

Terrain Stability Assessment

REVELSTOKE FOREST DISTRICT

BIGMOUTH CREEK

**TSL: A84538 – CUTBLOCKS K670, K 671, K672, K68Q
AND ASSOCIATED ACCESS ROADS**

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Table of Contents

1.0	Introduction and Proposed Development	2
2.0	Rationale for the TSA	2
3.0	Limitations of the TSA	2
4.0	Background Data and Fieldwork	3
5.0	General Site Description	4
6.0	Proposed Harvesting - Discussion, Results and Recommendations	5
6.1	Cutblock K68Q	5
6.1.1	<i>The steep gradient slopes present downslope of Branch 17.6E</i>	7
6.1.2	<i>The steep gradient slopes present downslope of the falling boundary between FC5 and FC3</i>	8
6.2	Cutblock K672	9
6.3	Cutblock K670	11
6.3	Cutblock K671	13
7.0	Proposed Roads - Discussion, Results and Recommendations	15
7.1	Anticipated Soil and Bedrock Conditions	15
7.2	Seepage Conditions	15
7.3	Cutslope Excavation Recommendations	15
7.4	Road Prism Recommendations	16
7.5	Road Drainage Recommendations	16
	Table 7.1 Branch 17.6 Road – Summary of Observations, Risk Analysis, and Construction Recommendations	17
	Table 7.2 Branch 17.6A Road – Summary of Observations, Risk Analysis, and Construction Recommendations	18
	Table 7.3 Branch 17.6D Road – Summary of Observations, Risk Analysis, and Construction Recommendations	20
8.0	Snow Avalanche Assessment	21
	General Discussion	21
8.1	Active Snow Avalanche Terrain – Discussion and Conclusions	21
8.2	Potential Snow Avalanche Terrain – Discussion and Conclusions	22
	Table 8.1: Factors in assessing avalanche hazard for the proposed development	22
8.2.1	Cutblock K670	22
	Results	23
8.2.2	Cutblock K671	23
8.2.3	Cutblock K672	23
8.2.4	Cutblock K68Q	24
9.0	Closure	25

1.0 Introduction and Proposed Development¹

As requested by Peter Gribbon, RPF of British Columbia Timber Sales (BCTS) in Revelstoke, BC, Forsite Consultants Ltd. (Forsite) has completed a Terrain Stability Assessment (TSA) for TSL: A84538 Cutblocks K68Q, K670, K671 and K672 in the Bigmouth Creek area, approximately 90km north of Revelstoke, BC.

The four cutblocks are proposed for clearcut logging using a combination of cable and conventional ground based methods. Several new spur roads are proposed to access the cutblocks.

Known elements at potential risk from a landslide initiating within the proposed cutblocks or from the proposed roads include: 1) the fisheries resource in Bigmouth Creek (S1) and 2) the standing timber and regenerating forest stand in the harvested cutblocks downslope.

2.0 Rationale for the TSA

Requirements detailed in the Forest Planning and Practices Regulation state that an authorized person who carries out a primary forest activity must ensure that the primary forest activity does not cause a landslide that has a material adverse effect in relation to one or more of the subjects listed in section 149 (1) (i.e. objectives set by government) of the Forest and Range Practices Act. A primary forest activity is defined in the regulation as:

1. timber harvesting;
2. silviculture treatments;
3. road construction, maintenance and deactivation.

In completion of the layout for this *development*, BCTS has identified sections of the proposed timber harvest areas and planned road construction on terrain that have slopes greater than 60%.

The objectives of this TSA are to:

1. Characterize the existing landslide hazard (terrain and terrain stability conditions) in areas within, adjacent to or connected to the *development* area;
2. Evaluate the potential or existing effects of the *development* on the terrain stability potential;
3. Determine the landslide hazard and potential effects of the *development* on the identified elements at risk (i.e. the resources); and
4. Recommend site-specific actions to reduce and/or manage the landslide hazard and risk resulting from the *development*.

3.0 Limitations of the TSA

This TSA has been prepared in accordance with generally accepted geotechnical practises in the British Columbia forest industry and in general conformance with the “Guidelines for Terrain Stability Assessments in the Forest Sector”². No other warranty, expressed or implied, is made. General observations are made on the existing slope gradients, 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. No subsurface information from deep test pits or drill holes was available.

¹ Aspects of forest management, existing and proposed, related to Planning and Operations.

² Association of Professional Engineers and Geoscientists in British Columbia (APEGBC), 2003.

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. Forsite does not represent or warrant that the conditions listed in the report are exact and the user should recognise that variations may exist. Sub-surface conditions other than those identified may be encountered, requiring a review of the recommendations contained in this report, 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 $P(H)^3$) is given in relation to the proposed activities. The magnitude and runout of this landslide will be estimated when the likelihood of occurrence exceeds very low.

The partial risk (*i.e.* the $P(HA)$) to the adjacent resources from the specific hazardous landslide will be assessed using methods described in the “Landslide Hazard and Risk Case Studies in the Forest Sector” document⁴. **Partial risk is 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.** Partial risk does not consider the vulnerability of the element(s), and therefore is not a complete estimate of risk. In practice, partial risk is usually the preferred type of analysis when little is known about the vulnerability of the element(s) or where an estimate of vulnerability is not required. For the purpose of this assessment only the spatial probability⁵ will be assessed and no analysis of the temporal probability⁶ will be undertaken. A risk analysis will only be completed where the likelihood of landslide occurrence exceeds low.

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. 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 by *BCTS* 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 aerial photographs were reviewed to determine terrain characteristics of the development area and to identify any specific terrain attributes and/or activity of any geomorphic processes within and adjacent to the proposed *development* that may be associated with existing or potential instability:

- 1) 30BCB92110 Nos. 110 to 112
- 2) 30BCB92110 Nos. 036 to 038

The following information was also referenced:

³ Probability of occurrence of a specific hazardous landslide.

⁴ Province of British Columbia, Ministry of Forests, 2004.

⁵ Spatial probability relates to the potential of a landslide to reach or otherwise affect the site occupied by an element.

