 and one proposed spur alignment, TA1918 CAR-177-01.

No signs of contemporary slope instability were observed in the proposed cutblock or downslope during an office based overview assessment of the development. One TSC P polygon is located downslope of the development to the north, associated with moderately steep to steep gradient terrain (Area B).

The incidence of development related landslides following past harvesting operations conducted on similar terrain nearby is low. Of minor concern is the potential for seasonal runoff patterns to be disrupted by roads, bladed trails, or soil ruts created by harvesting machinery which could have stability implications for the steeper terrain segments downslope of the proposed cutblock (Areas B & C).

For discussion purposes, the terrain within and adjacent to CAR-177 has been divided into 3 areas, designated as Areas A to C. See Table 6.4 for a full description of the terrain, partial risk assessment, and subsequent recommendations. A map of the proposed cutblock is provided in Figure 9.

6.5 CAR-178

General Observations and Discussion

Block CAR-178 is a 35.1 ha (gross) cutblock planned for clearcut harvesting using a combination of conventional ground and cable-based methods. The falling boundaries of the cutblock are broadly defined by the Black Bear Creek FSR to the north and two previously harvested areas to the northeast and southwest. Access to the cutblock is provided by the existing Black Bear Creek FSR and CAR-176-Rehab Road 1 and 2 and the proposed TA1918-CAR-178-01 and TA1918-CAR-178-02 Roads.

Several TSC-P polygons are mapped in the area, associated with moderately steep to steep gradient terrain. One is located in the lower portion of the block, upslope of the Black Bear Creek FSR, a second polygon is located downslope along the lower valley sidewall adjacent to Seller Creek, and the third is located in a deeply incised draw along the eastern side-line of the development. Contemporary slope instability within the area consists of active small scale stream bank erosion adjacent to Seller Creek (Lower Area B) and infrequent rock detachments from small bluffs along the sidewall of the draw near the east side-line of the development (Area C). No significant landslide features were observed during field assessments.

Seller Creek is located 100-160m downslope of the proposed block and is classified as fish bearing. The average channel gradient below the harvest area is 5%. Connectivity between the cutblock and the creek is moderate in the southeast and high downstream toward the northwest.

The incidence of development related landslides following past harvesting operations conducted on similar terrain nearby is low. Of minor concern is the potential for seasonal runoff patterns to be disrupted by roads, bladed trails or soil ruts created by harvesting machinery which could have stability implications for the steeper terrain segments downslope of the proposed cutblock (Areas B & C).

For discussion purposes, the terrain within and adjacent to CAR-178 has been divided into 3 areas, designated as Areas A to C. See Table 6.5 for a full description of the terrain, partial risk assessment, and subsequent recommendations. A map of the proposed cutblock is provided in Figure 10.

6.6 CAR-180

General Observations and Discussion

Block CAR-180 is a 24.9 ha (gross) cutblock planned for clearcut harvesting using conventional ground based methods. The falling boundaries of the cutblock are broadly defined by the Black Bear Creek FSR to the north and two large previously harvested areas to the east and west. Access to the lower elevation extents of the cutblock is provided by the existing Black Bear FSR and access to the upper elevation extents of the block will be provided by two proposed spur alignments, TA1918-CAR-180-01 and TA1918-CAR-180-02, respectively, which will branch off of the existing CAR-180 Rehab Road-1.

Seller Creek is located 90-250m downslope of the proposed block and is classified as fish bearing. The average channel gradient below the harvest area is 5%. Connectivity between the cutblock and the creek is relatively low.

One TSC P polygon partially overlaps the upper southwest corner of the block and a second TSC U polygon overlaps the southeast corner. The TSC U polygon is associated with moderately steep to steep gradient terrain and includes a development related landslide initiating in the fill slope of a an in-block road and running out into timbered slopes near the proposed development (Slide-A discussed in Section 5.0). Aside from this slide event, no signs of contemporary slope instability were observed in the proposed cutblock or downslope during an office based overview assessment of the development. Most of the cutblock area targets gentle to moderate slopes. The incidence of development related landslides following past harvesting operations conducted on similar terrain nearby is low.

See Table 6.6 for a full description of the terrain, partial risk assessment, and subsequent recommendations. A map of the proposed cutblock is provided in Figure 11.

Table 6.1: Cutblock TA1918 CAR-153 & CAR 155 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
A	Conventional Ground	Gentle	Well to Mod Well	<p>Uniform and slightly benched topography. There is gradual slope break along the west boundary leading into Areas B and D.</p> <p>There are no major streams present. An NCD was observed along the north boundary originating in a lateral swale and then turns westward to extend down into the lower slopes of Area A. minor seepage could be encountered in machine ruts.</p> <p>Surficial materials predominantly consist of compact silty gravel with trace sand and cobble till. These materials are estimated to be >3m in depth.</p> <p>No contemporary signs of instability were observed during field assessments.</p>	Within Area A: Very Low	N/A	N/A	<ul style="list-style-type: none">Recommend partial cut for all of CAR-153 & CAR-155 due to terrain concerns downslope in Areas G & H. 30% timber retention is recommended in CAR-153. 50% timber retention is recommended in CAR-155. Further rationale is provided in Table 6.1 rows G & H, and in Section 6.1. If these retention objectives are not considered feasible in certain areas of the development, those areas must be excluded from harvesting.	N/A
B	Conventional Ground & Cable	Moderate to Steep	Well to Imperfect	<p>Highly irregular in the south becoming uniform to benched in the north.</p> <p>No streams were observed in Area B. The local vegetation suggests sub-surface seepage or seasonal surface runoff could be encountered in the northern portion of this polygon.</p> <p>Surficial materials consist of loose glaciofluvial sand and gravel in the south transitioning into silty gravel with trace sand and cobble till in the north. These materials are estimated to be >3m in depth.</p> <p>No contemporary signs of instability were observed during field assessments.</p> <p>Harvesting may require the construction of bladed trails in order to access areas of moderately steep to steep gradient terrain.</p>	<p>Within Area B: Low</p> <p>Small surficial slide due to a drainage diversion along one of the proposed roads or trails and concentration onto unconditioned terrain. The maximum magnitude and areal extent of such an event is estimated as <250m³ and 0.03ha respectively. Runout is expected to terminate on benched terrain within or immediately downslope of Area B.</p>	Water quality and fisheries resources in the Cariboo River: Low	Very Low	<ul style="list-style-type: none">All bladed trails used to facilitate harvesting or ruts created by harvesting machinery must be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.	Very Low
C	Conventional Ground	Gentle	Well	<p>Slightly irregular terraced topography with benches.</p> <p>Surficial materials predominantly consist of loose to compact, glaciofluvial sand and gravel. These materials are estimated to be >10m in depth.</p> <p>No contemporary signs of instability were observed during field assessments.</p> <p>No harvesting related concerns.</p>	Within Area C: Very Low	N/A	N/A		N/A

Table 6.1: Cutblock TA1918 CAR-153 & CAR 155 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
D	Conventional Ground	Mod Steep to Steep	Imperfect to Poor	<p>Incised draw feature with steep sidewalls, 45% gradient, a prominent headwall, and seepage emerging at the base. Interpreted as a relic slide.</p> <p>Recurved trees along the sidewalls and base of the draw feature are an indication of contemporary soil creep.</p> <p>Surficial materials predominantly consist of stiff to hard silt some gravel some to trace clay, and trace sand. These materials are estimated to be >3m in depth.</p> <p>The draw is excluded from the harvest area by a 1.5 tree length buffer on all sides.</p>	Within Area D: Moderate Small surficial slide due on the draw sidewalls due to a drainage diversion along one of the proposed roads or trails upslope in Area A. Runout is expected to runout in the base of the draw where it could become entrained in a short debris pulse, terminating at the mouth of the draw in Area C. The maximum magnitude and areal extent of such an event is estimated as 2,000m ³ and 0.05ha respectively (assuming a length of 200m, a width of 10m and a depth of 1m).	Water quality and fisheries resources in the Cariboo River: Low	Low	<ul style="list-style-type: none">Exclude Area D from harvesting as suggested by layout personnel.Area E and F should be harvested in the winter months under frozen conditions and with a sufficient snowpack to prevent rutting and disruption of natural drainage patterns.Place 1-S6 and the adjacent NCD (Area E) in a machine free zone (MFZ) and remove all introduced logging debris from the flow paths.	Very Low
E	Conventional Ground	Gentle to Moderate Isolated Mod. Steep	Imperfect to Poor	<p>Irregular benched terrain superimposed by low gradient relic slump features. No contemporary movement.</p> <p>Two flow paths were observed in this area of the block. 1-S6 is approximately 1.5m wide with a cobble substrate and a gradient of 35-50% in the harvest area. An NCD flows adjacent to the stream 20-30m north and presumably draws it source from the mainstem higher on the hillside. Both of the flow paths are poorly confined and highly susceptible to diversion.</p> <p>Surficial materials predominantly consist of loose to compact, glaciofluvial sand and gravel. Depth to rock >3m, increasing to 10m to the west. The presence of low gradient slumps may indicate a soft fine-texture lacustrine layer at depth.</p> <p>Ground based harvesting during the spring, summer or fall months in this portion of the block could result in significant soil disturbance and disruption of natural drainage patterns.</p>	Within Area E: Low Small surficial slide due to excessive ground disturbance by ground based machinery. The maximum magnitude and areal extent of such an event is estimated as <250m ³ and 0.03ha respectively. Runout is expected to terminate on benched or terraced terrain within Area E. Sediment delivery to the Cariboo River is not expected.	Water quality and fisheries resources in the Cariboo River: Low	Very Low	<ul style="list-style-type: none">Recommend partial cut for all of CAR-153 & CAR-155 due to terrain concerns downslope in Areas G & H. 30% timber retention is recommended in CAR-153. 50% timber retention is recommended in CAR-155. Further rationale is provided in Table 6.1 rows G & H, and in Section 6.1. If these retention objectives are not considered feasible in certain areas of the development, those areas must be excluded from harvesting.All bladed trails used to facilitate harvesting or ruts created by harvesting machinery must be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.	Very Low
F	Cable	Moderate to Steep	Well to Imperfect	<p>Uniform to benched terrain.</p> <p>No streams were observed in Area F. The local vegetation suggests sub-surface seepage or seasonal surface runoff could be encountered in topographic low points throughout this polygon.</p> <p>Surficial materials predominantly consist of compact silt till with gravel and cobbles. Bedrock exposures are observed on the steepest pitches in the northeast consisting of fractured schist/shale. Veneers of angular rubble were observed around the rock exposures.</p> <p>Isolated areas of this polygon exhibit indicators of soil creep.</p>	Within Area F: Moderate Small surficial slide due to excessive soil disturbance or drainage diversion/concentration. The maximum magnitude and areal extent of such an event is estimated as 750m ³ and 0.08ha respectively (assuming a slide runout of 75m, a width of 10m and a depth of 1m). Runout is expected to terminate on benched terrain in Area F or on the terrace downslope in Area C. Sediment delivery to the Cariboo River is not expected.	Water quality and fisheries resources in the Cariboo River: Low	Low	<ul style="list-style-type: none">The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.	Very Low