⁶ Temporal probability relates to the potential of a mobile element, such as an occupant of a house or a moving vehicle, to be at the affected site at the time the event occurs.

- 1) Cruise Plan Map at a scale of 1:5000 provided by Forsite Consultants Ltd.
- 2) Road traverse data provided by Forsite Consultants Ltd.
- 3) Deflection line profiles for selected deflection lines in this development.
- 4) Canadian Climate Normals available at http://www.climate.weatheroffice.ec.gc.ca/climate_normals, retrieved May 2008.

Fieldwork was completed on September 11th and 12th, 2008 by Rod Williams, P.Geo of Forsite. Field work involved foot traverses of potential areas of concern with respect to terrain stability in the proposed cut blocks and along the proposed road alignments. Field conditions at the time of the assessment included clear and dry weather, seasonally dry soil conditions, and no residual snow.

5.0 General Site Description

The proposed development is located on southwest aspect slopes in the Bigmouth Creek watershed, approximately 18km upstream of its confluence with the Columbia River. The Bigmouth Creek watershed lies in the Selkirk Mountains physiographic region of BC. Bedrock in the area is mapped as Upper Proterozoic coarse clastic sedimentary rocks of the Horsethief Creek Group⁷.

The surficial materials encountered within the study area generally consist of sand and gravel to silty sand and gravel till and glaciofluvial materials with abundant cobble to boulder grade clasts. Localized deposits of sand and gravel to boulder colluvium are also present.

The area is dissected by several S6 and S5 classified tributaries that flow within well incised draws, southwest to Bigmouth Creek. It appears that these draws also host snow avalanche events. Slopes vary from planar in the upper portions of the cutblocks to concave through the lower slopes.

The development is located in the ICH biogeoclimatic zone with the upper portions of the blocks bordering the ESSF zone. The climate in these areas is generally fairly severe with long cold wet winters with abundant snowfall and warm to hot summers. Climate records from the nearest available weather station (Goldstream River/Stitt Creek confluence approx 25km south at an elevation of 700m) show an average annual precipitation of 1076.4mm, with 624.1mm, or 58% falling as rain. Similar values are associated with the climate station located at Mica Creek (30km northwest, 580m asl – 1340mm/year total precipitation, 750mm falling as rain) suggesting these can be considered representative for the development area.

The proposed cutblocks are bounded by existing harvested cutblocks south of K68Q and southwest (downslope) of K672. The existing cutblocks appear to have been harvested using ground based methods. The slopes in these cutblocks range from gentle to moderately steep with maximum gradients of 60 to 65% along the upper boundaries. No post harvest landslides were noted within these cutblocks during the field review.

Several post harvesting landslides were observed during the field review on steep slopes adjacent to (upslope) a cutblock to the north of K671. These slides initiated on steep slopes directly upslope of the cutblock in a burnt area, likely an escape of a slash fire within the cutblock. These slides are classified as shallow, translational open slope failures in a veneer of sand and gravel material overlying bedrock. The slides ran out approximately 60m to flat gradient slopes in the cutblock downslope.

⁷ Province of British Columbia, Ministry of Energy, Mines, and Petroleum Resources BCGS Geology Map.
<http://webmap.em.gov.bc.ca/mapplace/minpot/bcgs.cfm#>. Accessed February 2009.)

6.0 Proposed Harvesting - Discussion, Results and Recommendations

6.1 Cutblock K68Q

Cutblock K68Q is approximately 33 ha in size and is proposed for clear cut harvesting using cable yarding and ground based methods. The cutblock extent is limited by steep terrain of a large incised draw to the north, the riparian area of Stream A (S6) to the south, and terrain that is out of deflection for cable yarding to the west (refer to Figure 2).

The proposed Branch 17.6 Road switchbacks up through the cutblock on gentle to moderately steep gradient slopes. Two stub spurs are proposed off of the first and third switchbacks within the cutblock. General construction recommendations and specific recommendations by chainage for these roads are contained in Section 7.

The cutblock occupies primarily southwest aspect slopes of a broad ridge. The northern falling boundary between approximately FC 19 and FC 11 is situated along a prominent break from moderately steep to steep gradient west to southwest aspect slopes in the harvest area to north aspect steep to very steep slopes (i.e. greater than 80%) of the incised draw to the north. The majority of the slopes within the harvest area are moderately steep (i.e. 50 to 65%). Moderate gradient slopes (i.e. less than 50%) are present in the upper portion of the cutblock and in the lower portion of the cutblock, downslope of the road between the first and second switchback. A short pitch of steep gradient terrain (i.e. greater than 70%) is present between the road segments prior to and past the second switchback. These steep gradient slopes extend for approximately 100m to moderate gradient slopes at the lower road location. Steep gradient slopes that appear bedrock controlled are present upslope and downslope of the Br 17.6 E spur. The slopes below the spur have an overall concave profile and decrease to moderately steep (i.e. 65%) within 100m downslope. The southern falling boundary follows a broad draw containing Stream A (S6). The slope break from the slopes within the harvest area to the incised draw varies from a gradual roll in the upper portion of the cutblock to a distinct escarpment slope and associated terrace in the vicinity of FC 4.

The harvest plan map indicates that the cutblock will be harvested using a combination of cable and ground based methods. Currently the upper portion of the cutblock and the lower slopes between the lower switchback on the Branch 17.6 road are proposed for ground based methods (see Figure 2). It is likely that additional areas of moderate to moderately steep gradient terrain may also be harvested by ground based methods; however, the steep gradient slopes upslope and downslope of Branch 17.6E are not suitable for ground based methods. If areas of the cutblock currently proposed for cable based harvesting are harvested by ground based methods all trails must be rehabilitated as recommended below.

Surficial materials on the slopes within the cutblock generally consist of a thick blanket of loose to dense (at depth) silty sand and gravel to sand and gravel till and glaciofluvial materials. These materials are generally moderately well to well drained. Poor or imperfect drainage is encountered in swales, at toe-slope to bench transitions and in areas where convergent slopes concentrate drainage. Subsurface drainage may be concentrated at the contact between looser, sandier materials at the surface (glaciofluvial and weathered till) and more compact, finer grained underlying material.