Table 6.1: Cutblock TA1918 CAR-153 & CAR 155 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
G	N/A- Outside of the block	Moderately Steep to Steep	Mod Well to Poor	<p>Cariboo River escarpment. Highly irregular terrain related to deep seated historic slide activity. Active slope movement was observed along the toe of the slope. Refer to Section 6.1 and Figure 5 for more detail.</p> <p>Soils typically consist of deep deposits of loose glaciofluvial sand and gravel underlain by thin deposits of soft silt and clay lacustrine soils. Much of the surface drainage intercepted by the face unit of the hillside within the proposed block area readily infiltrates into the sand and gravel layers but likely becomes restricted at depth by the lacustrine sediments allowing flows to run horizontally and emerge in the mid to lower slope of the escarpment. While the majority of the slope movement is a function of ongoing bank erosion along the Cariboo River seepage emergence likely exacerbates the magnitude and frequency of these events.</p>	<p>Within Area G: High Natural Hazard, Moderate Harvesting Related Hazard. Two landslide scenarios exist:</p> <p><u>Scenario 1:</u> Increased slow slope movement within existing rotational failures. Most of these features are located near the base of the slope and are already encroaching on the Cariboo River. Sediment delivery to the water course is expected to be gradual. Small pulses of fine sediment are possible during the spring freshet.</p> <p><u>Scenario 2:</u> Translational landslide due to a drainage diversion along one of the proposed roads or trails and concentration onto unconditioned terrain. The magnitude and areal extent of such an event is estimated as 500-2,000m³ and 0.05-0.2ha respectively (assuming a slide width of 10m and runout length of 25-100m, and a depth of 2m). Coarse sediment delivery to the river is likely.</p>	Water quality and fisheries resources in the Cariboo River: High	High	<ul style="list-style-type: none">Exclude all terrain below the existing TA1918-CAR153-04 Road from Harvesting.Use the ditchline of the TA1918-CAR153-04 Road to re-direct the NCD into the main 1-S6 channel ~20m southwest. The intent of this recommendation is to re-establish the assumed drainage patterns that preceded the slide event in Area H by allowing the NCD to converge into the 1-S6 mainstem before it flows down the Cariboo River escarpment. This work should be overseen by a QRP. See Figure 4.Recommend partial cut for all of CAR-153 & CAR-155 due to terrain concerns downslope in Areas G & H. 30% timber retention is recommended in CAR-153. 50% timber retention is recommended in CAR-155. Further rationale is provided in Table 6.1 rows G & H, and in Section 6.1. If these retention objectives are not considered feasible in certain areas of the development, those areas must be excluded from harvesting.	Moderate
H	N/A- Outside of the block	Moderately Steep to Steep	Mod Well to Poor	<p>Steep backscarp of a historic rotational failure near the crest of the escarpment with evidence of active slope movement. The last major period of slope movement is estimated to have been between 1950-1957 (pre-forestry) and may be related to a natural flow path diversion. It is unclear if harvesting in the catchment upslope after 1970 has significantly contributed to slope movement. Refer to Section 6.1 and Figure 5 for more detail.</p> <p>The soil composition is similar to what was described above in Area G.</p>	<p>Within Area H: High Natural Hazard, Moderate Harvesting Related Hazard. Two landslide scenarios exist:</p> <p><u>Scenario 1:</u> Increased slow slope movement within existing rotational failure. Sediment delivery to the water course is expected to be gradual. Small pulses of fine sediment are possible during the spring freshet.</p> <p><u>Scenario 2:</u> If the slope were to fail rapidly either in response to a drainage diversion or a rapid increase in runoff related to timber removal it is expected to encompass a wedge of material approximately 140m long x 25m wide x 30m deep with an estimated magnitude of 105,000m³. Runout from such an event would extend another 140m downslope from the toe of the slide mass into the Cariboo River, and would likely strip away another 50,000-75,000m³ through the runout path (total magnitude of 155,000-180,000m³ and an areal extent of 3.4 ha).</p>	Water quality and fisheries resources in the Cariboo River: High	High	<ul style="list-style-type: none">All proposed bladed and excavated trails used to facilitate harvesting in the proposed cutblocks upslope must be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.	Moderate

Table 6.1: Cutblock TA1918 CAR-153 & CAR 155 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
I	N/A- Outside of the block	Moderately Steep to Steep	Well	<p>Collins Creek gully sidewall. South slope aspects. Predominantly steep uniform terrain.</p> <p>There is no evidence of contemporary slope instability in the mid to upper slopes of the sidewall. The adjacent harvest area has hardly any connectivity to the escarpment as it slopes towards the west, parallel to the slope break.</p> <p>Surficial materials predominantly consist of a veneer of sandy gravel with some silt glaciofluvial deposits. Near surface fractured schist/slate was observed in various locations along the top of the slope.</p>	<p>Within Area I: Low</p> <p>Large translational landslide due to a drainage diversion along one of the proposed roads or trails in the harvest area upslope. The magnitude and areal extent of such an event is estimated as 2,400m³ and 0.2ha respectively (assuming a slide width of 20m and runout length of 120m, and a depth of 1m). Runout is expected to terminate near Collins Creek at the toe of the slope. Fine sediment delivery to the Cariboo River or fish bearing reaches of Collins Creek near its confluence with the river is likely.</p>	<p>Water quality and fisheries resources in the Cariboo River:</p> <p>Moderate</p>	Low	<ul style="list-style-type: none">Refer to the recommendations presented above for Areas A, B & C.	Low

Table 6.2: Cutblock TA1918 CAR-160 & CAR-162 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
A	Conventional Ground	Gentle to Moderate	Imperfect to Poor	Uniform to slightly benched, dissected by shallow swales in the southwest. Numerous moderately well to poorly confined flow paths flow through this area including two small S6 streams (0.5-0.75m wide, sand and gravel substrate) and several NCDs (<0.25m wide). Surficial materials consist of firm to stiff silt with some clay and gravel till with trace sand. Estimated depth of >3m. No contemporary slope instability indicators were observed in this area during field assessments. Ground based harvesting during the spring, summer or fall months in this portion of the block could result in significant soil disturbance and disruption of natural drainage patterns which could have stability implications for the terrain downslope (See Area D).	Within Area A: Low Small surficial slide due to a drainage alteration/concentration along one of the proposed roads or trails. The maximum magnitude and areal extent of such an event is estimated as 150m ³ and 0.02ha respectively. Runout is expected to terminate in Area A. Sediment delivery to the Cariboo River is not expected.	Water quality and fisheries resources in the Cariboo River located ~2.5-3.0 km downstream: Low Temporary damage and loss of access to the Black Bear Creek FSR: Low	Very Low	Due to the elevated likelihood of a landslide downslope of the development in Areas C and D the following recommendations are made: <ul style="list-style-type: none">• Areas A and B must be harvested in the winter months under frozen conditions and with a sufficient snowpack to prevent rutting and disruption of natural drainage patterns.• S6 streams, NCDs and prolific wet sites should be designated in machine free zones.	Very Low
							Very Low		Very Low
B	Conventional Ground	Moderate	Imperfect to Poor	Uniform to slightly benched, dissected by shallow swales hosting NCDs or minor seepage. Surficial materials consist of stiff silt with some sand and gravel till. Estimated depth of >3m. No contemporary slope instability indicators were observed in this area during field assessments. Ground based harvesting during the spring, summer or fall months in this portion of the block could result in significant soil disturbance and disruption of natural drainage patterns which could have stability implications for the terrain downslope (See Area C).	Within Area B: Low Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery. The maximum magnitude and areal extent of such an event is estimated as 150m ³ and 0.02ha respectively. Runout is expected to terminate in Area B. Sediment delivery to the Cariboo River is not expected.	Water quality and fisheries resources in the Cariboo River located ~2.5 km downstream: Low Temporary damage and loss of access to the Black Bear Creek FSR: Low	Very Low	<ul style="list-style-type: none">• All proposed bladed and excavated trails used to facilitate harvesting must be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.• The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.	Very Low
							Very Low		Very Low
C	N/A- Outside of the block	Moderate to Steep	Imperfect to Poor	Benched to uniform in profile, dissected by swales hosting NCDs or minor seepage. Surficial materials consist of stiff silt with some sand and gravel till at depth occasionally overlain by a loose to compact deposit of gravelly silt with some sand. Estimated depth of >3m. No contemporary slope instability indicators were observed in this area during field assessments. Ground based harvesting during the spring, summer or fall months in the proposed block upslope could result in disruption of natural drainage patterns and subsequent landslide activity in Area C.	Within Area C: Moderate Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the proposed block area upslope. The magnitude and areal extent of such an event is estimated as 250-500m ³ and 0.03-0.05ha respectively. Runout is expected to terminate directly in Collins Creek at the toe of the slope. A secondary debris transport event on Collins Creek is not expected. Fine sediment may be delivered to the Cariboo River ~2.5km downstream.	Water quality and fisheries resources in the Cariboo River located ~2.5 km downstream: Moderate Temporary damage and loss of access to the Black Bear Creek FSR: Low	Moderate Low	<ul style="list-style-type: none">• Road construction must be conducted in the driest months of the year (Late summer, August).	Low Very Low