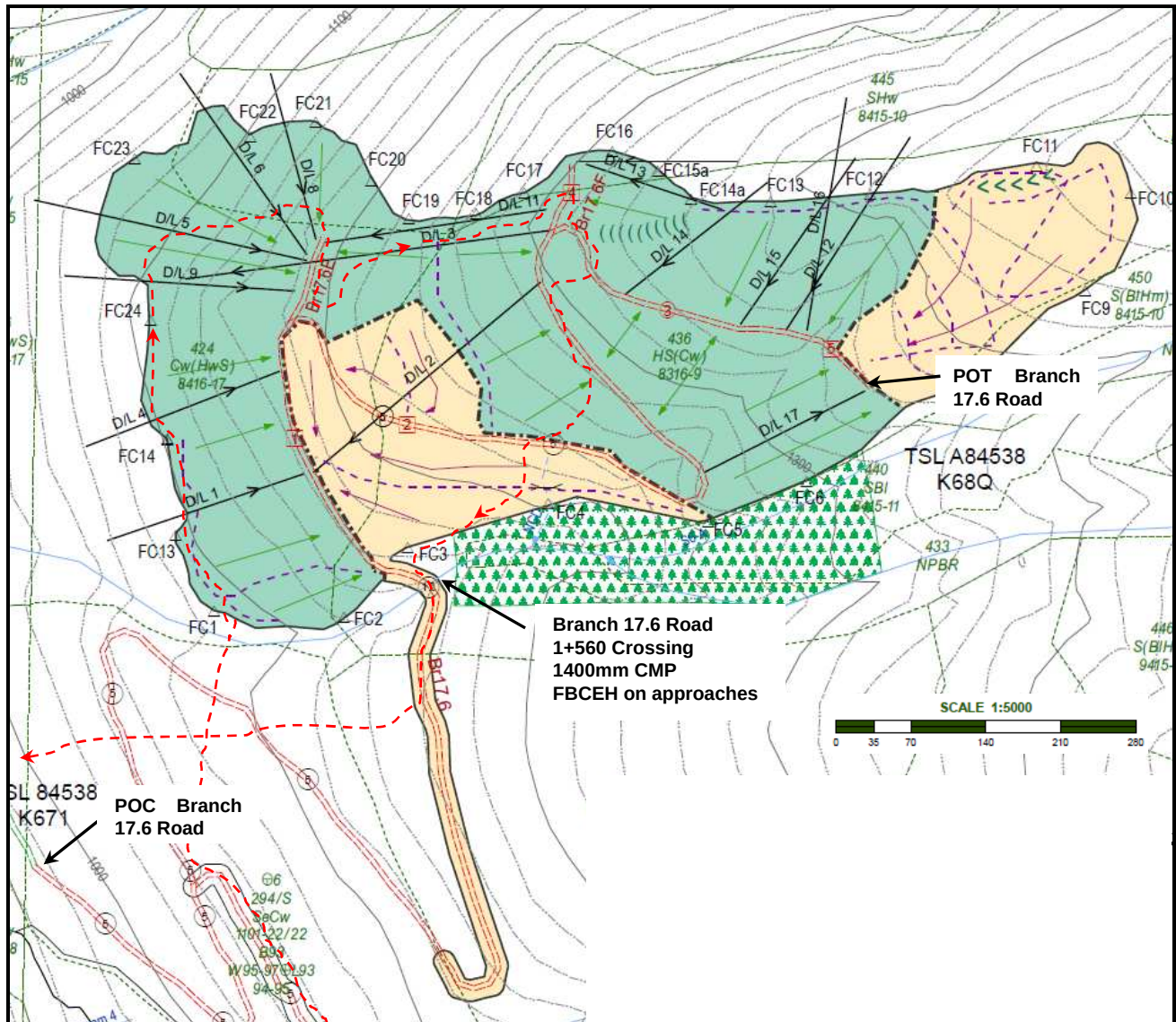


Figure 2 A copy of the Harvest Plan map for the proposed cutblock K68Q. North is to the top of the page and the original map scale was 1:5000. The traverse route is depicted by the red dashed line.

Results

Within the majority of the cutblock the proposed harvesting is expected to result in a **low likelihood**⁸ of landslide initiation and any landslides that do initiate will have a low runout potential (i.e. generally less than 100m). Several areas of the cutblock with a potentially higher likelihood of landslide initiation and/or potential for increased runout are discussed in the following sections.

Although the likelihood of a landslide within or downslope of this cutblock following the proposed harvesting is determined to be low, to reduce the potential for impact on natural hillslope runoff patterns it is recommended that within the areas where ground based harvesting occurs and where

⁸ A **low** likelihood means that the likelihood of a landslide is **remote** over the lifetime of the proposed development. Quantitatively the probability of a landslide is estimated as 1/1000 to 1/2500 annual probability $[P(H)_a]$ and a long term 20 year probability $[P(H)_{20}]$ of 0.02 to 0.01.

backspar trails are required to facilitate cable harvesting, bladed or scoured trails should be rehabilitated upon completion of harvesting operations, typically by recontouring excavated/bladed sections and restoring pre-existing drainage pathways by ensuring no excess soil or logging debris is blocking them.

6.1.1 The steep gradient slopes present downslope of Branch 17.6E

Discussion

From approximately 0+110 on DL 5 north to cruise plot 113 the slope gradients are steep (i.e. 65 to 75%) and the surficial materials are assessed as moderately well to imperfectly drained. Several areas of seepage are present as well as several leaning or jack-strawed cedar trees. The steep gradient slopes transition upslope to steeper bedrock slopes directly downslope of Branch 17.6E. Slopes gradients decrease downslope to moderate gradient slopes at the lower falling boundary. Slopes break over below the falling boundary into the incised draw of Stream 1 (S5).

The surficial materials present on this slope consist of veneer to thin blanket of sand and gravel colluvium and/or till with organic accumulations. The leaning trees on this slope may indicate localized soil creep and/or decreased rooting strength in the areas of higher soil moisture.

Stream 1 flows within a well incised draw downslope of this area of the cutblock. The stream gradient as measured off of 20m TRIM contours is approximately 20%, decreasing to 15% in the fish bearing reach adjacent to Bigmouth Creek approximately 400m downslope.

Results

Results from this TSA conclude that there is an estimated **high likelihood⁹ of post harvesting landslide occurrence** within this area of Cutblock K68Q following the proposed harvesting. This rating is based on:

- (i) The potential for imperfectly drained soils in this area of the cutblock; and
- (ii) The steep gradient slopes

A landslide initiating on the steeper slopes within this area of the cutblock following the proposed harvesting would likely be in the form of a small open slope failure with an estimated magnitude of 50 to 500m³. A landslide of this magnitude would be expected to terminate on the moderate slopes near the lower falling boundary but could run out to Stream 1 (i.e. the P(S:H) is estimated as moderate). A landslide impacting this stream would not likely result in a debris flow event due to the relatively low gradient; however, sediment and debris that is delivered to the stream would likely be transported to the fish bearing reach during a high flow event.

Resources that would be impacted by a landslide of this magnitude and runout include:

1. The soils and timber resources on the slopes within and downslope of the cutblock. The partial risk (i.e. the P(S:H)¹⁰) to this resource is estimated as very high.
2. The water quality in Stream 1 (non fish bearing). The partial risk to this resource is estimated as high.
3. The fisheries resource in Bigmouth Creek. The partial risk to this resource is estimated as high.

⁹ A **high** likelihood means that a landslide **is probable** over the life of the development. Quantitatively the probability of a landslide is estimated as 1/20 to 1/100 annual probability [P(H)_a] and a long term 20 year probability [P(H)₂₀] of 0.64 to 0.18

¹⁰ P(S:H) The probability that there will be a spatial effect, given that a specific hazardous landslide occurs. The probability that the landslide will reach the resource.

Recommendations

1. **These slopes must be harvested by cable based methods. This area is not suitable for winter or summer ground based harvesting (i.e. cat logging).**
2. **Adequate deflection must be maintained during harvesting to maintain lift and prevent excessive ground lead.**

Successful implementation of these recommendations will reduce the likelihood of a post harvesting landslide on these slopes to moderate¹¹.

6.1.2 The steep gradient slopes present downslope of the falling boundary between FC5 and FC3

Discussion

Between FC 5 and FC 3 the falling boundary is situated adjacent to the break from moderate slopes within the cutblock to the steep escarpment slope of Stream A. The escarpment slope ranges from 30 to 60m in length and the falling boundary has been located up to 10m downslope of the break effectively feathering the edge of the cutblock. The escarpment slope is dissected by shallow draws, some of which contained seepage. The proposed harvest area is situated on a gentle over steep landform with respect to the steep gradient slopes of the escarpment slope below.

The surficial materials present on this slope consist of veneer to blanket of loose to medium dense sand and gravel glaciofluvial materials and/or till. These materials are expected to be well drained.

Stream A flows within a well incised draw downslope of this area of the cutblock. The stream gradient as measured off of TRIM and from field observations is approximately 35%, decreasing to 15% in the fish bearing reach adjacent to Bigmouth Creek approximately 900m downslope. The stream flows within a confined draw down to the lower gradient reach.

Results

Results from this TSA conclude that there is an estimated **moderate likelihood of post harvesting landslide occurrence** on the escarpment slope downslope of this area of Cutblock K68Q following the proposed harvesting. This rating is based on:

- (i) The steep gradient slopes
- (ii) The potential for the proposed harvesting to result in a drainage concentration or alteration on the terrain downslope.

A gentle over steep landslide initiating within this area following the proposed harvesting would likely be in the form of a small open slope failure with an estimated magnitude of 50 to 500m³. A landslide of this magnitude would be expected to terminate on the moderate slopes in the invert of the draw of Stream A. A portion of the mobilized sediment and debris would likely impact the channel (i.e. the P(S:H) is estimated as high). A landslide impacting this stream would not likely result in a debris flow event due to the relatively low

¹¹ A **moderate** likelihood means that a landslide is **not likely, but possible** over the life of the proposed development. Quantitatively the probability of a landslide is estimated as 1/200 to 1/500 annual probability [P(H)_a] and a long term 20 year probability [P(H)₂₀] of 0.10 to 0.04.

channel gradient; however, sediment and debris that is delivered to the stream would likely be transported to the fish bearing reach during a high flow event.

Resources that would be impacted by a landslide of this magnitude and runout include:

1. The soils and timber resources on the slopes within and downslope of the cutblock. The partial risk (i.e. the P(S:H)) to this resource is estimated as moderate.
2. The water quality in Stream A (non fish bearing). The partial risk to this resource is estimated as high.
3. The fisheries resource in Bigmouth Creek. The partial risk to this resource is estimated as moderate.

Recommendations

1. **Bladed or scoured trails associated with skidding and log forwarding in this section of the cutblock must be rehabilitated upon completion of harvesting operations, typically by recontouring excavated/bladed sections and restoring pre-existing drainage pathways by ensuring no excess soil or logging debris is blocking them.**
2. **Drainage structures on the proposed road upslope of this area must be spaced so that the catchment areas of the draws downslope are not significantly increased.**

6.2 Cutblock K672

Discussion

Cutblock K672 is approximately 25 ha in size and is proposed for clear cut harvesting using cable yarding methods. The cutblock extent is limited by steep terrain upslope, an existing cutblock downslope and it is flanked by well defined stream draws (refer to Figure 3).

The proposed Branch 17.6A and Branch 17.6D roads will provide access and facilitate yarding. These roads are generally situated on moderately steep (i.e. 55 to 65%) slopes. General construction recommendations and specific recommendations by chainage for these roads are contained in Section 7.