Table 6.2: Cutblock TA1918 CAR-160 & CAR-162 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
D	N/A- Outside of the block	Moderate to Moderately Steep	Imperfect to Poor	<p>The majority of this area features a convex slope profile dissected by shallow ridges and swales on contour. Irregularly benched in the northwest.</p> <p>Numerous moderately well to poorly confined flow paths flow through this area including two small S6 streams (0.5-0.75m wide, sand and gravel substrate) and several NCDs (<0.25m wide).</p> <p>Surficial materials consist of firm to stiff silt with some clay and gravel till with trace sand. Estimated depth of >3m.</p> <p>Semi-circular bowl-shaped features were observed in the northwest portion of this polygon with prolific seepage, interpreted as relic post-glacial rotational slides. No indicators of contemporary slope movement were observed. Soils in the area consist of soft silt with some sand and gravel.</p> <p>Ground based harvesting during the spring, summer or fall months in the proposed block upslope could result in disruption of natural drainage patterns and subsequent landslide activity in Area D.</p>	<p>Within Area D: Moderate</p> <p>Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the proposed block area upslope. The magnitude and areal extent of such an event is estimated as 250-500m³ and 0.03-0.05ha respectively. Runout is expected to terminate in the valley bottom near Collins Creek. Fine sediment may be delivered to the Cariboo River ~3.0km downstream.</p>	<p>Water quality and fisheries resources in the Cariboo River located ~3.0 km downstream:</p> <p>Moderate</p> <p>Temporary damage and loss of access to the Black Bear Creek FSR:</p> <p>Low</p>	<p>Moderate</p> <p>Low</p>	<ul style="list-style-type: none">Refer to the recommendations presented above for Areas A and B.	<p>Low</p> <p>Very Low</p>
E	Conventional Ground	Gentle	Imperfect to Poor	<p>Note: Field assessments were not conducted for this area of the development.</p> <p>Area E covers the two harvesting patches on the west side of Collins Creek, both are situated on planar terrain with two mapped NCDs extending through or adjacent to their boundary. Both NCDs are tributaries to Collins Creek downstream.</p> <p>Based on field assessments conducted nearby, the surficial materials are expected to consist of firm to stiff silt with some clay and gravel till with trace sand. Estimated depth of >3m.</p> <p>A steep sided draw dissects the upper slopes of the southern-most harvesting patch, interpreted as a relic feature related to the last major deglacial period. Features like these are common in the mid to upper elevations of the valley sidewalls across the study area and are rarely associated with contemporary erosional processes.</p> <p>Due to the predominantly gentle slopes and the lack of connectivity to any steep downslope terrain harvesting activities in the proposed block are unlikely to result in a landslide.</p>	<p>Within Area E: Very Low</p>	<p>N/A</p>	<p>N/A</p>	<ul style="list-style-type: none">With respect to worker safety, a 5m wide machine free zone (MFZ) should be designated around the sidewalls of the relic draw in the southern-most harvesting patch.	<p>N/A</p>

Table 6.3: Cutblock TA1918 CAR-176 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
A	Conventional Ground & Cable	Gentle to Moderate Isolated Mod Steep	Mod Well	Planar to benched terrain. Surficial materials consist of compact silty sand with some gravel. Estimated depth of 0-2m. Shale outcrops were observed in parts of the Black Bear Creek FSR downslope to the southeast. No contemporary slope instability indicators were observed in this area during field assessments. Minor concern for seasonal runoff patterns to be disrupted by the existing/proposed roads or bladed trails in the cutblock which could have stability implications for the terrain downslope (See Area B).	Within Area A: Low Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery. The magnitude and areal extent of such an event is estimated as 150m ³ and 0.02ha respectively. Runout is expected to terminate on benched terrain in Area A.	Water quality and fisheries resources in Seller Creek: Low Temporary damage and loss of access to the Black Bear Creek FSR: Low	Very Low Very Low	<ul style="list-style-type: none">All proposed bladed and excavated trails used to facilitate harvesting must be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.	Low
				Predominantly uniform terrain. Irregular topography downslope below the southeast extents. Dissected by an S6 stream draw in the southern portion. The S6 stream is 3-4m wide with a gradient of 50-55% and a cobble substrate. The channel is moderately well confined in a broad swale. No evidence of recent debris transport was observed. The channel flows through twin 500mm/600mm culverts upslope on the Black Bear Creek FSR. Surficial materials consist of shale rubble in a matrix of gravelly sandy silt in the south, and gravelly silt some sand in the north. Both deposits are loose to compact in the upper meter. Estimated depth of 0-2m. No contemporary slope instability indicators were observed in this area during field assessments. Minor concern for seasonal runoff patterns or the S6 stream to be disrupted by the existing/proposed roads or bladed trails in the cutblock upslope, resulting in potential slide activity in Area B.	Within Area B: Moderate Mid-sized surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the proposed block area upslope. Two slide scenarios exist depending on the initiation site: B¹: The magnitude and areal extent is estimated as 2000m ³ and 0.2ha, respectively. A slide of this size is expected to runout into Seller Creek 200m downslope at the toe of the slope. Fine sediment could reach the Cariboo River 6.9km downstream. B²: The magnitude and areal extent is estimated as 750m ³ and 0.08ha, respectively. A slide of this size is expected to runout onto irregular terrain in the valley bottom prior to Seller Creek. Fine sediment could be delivered to the channel depending on the proximity of the slide to the large S6 stream draining the hillside.	Water quality and fisheries resources in Seller Creek: High Water quality and fisheries resources in the Cariboo River located ~6.9 km downstream: Moderate	High Moderate		Moderate Low
B	Mostly outside of the block, Cable proposed in the south	Moderate to Steep	Mod Well			Water quality and fisheries resources in Seller Creek: Moderate Water quality and fisheries resources in the Cariboo River located ~6.9 km downstream: Low	Moderate Low	<ul style="list-style-type: none">The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.Clean-out the inlets of the twin 500mm/600mm culverts on the Black Bear Creek FSR between the two harvesting patches (see Figure 8). Install a deep (≥0.6m) back-up cross ditch immediately following completion of harvesting.	Moderate Low Very Low

Table 6.4: Cutblock TA1918 CAR-177 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
A	Conventional Ground	Primarily Gentle to Moderate Isolated Mod Steep to Steep	Imperfect	Note: Field assessments were not conducted for this area of the development. Irregular benched terrain on a ridge. Based on field assessments conducted nearby, the surficial materials are expected to consist of loose to compact shale rubble in a gravelly sandy silt matrix. Estimated depth of 0-2m Based on the low incidence of landslides in the area following past harvesting on similar terrain, harvesting activities in the proposed block are unlikely to result in a major landslide.	Within Area A: Very Low	N/A	N/A	<ul style="list-style-type: none">All proposed bladed and excavated trails used to facilitate harvesting should be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.	N/A
B	N/A- Outside of the Block	Moderate to Steep	Imperfect to Poor	Note: Field assessments were not conducted for this area of the development. Irregularly benched, short (<50m) moderately steep/steep planar segments. Based on field assessments conducted nearby, the surficial materials are expected to consist of loose to compact shale rubble in a gravelly sandy silt matrix. Estimated depth of 0-2m. Open alder fields visible in imagery suggest this slope could be wetter in comparison to the ridge upslope in the block. Saturated soils could potentially more sensitive to drainage path alterations in the cutblock area upslope.	Within Area B: Moderate Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the block area upslope. The maximum magnitude and areal extent of such an event is estimated as 250m ³ and 0.03ha respectively. Runout is expected to terminate on gentle terrain within or immediately downslope of Area B. Sediment delivery to Seller Creek is not expected.	Water quality and fisheries resources in Seller Creek: Low	Low		Very Low
C	N/A- Outside of the Block	Mod Steep to Steep	Imperfect	Note: Field assessments were not conducted for this area of the development. Concave slope in a logged block along the southeast side of the proposed block. A small portion of the proposed block slopes towards this area. Based on field assessments conducted nearby, the surficial materials are expected to consist of loose to compact shale rubble in a gravelly sandy silt matrix. Estimated depth of 0-2m. No contemporary slope instability indicators were observed in this area during the office based overview assessment.	Within Area C: Low Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the block area upslope. The maximum magnitude and areal extent of such an event is estimated as 250m ³ and 0.03ha respectively. Runout is expected to terminate in Area A. Sediment delivery to Seller Creek is not expected.	Water quality and fisheries resources in Seller Creek: Low	Very Low		Very Low

Table 6.5: Cutblock TA1918 CAR-178 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
A	Conventional Ground & Cable	Gentle to Moderate Isolated Mod Steep	Mod Well to Imperfect Poor drainage in the south-east	<p>Area A covers the entire proposed harvest area. Variable morphology. Benched/irregular in the lower north-eastern lobe, planar in the upper southern portion. A lateral swale cuts across the slope in the northwest, breaking over into a concave configuration down to the Black Bear Creek FSR.</p> <p>Surficial materials are largely composed of loose to compact, Shale rubble in a gravelly sandy silt matrix. Estimated depth of 0-2m.</p> <p>The western side-line of the block is defined by a large 4-5m wide stream with a cobble and boulder substrate and a channel gradient of 25-45%. The stream flows through an adequately sized 1200-1500mm culvert on the FSR.</p> <p>Very few surface flow paths were observed in the majority of the block; however, the southeastern portion of Area A features at-least one small S6 stream (1m wide, 20-25%, sand and gravel substrate) and several seepage sites above a prominent slope break into Area C.</p> <p>No contemporary slope instability indicators were observed in this area during field assessments.</p> <p>Minor concern for seasonal runoff patterns to be disrupted by the roads, bladed trails, or soil ruts created by harvesting machinery which could have stability implications for the terrain downslope (See Areas B and C).</p>	<p>Within Area A: Low</p> <p>Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the block area upslope. The maximum magnitude and areal extent of such an event is estimated as 250-500m³ and 0.03-0.05ha respectively. Runout is expected to terminate on gentle terrain within Area A. Fine sediment delivery to Seller Creek is not expected from a slide in the upper portions of this polygon. A slide in the lower eastern portion of this polygon could result in fine sediment delivery to Seller Creek due to the close proximity.</p>	<p>Water quality and fisheries resources in Seller Creek: Low to Moderate</p> <p>Temporary damage and loss of access to the Black Bear Creek FSR: Low to Moderate</p>	<p>Very Low to Low</p> <p>Very Low to Low</p>	<ul style="list-style-type: none">All proposed bladed and excavated trails used to facilitate harvesting must be fully rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must include the restoration of all natural drainage paths, decompaction (roughing up) of the trail running surface, pull back of fill and placement against the trail cuts (or within ruts) to recontour the slope, and placement of logging slash and other woody debris over the recontoured surface to reduce erosion.The proposed roads & existing roads used to facilitate harvesting should be temporarily deactivated upon completion of harvesting. Deactivation is to include the construction of back-up cross ditches at all culvert locations as well as frequently spaced (<50m) waterbars on sustained road grades.The proposed cutblock should be harvested in the winter months under frozen conditions and with a sufficient snowpack to prevent rutting and disruption of natural drainage patterns.S6 streams, NCDs and prolific wet sites should be designated in machine free zones.	<p>Very Low</p> <p>Very Low</p>
				<p>Uniform topography with isolated benches.</p> <p>Surficial materials consist of compact shale rubble in a gravelly silt matrix. Shale outcrops were observed near the toe of the slope adjacent to Seller Creek.</p> <p>The western side-line of this polygon is defined by the large 4-5m wide stream previously discussed above. No other flow paths were observed in the area.</p> <p>The majority of this polygon has no contemporary slope instability indicators aside from isolated areas of stream bank erosion at the toe of the hillside adjacent to Seller Creek.</p> <p>Minor concern for seasonal runoff patterns to be disrupted by the roads, bladed trails, or machine ruts in the cutblock upslope, resulting in potential slide activity in Area B.</p>	<p>Within Area B: Moderate</p> <p>Mid-sized surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the block area upslope. Two slide scenarios exist depending on the initiation site:</p> <p>B¹: The magnitude and areal extent is estimated as 1000m³ and 0.1ha, respectively. A slide of this size is expected to runout onto timbered benches below the Black Bear Creek FSR or directly into Seller Creek. Coarse sediment delivery to Seller Creek is likely.</p> <p>B²: The magnitude and areal extent is estimated as 500-750m³ and 0.05-0.08ha, respectively. A slide of this size is expected to runout onto benched irregular terrain in Area A downslope. Fine sediment delivery to Seller Creek is possible.</p>	<p>Water quality and fisheries resources in Seller Creek: High</p> <p>Temporary damage and loss of access to the Black Bear Creek FSR: Moderate</p> <p>Water quality and fisheries resources in Seller Creek: Moderate</p> <p>Temporary damage and loss of access to the Black Bear Creek FSR: Moderate</p>	<p>High</p> <p>Moderate</p> <p>Moderate</p> <p>Moderate</p>		<p>Moderate</p> <p>Low</p> <p>Low</p>

Table 6.5: Cutblock TA1918 CAR-178 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
C	N/A- Outside of the block	Steep	Mod Well to Imperfect	<p>Steep sided draw sidewall below eastern harvest boundary. The steep slope break separating Area A and C constitutes a GOS configuration.</p> <p>Frequent rock exposures and small bluffs along the crest, grading into shale rubble in a gravelly sandy silt matrix in the mid to lower slopes. Soil depths increases from 0-3m moving downslope.</p> <p>At-least one small S6 stream flows over the break of Area A and C and several seepage sites were observed near the slope crest.</p> <p>Contemporary slope instability in this polygon primarily takes the form of small scale rockfall events. No landslide features were observed during field assessments.</p> <p>Minor concern for seasonal runoff patterns to be disrupted by the roads, bladed trails, or soil ruts created by harvesting machinery in the cutblock upslope, resulting in a slide in the mid to lower slopes of Area C.</p>	<p>Within Area C: Moderate</p> <p>Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the block area upslope. The maximum magnitude and areal extent of such an event is estimated as 500-750m³ and 0.05-0.08ha respectively (assuming a slide width of 15-20m, a depth of 0.5m and a length of 75m). The slide is expected to deposit in the stream channel in the base of the draw. A secondary debris transport event is not expected. Fine sediment delivery to Seller Creek is expected.</p>	<p>Water quality and fisheries resources in Seller Creek: Moderate</p> <p>Temporary damage and loss of access to the Black Bear Creek FSR: Low</p>	<p>Moderate</p> <p>Low</p>	<ul style="list-style-type: none">Refer to the recommendations presented above for the proposed harvest area.With respect to worker safety, a 5-10m wide machine free zone (MFZ) should be designated across the crest of the draw sidewall (i.e. the boundary of Areas A and C).	<p>Low</p> <p>Very Low</p>

Table 6.6: Cutblock TA1918 CAR-180 - Summary of Observations, Risk Analysis, and Harvesting Recommendations

Area	Harvest Method	Slope Gradient %	Drainage	Description	Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendations	Residual Partial Risk P(HA)
A	Conventional Ground	Gentle to Moderate	Imperfect to Poor	<p>Variable morphology. Benched in the west, irregular in the east dissected by stream draws.</p> <p>Several LiDAR based streams are mapped within and adjacent to the proposed development, particularly in the east. The northeast extents of the area are expected to be wet with seepage sites.</p> <p>Based on field assessments conducted nearby, the surficial materials are expected to consist of loose to compact shale rubble in a gravelly sandy silt matrix or a blanket of compact to dense silt dominated till.</p> <p>No contemporary slope instability indicators were observed in this area during the office based overview assessment; however, a fill slope failure was observed upslope of the southeast corner of the cutblock that ran out in close proximity to the proposed development (worker safety hazard).</p>	<p>Within Area A: Low</p> <p>Small surficial slide due to a drainage path disruption by roads, trails, or ruts created by harvesting machinery in the harvest area. The maximum magnitude and areal extent of such an event is estimated as 250m³ and 0.03ha respectively. Runout is expected to terminate on gentle terrain within Area A. Fine sediment delivery to Seller Creek is possible depending on the slide initiation point relative to the stream systems draining the hillside.</p>	<p>Water quality and fisheries resources in Seller Creek: Low to Moderate</p> <p>Temporary damage and loss of access to the Black Bear Creek FSR: Low</p>	<p>Very Low to Low</p> <p>Very Low</p>	<ul style="list-style-type: none">No harvesting related recommendations are suggested at this time.With respect to worker safety, logging personnel should be made aware of the potential for slide activity upslope of the proposed cutblock to the southeast corner (yellow area shown on Figure 11). Plan harvesting operations accordingly (i.e. avoid working in the southeast corner during excessively wet conditions when slide activity is most likely to occur).	<p>Very Low to Low</p> <p>Very Low</p>
B	N/A - Outside of the Block	Gentle to Moderate	Imperfect to Poor	<p>Hummocky terrain in the valley bottom with several converging LiDAR streams.</p> <p>Based on field assessments conducted nearby, the surficial materials are expected to consist of loose to compact shale rubble in a gravelly sandy silt matrix or a blanket of compact to dense silt dominated till.</p> <p>No contemporary slope instability indicators were observed in this area during the office based overview assessment.</p>	<p>Within Area B: Very Low</p>	<p>N/A</p>	<p>N/A</p>		<p>N/A</p>

7.0 Closure

This report contains information relating to the terrain stability following the proposed harvesting and/or road/trail building activities. OEL must be contacted should the proposed development change and/or the soil/bedrock conditions encountered differ from those outlined in this report so that the recommendations contained in this report can be reviewed.

Factual data and interpretation contained within this report were prepared specifically for British Columbia Timber Sales – Cariboo Chilcotin Business Area with whom Onsite Engineering Ltd. has entered into a contract. No other party may rely upon this report without the express written permission of OEL.

We trust that this report satisfies your present requirements. Should you have any questions or comments, please contact our office at your convenience.

Sincerely,

Onsite Engineering Ltd.

Prepared by:

A blue circular professional stamp for Justin H. Tamas, a Geoscientist in the Province of British Columbia, registration number 52936. To the right of the stamp is a handwritten signature and the date "Dec 12, 2022".

Justin Walch, GIT
Geoscientist-in-Training

Justin Tamas, P. Geo.
Project Geoscientist

Reviewed by:

Richard Norman, P. Geo.
Senior Geoscientist



Figure 1: Location Key Map

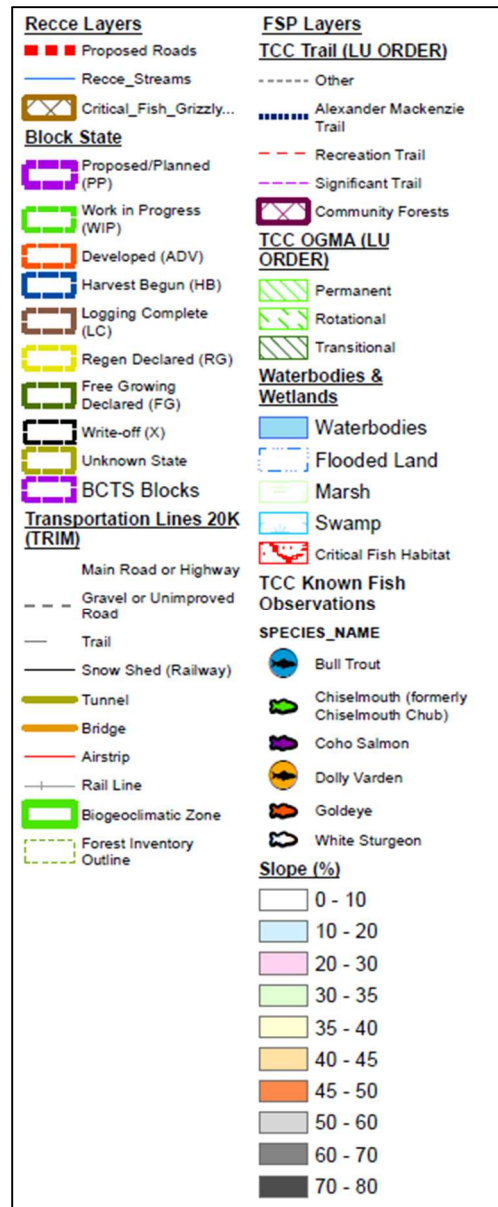


Figure 2: Clip of Legend to Accompany Harvest Plan Maps

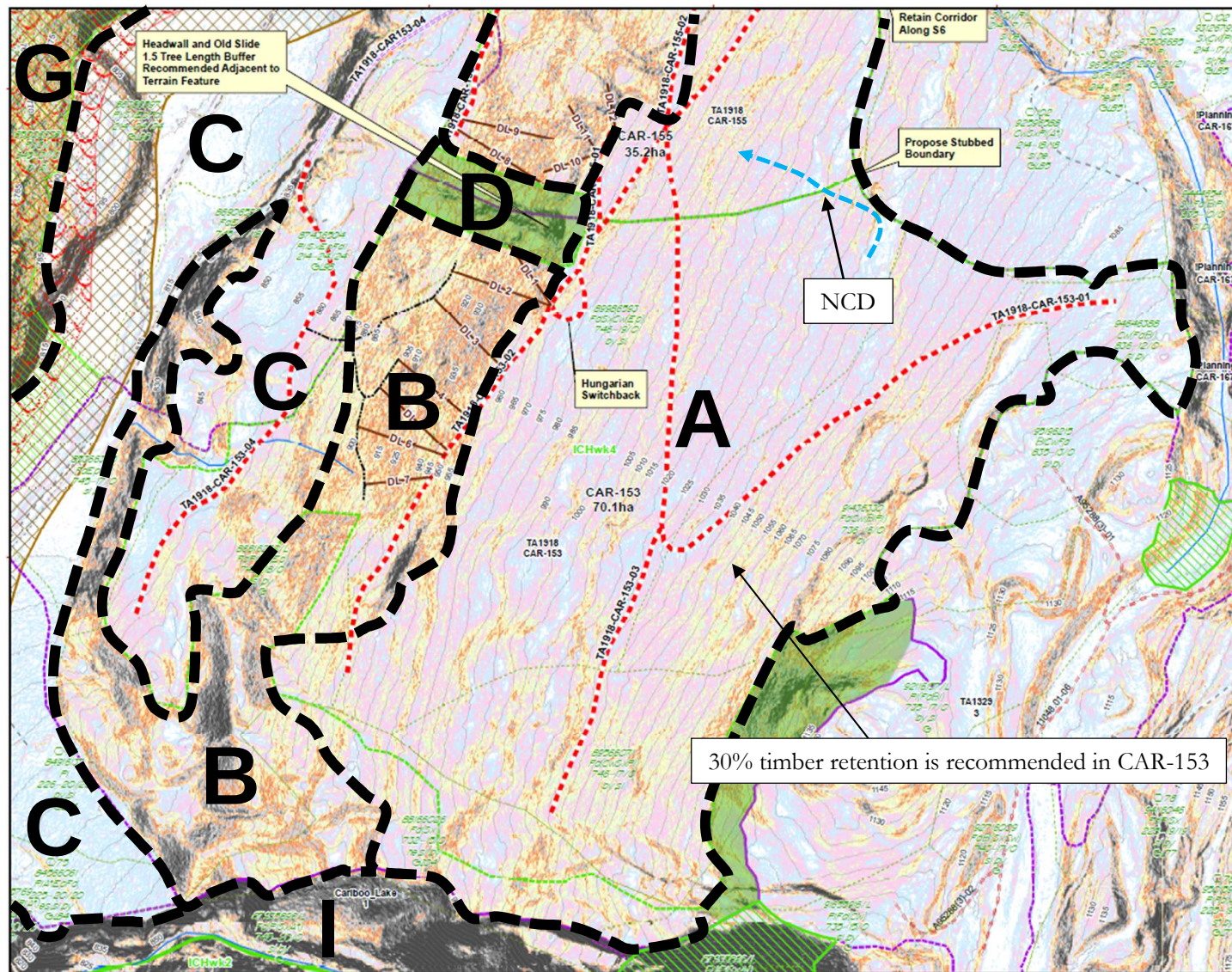


Figure 3: Clip of the Preliminary Harvest Plan and Slope Map provided by BCTS for Cutblock TA1918 CAR-153. The map original scale was 1:5,000 but has been altered slightly to fit the page.