The cutblock occupies primarily southwest aspect face unit slopes. The slopes are broken or benched in the upper northeast corner of the cutblock becoming straight to slightly concave in the lower portion. The southeast corner of the cutblock contains uniform, straight to concave slopes. The slope gradients are generally moderately steep (i.e. 55 to 65%) with steeper gradient slopes present in the southeast (upper) corner. The benched slopes in the northeast corner are overall moderate (i.e. less than 50%).

The face unit slopes are dissected by several prominent gully-like draws. These features are either dry or have small S6 streams or NCDs in them (i.e. Stream B, Stream 4, NCD 5 and Stream 1). The gullies are interpreted to be relic features formed during deglaciation and are no longer active. However, if an open slope failure were to initiate in the cutblock and enter one of the gullies the gradient and confinement would extend the runout of a landslide event. The headwall areas of the gullies can be expected to have seepage and higher soil moisture. The gullies diminish on the moderate gradient slopes in the cutblock downslope.

Surficial materials on the slopes within the cutblock generally consist of a thick blanket of loose to dense (at depth) silty sand and gravel to sand and gravel till and glaciofluvial materials. These materials are generally moderately well to well drained. Poor or imperfect drainage is encountered in swales, at toe-slope to bench transitions and in areas where convergent slopes concentrate drainage. Subsurface drainage may be concentrated at the contact between looser, sandier materials at the surface (glaciofluvial and weathered till)

and more compact, finer grained underlying material.

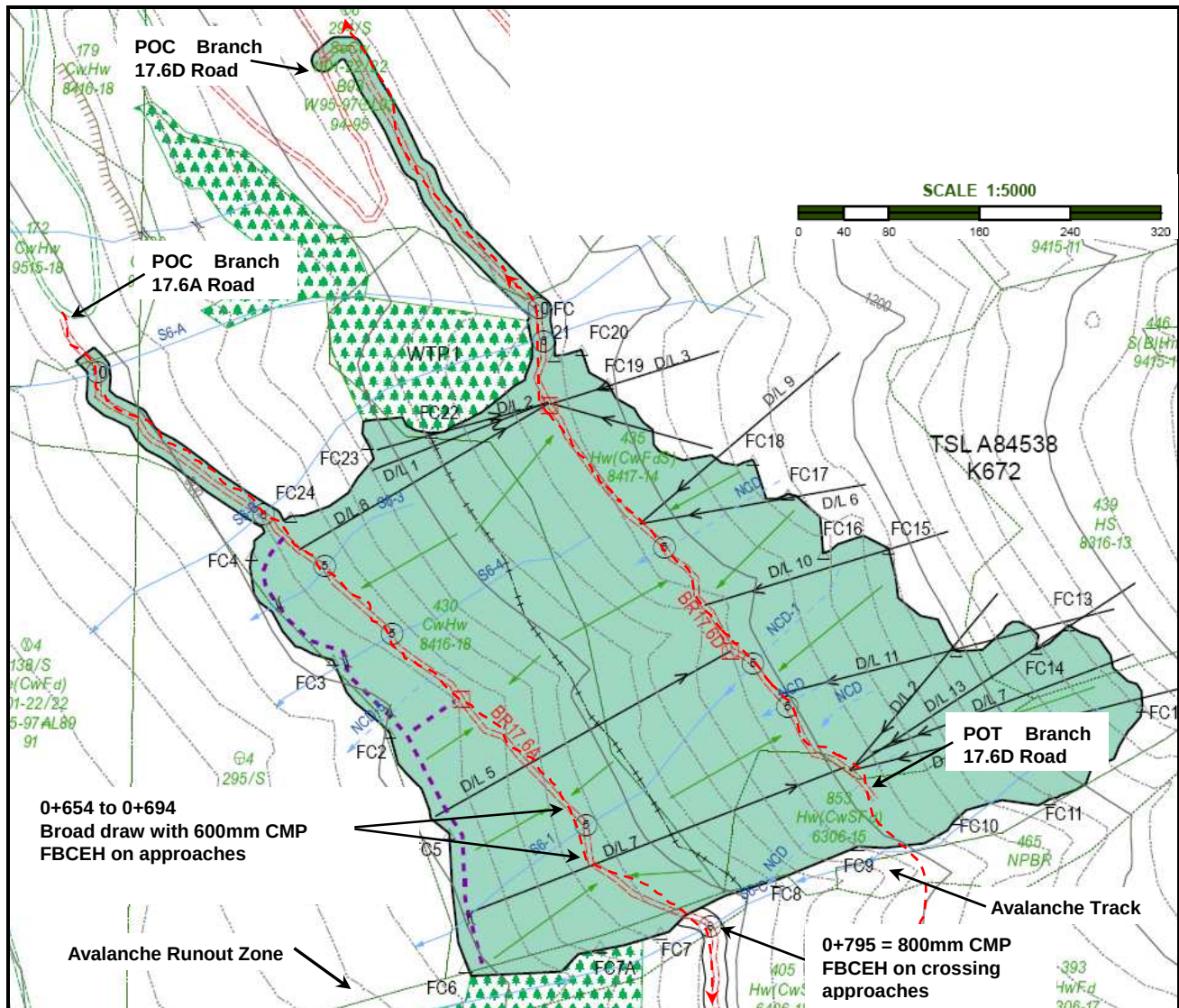


Figure 3 A copy of the Harvest Plan map for the proposed cutblock K672. North is to the top of the page and the original map scale was 1:5000. The traverse route is depicted by the red dashed line.

Results

Results from this TSA conclude that there is an estimated **low likelihood of post harvesting landslide occurrence** within Cutblock K672 following the proposed harvesting. This rating is based on:

- (i) The well drained nature of the surficial materials overlying the steeper slopes in the cutblock

A landslide initiating on the steeper slopes within this cutblock following the proposed harvesting would likely be in the form of a small open slope failure with an estimated magnitude of 50 to 500m³. Landslides of this magnitude would be expected to terminate on gentle to moderate slopes within the lower cutblock area. It is very unlikely that a landslide would reach the existing road downslope or Bigmouth Creek (i.e. the P(S:H) is estimated as low).

Recommendations

- 1. Minor ground based harvesting may occur immediately adjacent to the proposed road locations; however, the majority of the cutblock is not suitable for winter or summer ground based harvesting (i.e. cat logging) and must be harvested by cable based methods as proposed.**
- 2. Bladed or scoured trails associated with backspars or log forwarding (adjacent to the road locations) must be rehabilitated upon completion of harvesting operations, typically by recontouring excavated/bladed sections and restoring pre-existing drainage pathways by ensuring no excess soil or logging debris is blocking them.**

6.3 Cutblock K670

Discussion

Cutblock K670 is approximately 32 ha in size and is proposed for clear cut harvesting using cable yarding methods in the upper portion of the cutblock and ground based methods on the lower slopes. The cutblock extent is limited by steep terrain upslope, the existing road and riparian area of Bigmouth Creek downslope and it is flanked by well defined stream draws (refer to Figure 4).

The proposed Branch 17.6A road will provide access and facilitate yarding in the upper portion of the cutblock. This road is situated on moderately steep to steep (i.e. 50 to 75%) slopes. General construction recommendations and specific recommendations by chainage for this road are contained in Section 7.

The cutblock occupies primarily southwest aspect face unit slopes. A prominent ridge is present in the northeast portion of the cutblock. The ridge parallels a large avalanche chute and appears to be bedrock controlled. Slope gradients are steep (i.e. up to 75%) on the sides of the ridge and lead down to the lower valley bottom slopes. Coarse colluvium deposits drape the ridge. The upper portion of the cutblock contains moderately steep to steep gradient slopes (i.e. 60 to 70%). The slope profile is straight transitioning to convex at the location of the proposed Branch 17.6A Road. Moderately steep (60 to 70%) gradient slopes continue for approximately 120m downslope of the proposed Branch 17.6A Road and then transition to moderate gradient valley bottom slopes in the lower portion of the cutblock.

One prominent gully (see Figure 4) extends down into the cutblock area from the steep terrain upslope of the cutblock. This gully had very little vegetation in the lower reaches and led down to a fan-like depositional area with primarily deciduous (cottonwood) stems. The gully is timbered further upslope. It is likely that the lower reach experiences frequent snow accumulation and small avalanche events. Two additional gullies extend down to the upper falling boundary near FC 13 and FC 14. These features are bedrock controlled with steep bedrock sidewalls. A less pronounced fan or cone depositional area is found at the base of these features.

Surficial materials on the slopes within the cutblock generally consist of a thick blanket of loose to dense (at depth) silty sand and gravel to sand and gravel till and glaciofluvial materials. These materials are generally moderately well to well drained. Poor or imperfect drainage is encountered in swales, at toe-slope to bench transitions and in areas where convergent slopes concentrate drainage. Subsurface drainage may be concentrated at the contact between looser, sandier materials at the surface (glaciofluvial and weathered till) and more compact, finer grained underlying material.

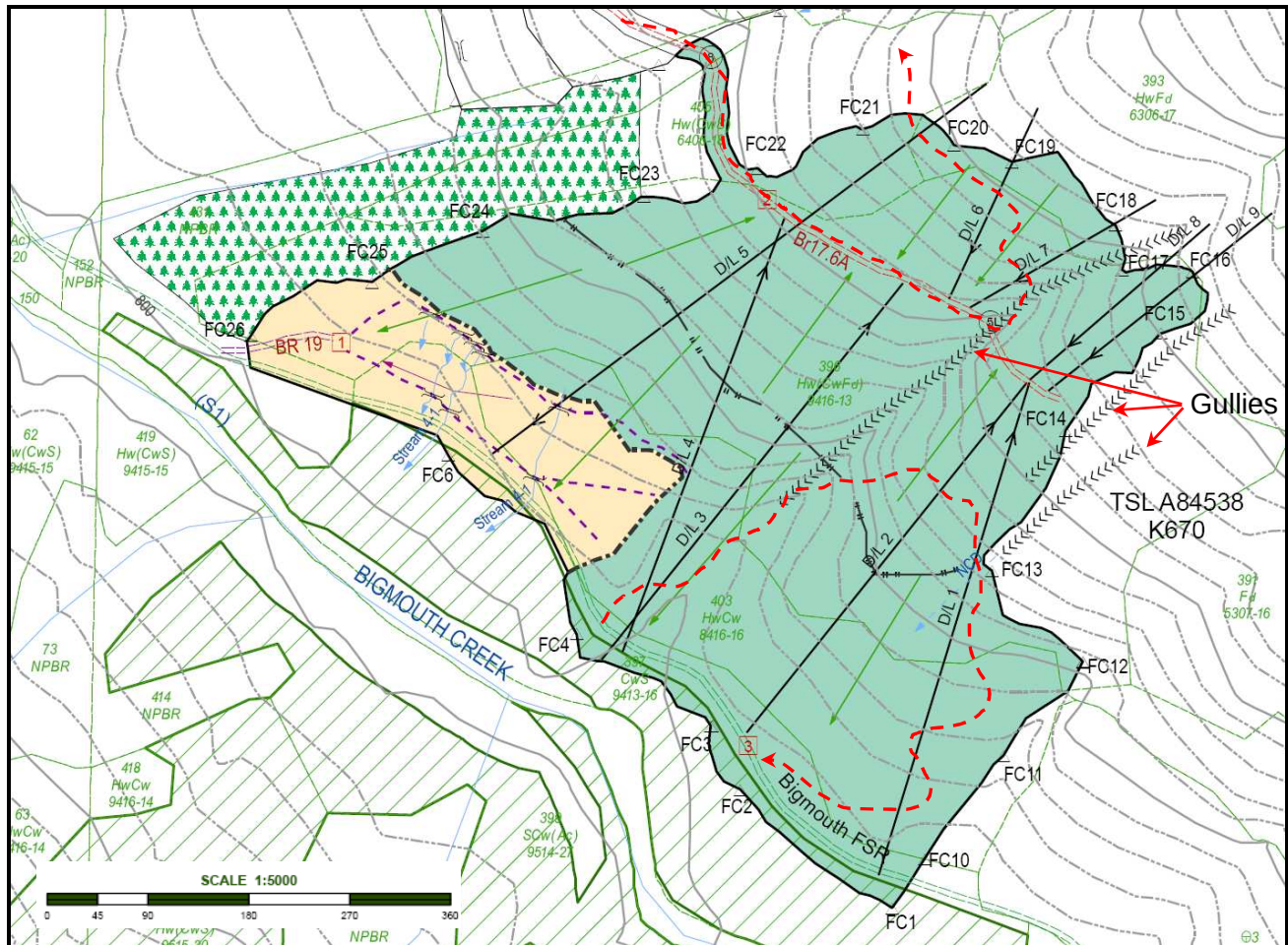


Figure 4 A copy of the Harvest Plan map for the proposed cutblock K670. North is to the top of the page and the original map scale was 1:5000. The traverse route is depicted by the red dashed line.