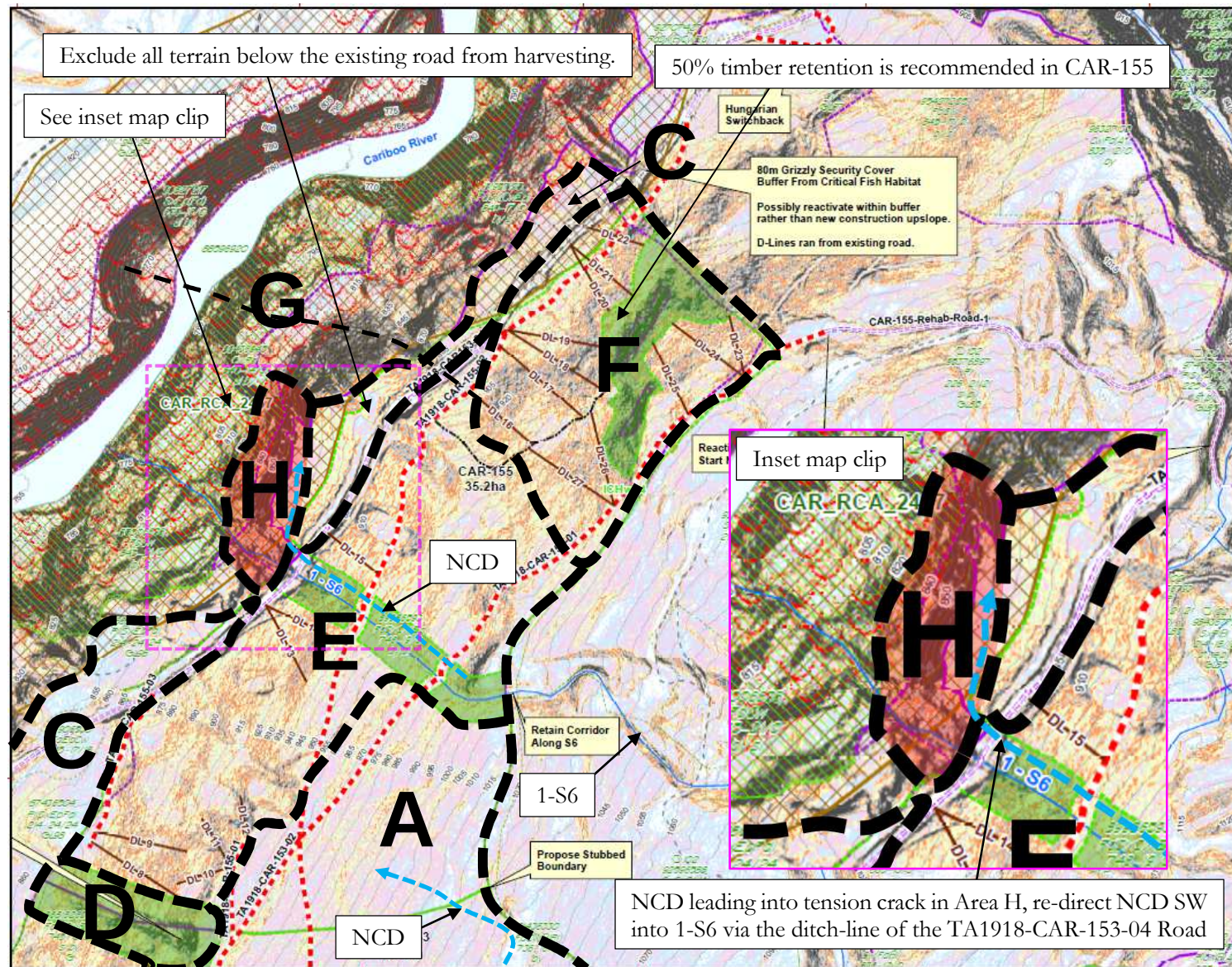


Figure 4: Clip of the Preliminary Harvest Plan and Slope Map provided by BCTS for Cutblock TA1918 CAR-155. The map original scale was 1:5,000 but has been altered slightly to fit the page.

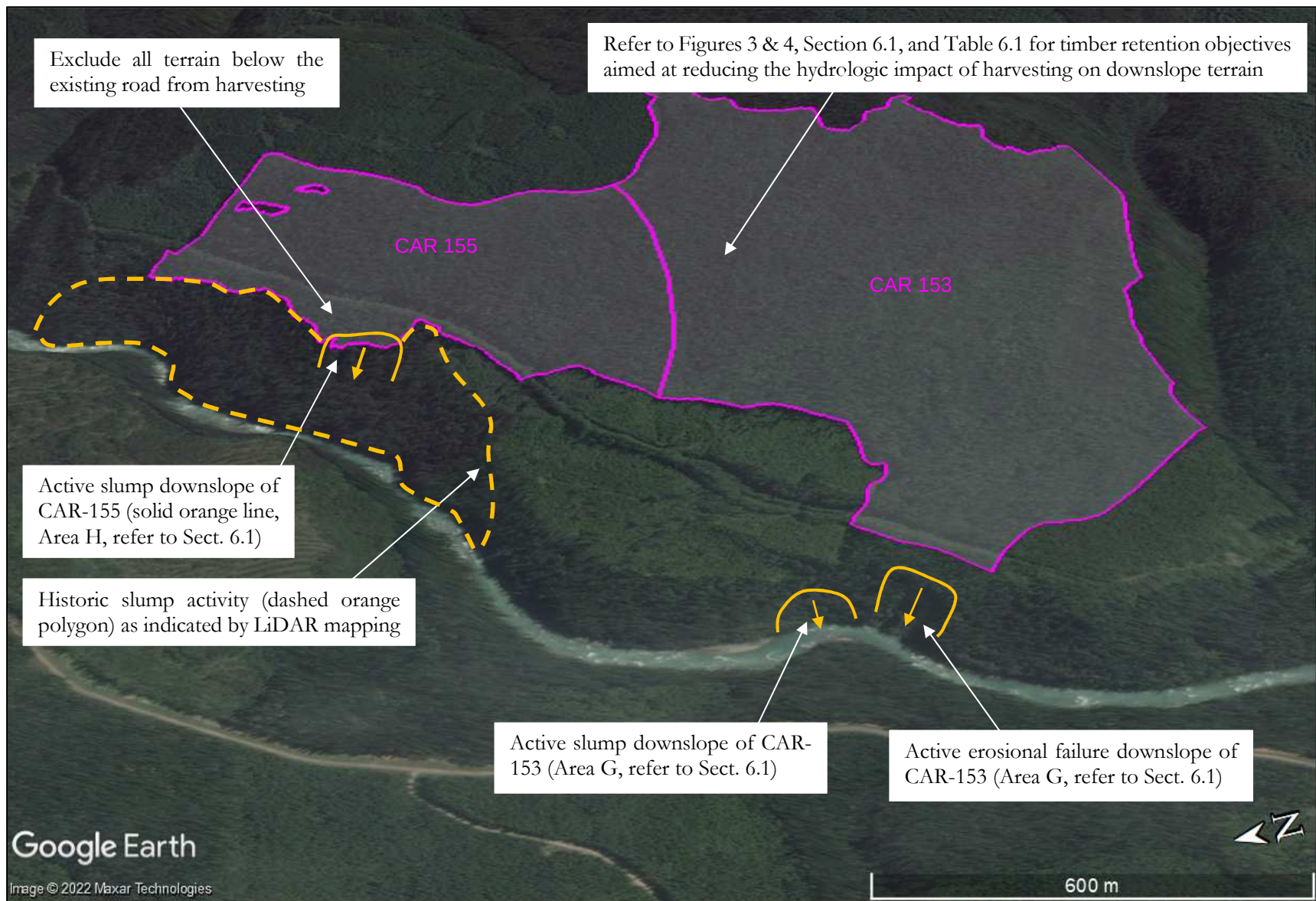


Figure 5: Oblique Google Earth Image of the Recce polygons for TA918 CAR-153 and CAR-155. Areas of instability observed during the field assessment or during the airphoto review are indicated by the orange linework.