Results

Results from this TSA conclude that there is an estimated **low likelihood of post harvesting landslide occurrence** within Cutblock K670 following the proposed harvesting. This rating is based on:

- (i) The well drained nature of the surficial materials overlying the steeper slopes in the cutblock

A landslide initiating on the steeper slopes within this cutblock following the proposed harvesting would likely be in the form of a small open slope failure with an estimated magnitude of 50 to 500m³. Landslides of this magnitude would be expected to terminate on gentle to moderate slopes within the lower cutblock area. It is very unlikely that a landslide would reach the existing road downslope or Bigmouth Creek (i.e. the P(S:H) is estimated as low).

Recommendations

1. Minor ground based harvesting may occur immediately adjacent to the proposed and existing road locations and on moderate to moderately steep slopes (<55%) in addition to those areas presently proposed for ground based harvesting; however, the majority of the proposed cable ground in this cutblock is not suitable for winter or summer ground based harvesting (i.e. cat

logging) and must be harvested by cable based methods as proposed.

2. **Bladed or scoured trails associated with backspars or log forwarding (in the areas described above) must be rehabilitated upon completion of harvesting operations, typically by recontouring excavated/bladed sections and restoring pre-existing drainage pathways by ensuring no excess soil or logging debris is blocking them.**

6.3 Cutblock K671

Discussion

Cutblock K671 is approximately 31 ha in size and is proposed for clear cut harvesting using cable yarding methods in the upper portion of the cutblock and ground based methods on the lower slopes. The cutblock extent is limited by steep terrain upslope, adjacent incised draws and riparian areas and existing harvesting (refer to Figure 5). The cutblock was not specifically assessed during the fieldwork component of this TSA as the office component concluded that it occupies primarily gentle to moderate gradient slopes. The existing Branch 17.6 road in the southern unit of the cutblock was traversed when accessing the other cutblocks in this development and no stability concerns were identified by the author.

The proposed Branch 17.4 road will provide access and facilitate yarding in the upper portion of the northern unit of the cutblock. This road is situated on gentle gradient slopes suitable for conventional cut and fill road construction.

The cutblock occupies primarily southwest aspect lower valley sidewall and valley bottom slopes. The riparian area of Streams S6-2 and S2-1 separate the northern and southern units of the cutblock. The southern unit is generally situated on gentle to moderate gradient slopes with moderately steep (to 60%) gradient slopes in the cable portion. The northern unit is generally situated on gentle gradient slopes (i.e. less than 35%) with a short moderately steep gradient (i.e. 65 to 75%) pitch at the upper end of the cutblock. The moderately steep to steep gradient slope is less than 100m long.

Surficial materials on the slopes within the cutblock generally consist of a thick blanket of loose to dense (at depth) silty sand and gravel to sand and gravel till and glaciofluvial materials. These materials are generally moderately well to well drained. Poor or imperfect drainage is encountered in swales, at toe-slope to bench transitions and in areas where convergent slopes concentrate drainage.

Results

Results from this TSA conclude that there is an estimated **low likelihood of post harvesting landslide occurrence** within Cutblock K671 following the proposed harvesting. This rating is based on:

- (i) The well drained nature of the surficial materials overlying the steeper slopes in the cutblock

A landslide initiating on the steeper slopes within this cutblock following the proposed harvesting would likely be in the form of a small open slope failure with an estimated magnitude of 50 to 500m³. Landslides of this magnitude would be expected to terminate on gentle to moderate slopes within the lower cutblock area. It is very unlikely that a landslide would reach the existing road downslope, Bigmouth Creek or one of the smaller tributary streams that dissect the cutblock (i.e. the P(S:H) is estimated as low).