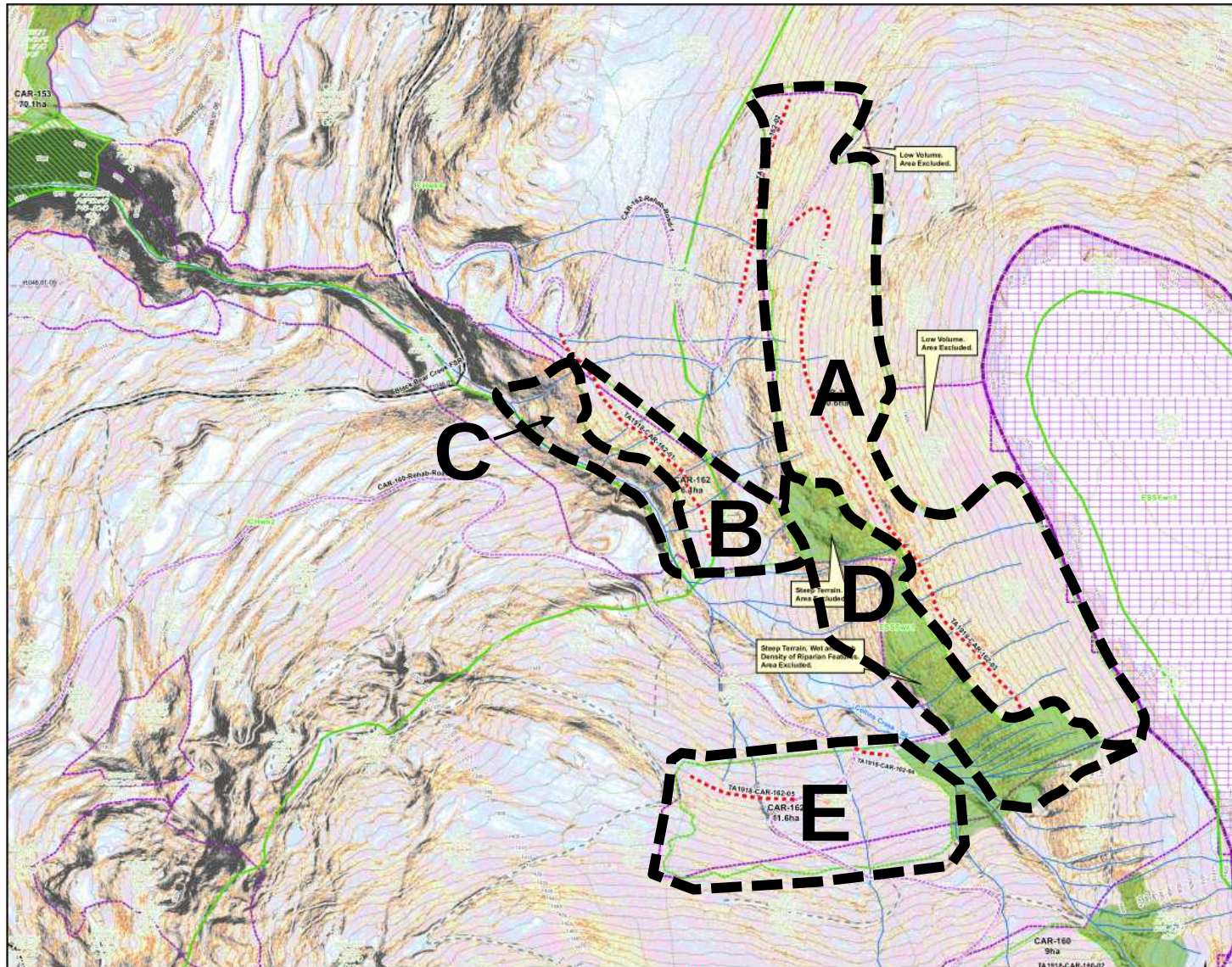


Figure 6: Clip of the Preliminary Harvest Plan and Slope Map provided by BCTS for Cutblock TA1918 CAR-162. The map original scale was 1:7500 but has been altered slightly to fit the page.

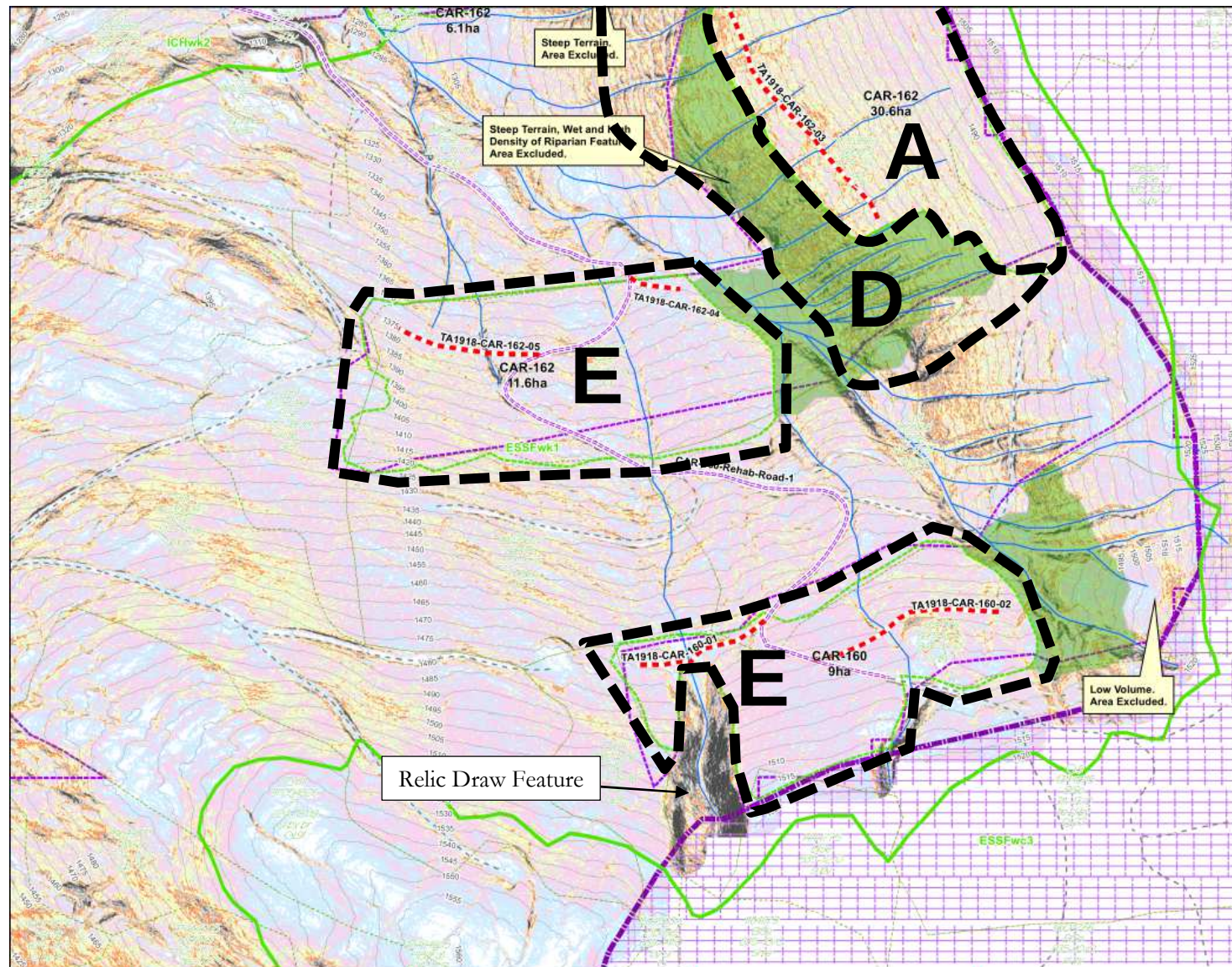


Figure 7: Clip of the Preliminary Harvest Plan and Slope Map provided by BCTS for Cutblock TA1918 CAR-162. The map original scale was 1:5000 but has been altered slightly to fit the page.

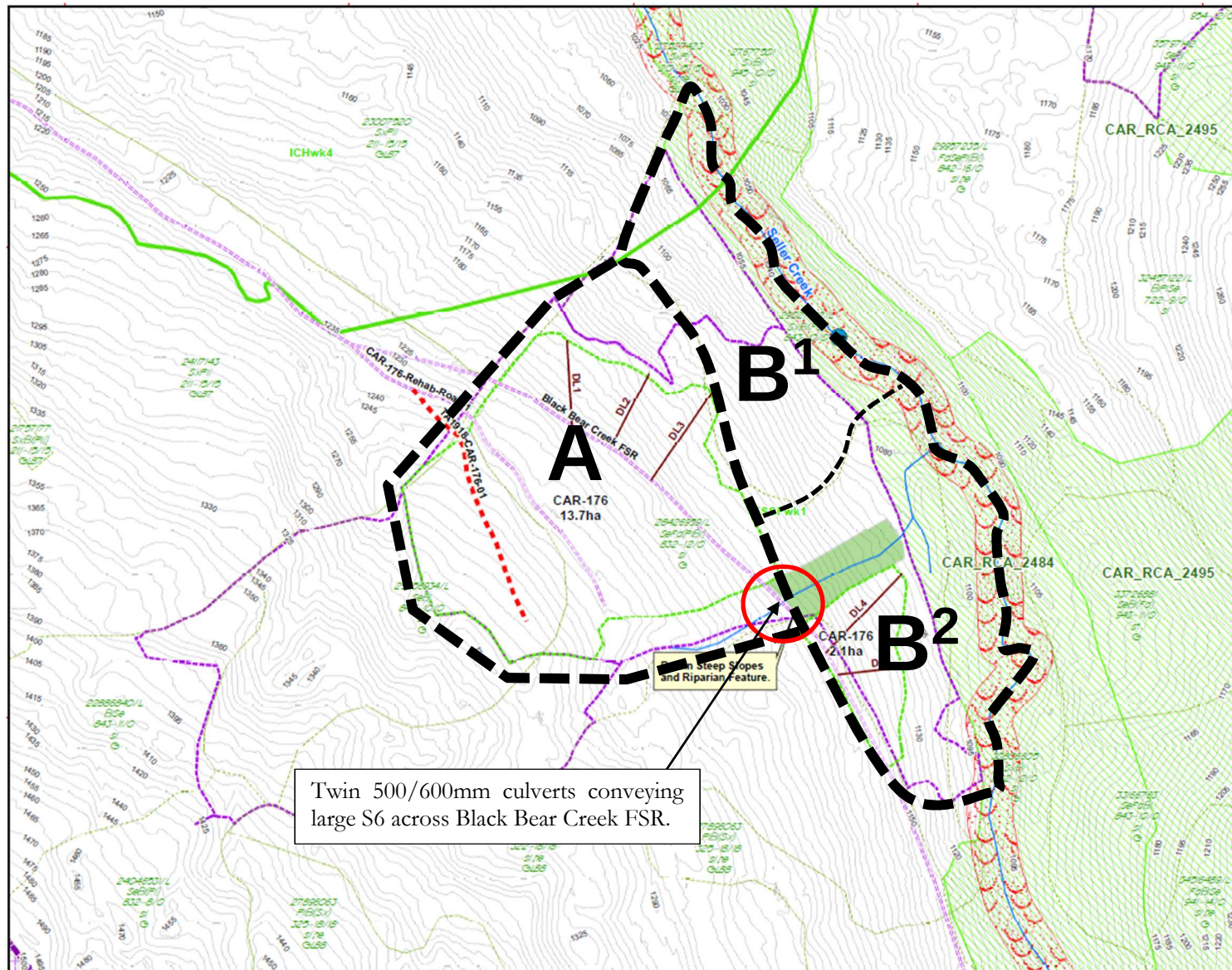


Figure 8: Clip of the Preliminary Harvest Plan Map provided by BCTS for Cutblock TA1918 CAR-176. The map original scale was 1:5,000 but has been altered slightly to fit the page.

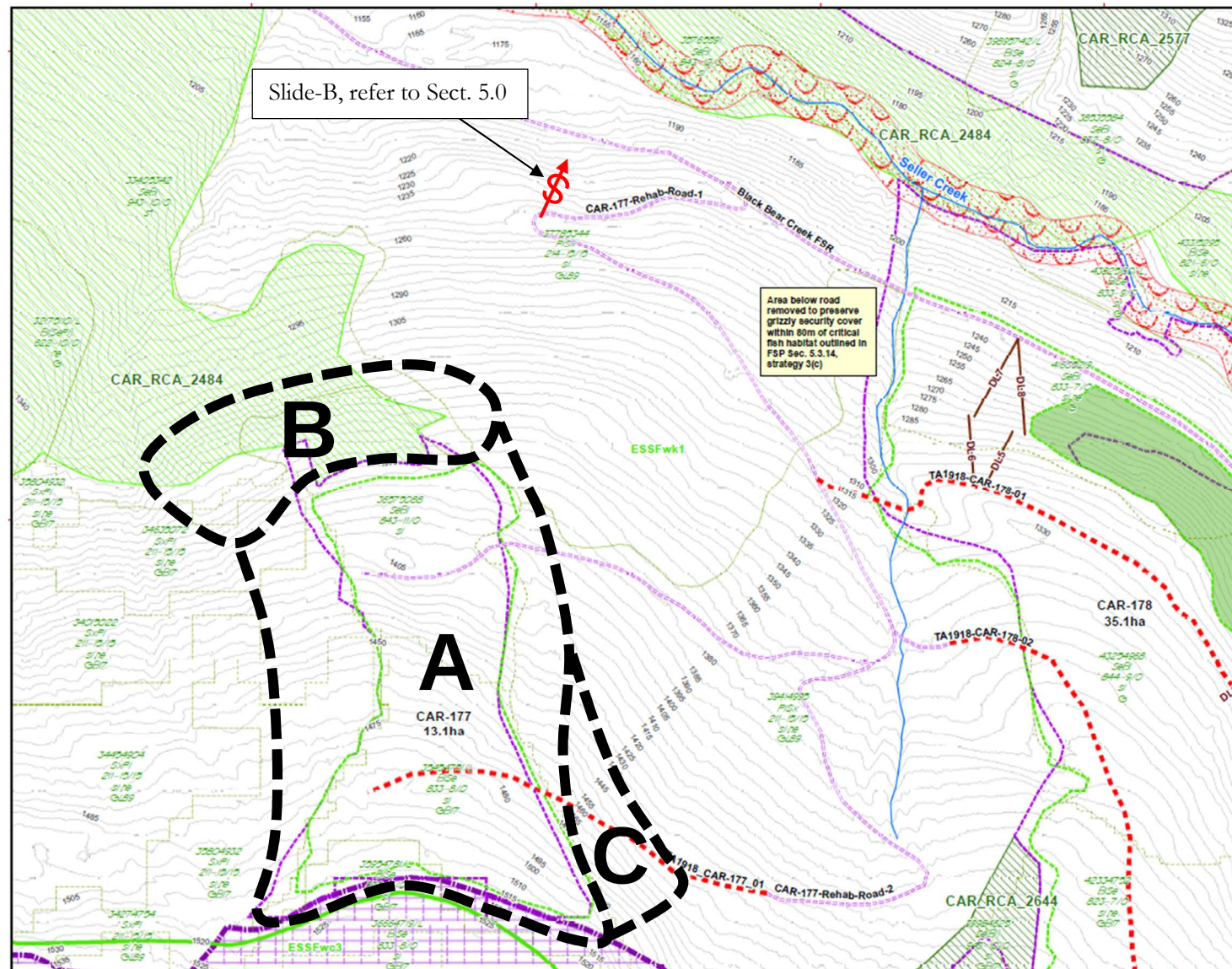


Figure 9: Clip of the Preliminary Harvest Plan Map provided by BCTS for Cutblock TA1918 CAR-177. The map original scale was 1:5,000 but has been altered slightly to fit the page.

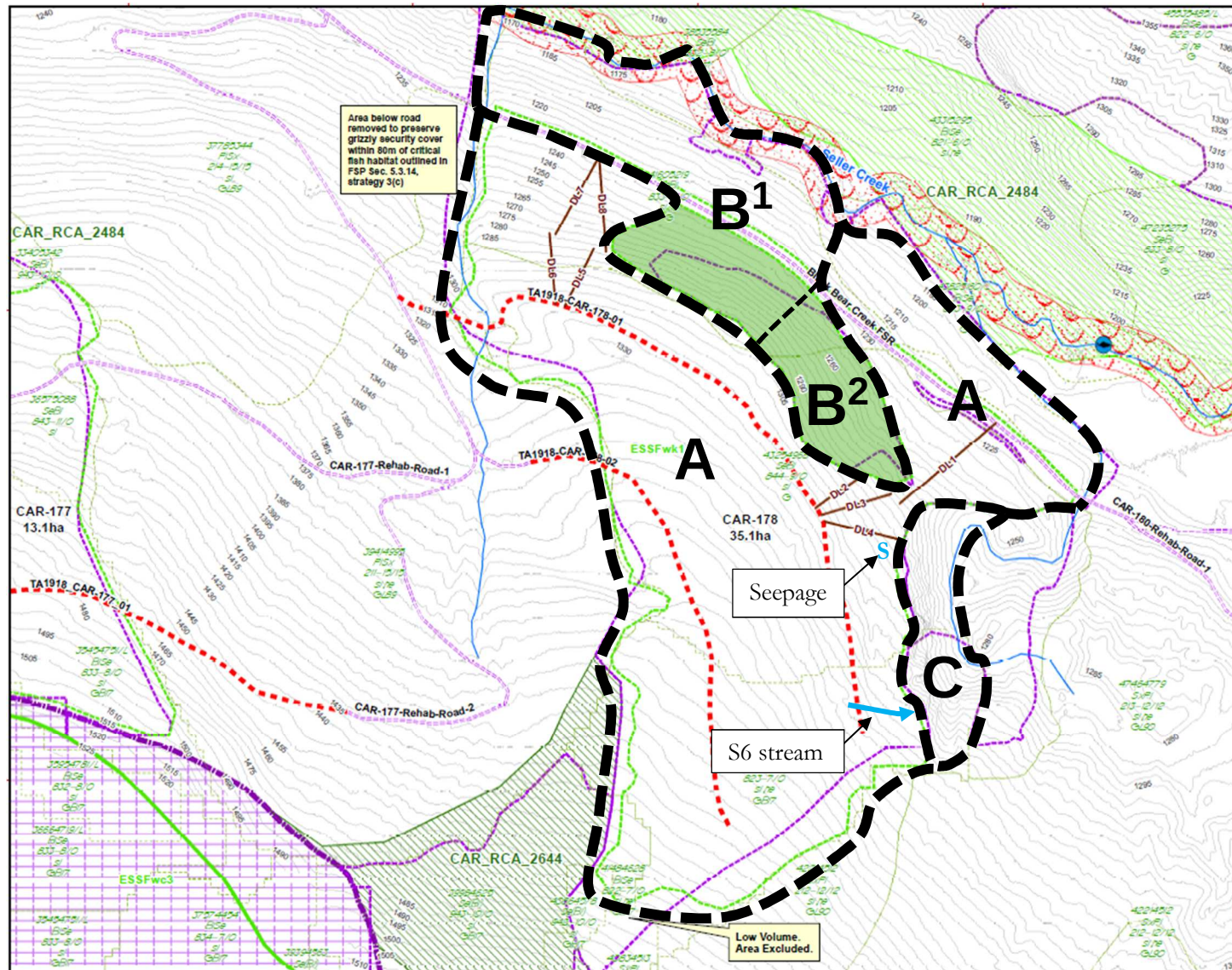


Figure 10: Clip of the Preliminary Harvest Plan Map provided by BCTS for Cutblock TA1918 CAR-178. The map original scale was 1:5,000 but has been altered slightly to fit the page.

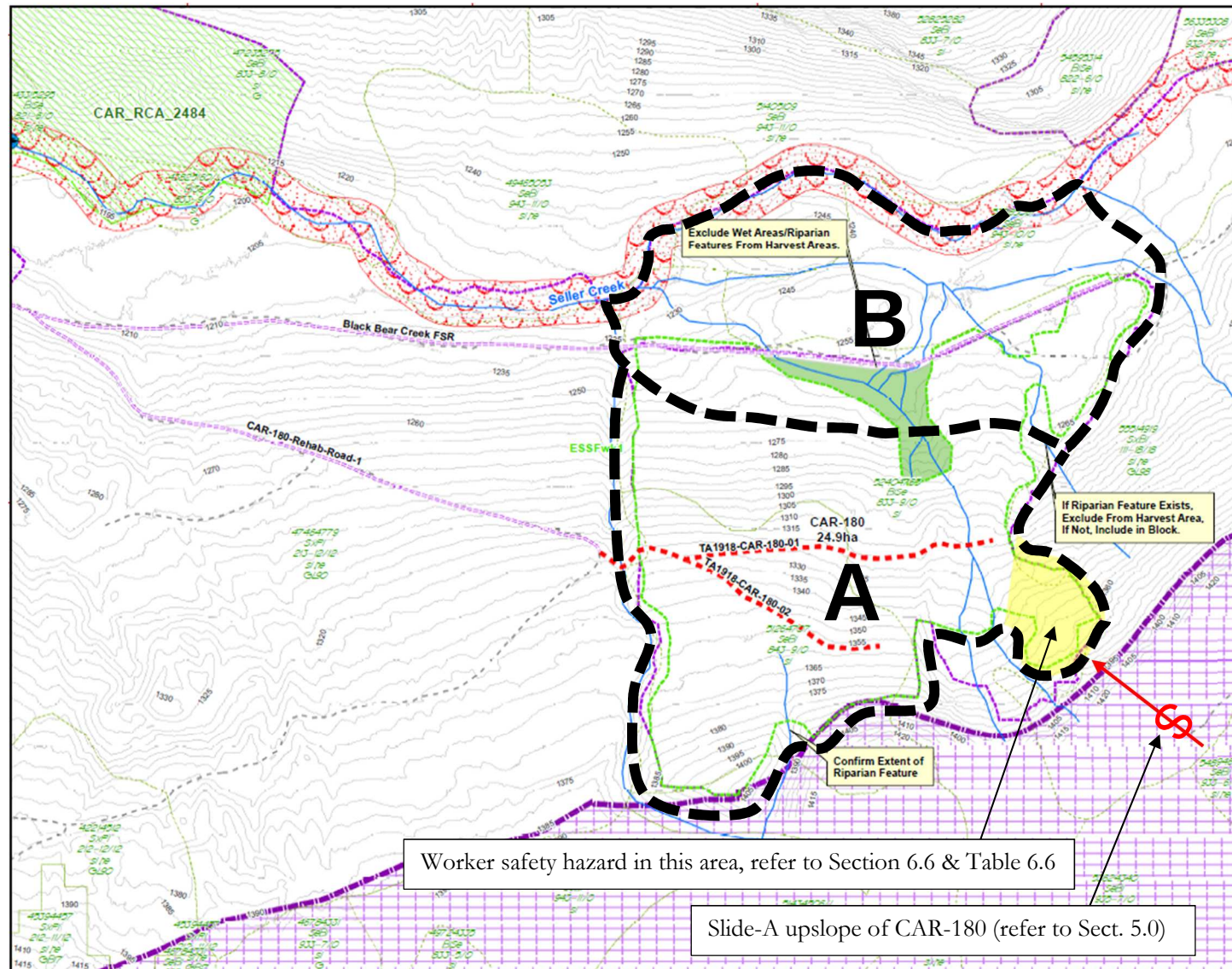


Figure 11: Clip of the Preliminary Harvest Plan Map provided by BCTS for Cutblock TA1918 CAR-180. The map original scale was 1:5,000 but has been altered slightly to fit the page.



Figure 12: Oblique Google Earth Image of the Recce Polygons for TA1918 CAR-177, CAR-178, and CAR-180.

APPENDIX A RISK ASSESSMENT METHODOLOGY

Risk analysis is a process by which the possibility of an injury or loss is quantified through the determination of the likelihood or probability of an adverse event occurring and the estimation of the likelihood or probability of a given element being impacted by the landslide event and the expected damage to that element. The general formula for this statement is as follows:

$$\text{Risk} = \text{Probability of Occurrence (P)} \times \text{Consequence (C)}$$

In practice in the BC resource sector, the Probability of Occurrence refers to the likelihood of a specific landslide occurring or the incremental increase in the likelihood of the landslide occurring as a result of the proposed operations and the Consequence refers to the likelihood of an element at risk being impacted by the landslide and the extent of the impact (*i.e.* the damage to the element).

Partial Risk Analysis

Terrain Stability Assessments (TSA) typically involve an estimation of the likelihood of a landslide following a given development or operation, an estimation of the size of the landslide and an estimate of the landslide runout. The likelihood of a specific landslide initiating and running out to a given element is referred to as the Partial Risk. The term Partial Risk is used as the damage to the element is not assessed. Partial risk is defined in the Landslide Management Handbook (LMH 56) as the product of the probability of occurrence of a specific hazardous landslide and the probability of that landslide reaching or otherwise affecting the site occupied by a specific element.

$$\text{Partial Risk P(HA)} = \text{P(H)} \times \text{P(S:H)} \times \text{P(T:S)}$$

Where,

P(H) = the probability of occurrence of a specific hazardous landslide.
P(S:H) = the probability that a specific landslide will impact an element at a given location. This is the spatial impact of a landslide.
P(T:S) = the probability that the element at risk will occupy the hazardous location given that a spatial impact occurs. This is the temporal impact of a landslide.

Table 1: Qualitative Descriptors and Corresponding Probability Ranges for Landslide Likelihood (P(H))

Landslide Likelihood P(H)	Description	Probability Range	
		Annual Probability P(H) _a	10 Year Probability P(H) ₁₀
Very High	The event is expected to occur	> 1/10	> 0.65
High	The event will probably occur under adverse conditions, <i>i.e.</i> the event is probable over a 10 year period	1/20 to 1/10	0.40 to 0.65
Moderate	The event could occur under adverse conditions, <i>i.e.</i> the event is not probable but possible over a 10 year period	1/100 to 1/20	0.10 to 0.40
Low	The event could occur under very adverse conditions	1/500 to 1/100	0.02 to 0.10
Very Low	The event is conceivable but only under exceptional circumstances	< 1/500	< 0.02

*The likelihood of occurrence in a 10 year period (P(H)₁₀) is assessed to be suitable for resource development as research¹ and our experience has shown that most harvesting related landslides occur in the first 10 years following road building or harvesting.

Table 2: Qualitative Descriptors and Corresponding Probability Ranges for Spatial Probability (P(S:H))

Likelihood of a Spatial Impact P(S:H)	Description	Probability Range
High	It is probable that a landslide will impact an element at risk	> 0.5
Moderate	It is possible that a landslide will impact an element at risk	0.5 to 0.1
Low	It is unlikely that a landslide will impact an element at risk	< 0.1

¹ Horel, G. 2006. Summary of landslide occurrence on northern Vancouver Island. Streamline Watershed Manag. Bull. 10(1):1-9.

APPENDIX A RISK ASSESSMENT METHODOLOGY

Table 3: Qualitative Risk Matrix for Partial Risk

Specific Risk P(HA), probability (likelihood) of occurrence of a specific hazardous landslide and the probability of it reaching or otherwise affecting the site occupied by a specific element; i.e. $P(HA) = P(H) \times P(S:H)$		P(S:H), probability (likelihood) that the landslide will reach or otherwise affect the site occupied by a specific element, given that the landslide occurs		
		High	Moderate	Low
P(H), annual probability (likelihood) of occurrence of a specific hazardous landslide	Very High	Very High	Very High	High
	High	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low
	Very Low	Low	Very Low	Very Low

Example 1: The following is an example of a partial risk analysis in order to illustrate the relationship between P(H), P(S:H), P(T:S), and P(HA).

1. The terrain stability professional determines that a section of steep terrain contained within a cutblock is estimated to have a **Moderate** likelihood of a post harvest landslide up to 1000m³ in size and 0.10ha in aerial extent (i.e. the P(H)= Moderate).
2. The section of terrain is located 100m upslope of a fish bearing creek and the terrain is generally moderately steep down into the creek. The terrain stability professional estimates that there is a **High** likelihood that the landslide will reach the fish bearing creek if it occurs (i.e. the P(S:H) = High).
3. Since the creek is stationary it will always occupy the runout path of the landslide and the P(T:S) = 1.
4. Using the Qualitative Risk Matrix a **P(H) = Moderate and P(S:H) x P(T:S) = High therefore, P(HA) = High.**

This indicates that there is a high partial risk to fish bearing habitat in the S2 creek due to the proposed development. However, the degree of damage that the landslide could do to the stream or the impact on fish habitat (i.e. the vulnerability) has not been evaluated by the terrain professional. It is up to the client forest professional to determine the landslide consequence (vulnerability and worth), complete the specific risk analysis, determine if that risk is acceptable, and decide whether to proceed with any development based on that risk assessment.

Specific Risk Analysis

The next level of analysis beyond a partial risk assessment is referred to as **Specific Risk R(S)**. This is the risk of loss or damage to a specific element, resulting from a specific hazardous affecting landslide. Specific risk is defined in LMH 56 as the product of the probability of occurrence of a specific hazardous landslide, the probability of that landslide reaching or otherwise affecting the site occupied by a specific element, and the probability of loss or damage to that element given that the element is impacted. The vulnerability of an element is assessed through consultation with another professional specializing in the relevant field, such as a fisheries biologist for impacts to a fish stream. Specific risk is mathematically represented by the following equation:

APPENDIX A RISK ASSESSMENT METHODOLOGY

$$\text{Specific Risk } R(S) = P(H) \times P(S:H) \times P(T:S) \times V(L:T)$$

This equation can be reduced to:

$$R(S) = P(HA) \times V(L:T)$$

Where,

$V(L:T)$ = the probability of loss or damage to an element given that the element is impacted by a landslide.
This is the vulnerability of an element.

Table 5: Examples of Vulnerability Ratings (V(L:T))

Vulnerability rating	Description of transportation corridor	Description of timber resource	Description of fisheries resource
High loss or damage	<ul style="list-style-type: none"> Destruction of, or extensive (not easily repairable) damage to, the transportation corridor, or Long-term (>1 week) disruption to the transportation corridor 	<ul style="list-style-type: none"> Total or large-scale loss or major damage to most of the timber 	<ul style="list-style-type: none"> Destruction of, or extensive (irreversible) damage to the fisheries resource (i.e. the stream)
Moderate loss or damage	<ul style="list-style-type: none"> Moderate (easily repairable) damage to the transportation corridor, or Short-term (1 day to 1 week) disruption to the transportation corridor 	<ul style="list-style-type: none"> Some loss or moderate damage to some of the timber 	<ul style="list-style-type: none"> Moderate (reparable) damage to the fisheries resource
Low loss or damage	<ul style="list-style-type: none"> Minor (inconvenient) damage to the transportation corridor, or Very short (<1 day) disruption to the transportation corridor 	<ul style="list-style-type: none"> Little loss or limited damage to most of the timber 	<ul style="list-style-type: none"> Minor damage, usually limited to sediment delivery, to the fisheries resource

Table 6: Qualitative Risk Matrix for Specific Risk (R(S))

R(S), risk to a specific element, but worth of the element is not considered; i.e. $R(S) = P(HA) \times V(L:T)$		V(L:T), proportion of loss or damage to a specific element		
		High	Moderate	Low
P(HA), probability (likelihood) of occurrence of a specific hazardous landslide and it reaching or otherwise affecting the site occupied by a specific element	Very High	<i>Very High</i>	<i>Very High</i>	<i>High</i>
	High	<i>Very High</i>	<i>High</i>	<i>Moderate</i>
	Moderate	<i>High</i>	<i>Moderate</i>	<i>Low</i>
	Low	<i>Moderate</i>	<i>Low</i>	<i>Very Low</i>
	Very Low	<i>Low</i>	<i>Very Low</i>	<i>Very Low</i>

Example 2: The following is an example of a specific risk analysis in order to illustrate the relationship between P(H), P(S:H), P(T:S), V(L:T), and R(S).

- The terrain stability professional identifies that a section of terrain under a proposed road is mapped as unstable and the likelihood of a road-related landslide up to 500m³ in size and 0.05ha in aerial extent is estimated as **Moderate** (i.e. the P(H) = Moderate).
- The section of terrain is located 200m upslope of a fish stream and the terrain down to the fish stream is moderate to moderately steep gradient. The terrain stability professional estimates that there is a **Moderate** likelihood that the landslide will reach the fish stream if it occurs (i.e. the P(S:H) = Moderate).
- Since the fish stream is stationary, it will always occupy the runout path of the landslide and the P(T:S) = 1.
- Using the Qualitative Risk Matrix for partial risk **P(H) = Moderate and P(S:H) x P(T:S) = Moderate therefore, P(HA) = Moderate**.
- A professional biologist was consulted and in their judgement it was determined that if a landslide of this size reached the fish stream it would result in reparable damage to the fisheries resource and therefore, the vulnerability of the fish stream is estimated as **Moderate** (i.e. V(L:T) = Moderate).
- Using the Qualitative Risk Matrix for specific risk **P(HA) = Moderate and V(L:T) = Moderate therefore, R(S) = Moderate**.

This indicates that there is a moderate specific risk to the fish stream due to the proposed road alignment.