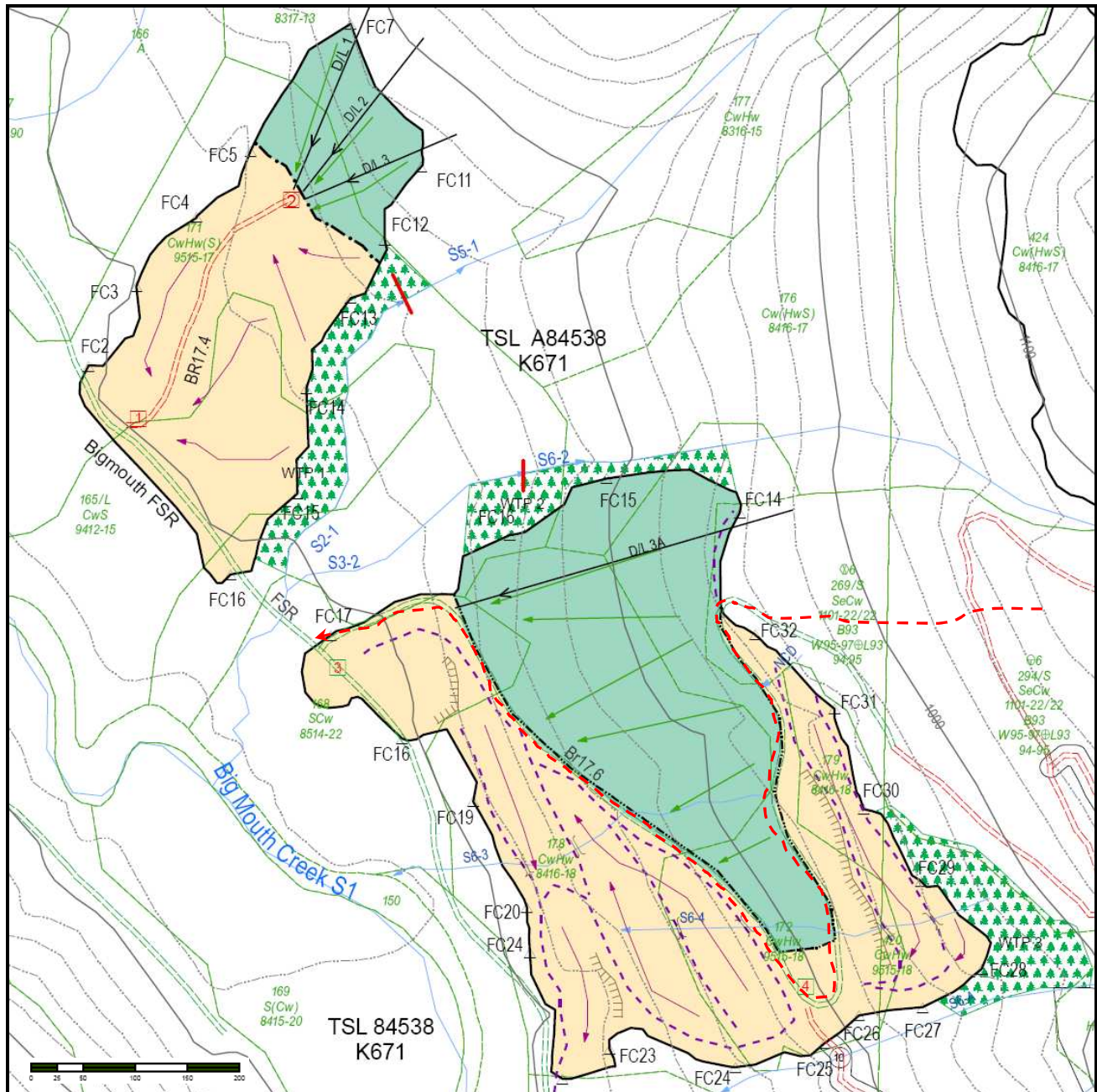


Figure 5 A copy of the Harvest Plan map for the proposed cutblock K671. North is to the top of the page and the original map scale was 1:5000. The traverse route is depicted by the red dashed line.

Recommendations

1. **Bladed or scoured trails associated with backspars or log forwarding must be rehabilitated upon completion of harvesting operations, typically by recontouring excavated/bladed sections and restoring pre-existing drainage pathways by ensuring no excess soil or logging debris is blocking them.**
2. **The steep gradient slopes in the northern unit, upslope of a line between FC 5 and FC 12 are not**

suitable for winter or summer ground based harvesting (i.e. cat logging) and must be harvested by cable based methods as proposed.

7.0 Proposed Roads - Discussion, Results and Recommendations

Several roads are proposed to access this development. The Branch 17.6, Branch 17.6 A, Branch 17.6D, and Branch 17.6E roads were reviewed as part of this assessment. These roads generally traverse moderate to moderately steep gradient terrain with isolated sections located on steep gradient (i.e. greater than 70%) slopes.

To our knowledge the roads are proposed as permanent access structures that will be maintained following harvesting. If the roads will not be maintained they must be deactivated concurrently with the completion of harvesting.

7.1 Anticipated Soil and Bedrock Conditions

Observations made during the fieldwork for the TSA suggest that the following subsurface conditions should be encountered during road construction:

1. The majority of the road excavation will occur within thick blanket (>2m deep) deposits of medium dense to dense silty sand and gravel colluvium and/or till and till derived colluvium with common boulders (0.5-1.0m) and occasional large boulders (2m+). These materials are generally well drained. Poor or imperfect drainage may be encountered in swales, at toe-slope to bench transitions and in areas where convergent slopes concentrate drainage. Subsurface drainage may be concentrated at the contact between looser, sandier materials at the surface (glaciofluvial and weathered till) and more compact, finer grained underlying material.
2. The local bedrock, where encountered, is expected to be highly variable in strength and friability. Most is expected to be rippable, although some blasting may be required. Surface bedrock was only encountered in isolated locations but can be expected on the upper slopes of K68Q, K670 and K672 and in the prominent ridges.

When adverse sub-surface conditions that differ from those described above or detailed in Tables 7.1 to 7.3 are encountered in the cutslope excavation, the road crew should notify BCTS personnel so that sufficient detail can be collected and forwarded to the project geoscientist. Upon review of the information the excavation recommendations contained in Section 7.3 may be amended.

7.2 Seepage Conditions

Surficial materials within the study area appear to be well drained, however indicators of significant subsurface flow are suggestive that seepage emergence from fresh cuts should be anticipated during road construction on the lower slopes and possibly within draws.

7.3 Cutslope Excavation Recommendations

The till and colluvial materials expected to be encountered during construction should generally be excavated at a slope angle of 1V to 1.5H. Where the layer is less than 2 m thick and sideslopes are moderately steep or steep the angle may be increased to 1V to 1H. Cutslopes may ravel or slough at this angle whereby requiring seasonal maintenance of the ditchlines. If minor seepage is encountered in this layer in the excavation, this slope angle may have to be reduced. If considerable seepage (i.e. a spring) is encountered in the excavation

and/or slumping of the exposed soils occurs during construction, road building activities at these locations should cease and the project geoscientist should be contacted for further direction.

The overall design cutslope in bedrock should be no steeper than 4V to 1H. This is a design angle, the actual bedrock cutslope could be steeper in isolated areas depending on natural joints or fractures in the rock and how the rock breaks. During excavation the road crews must do visual inspections and check scale the bluffs after every blast (using the excavation equipment). Construction inspections by the project geoscientist are only required if the road crew notes the formation of new open fractures, or the formation of detached blocks that cannot be scaled down. During road construction, workers must not pass directly between the cutslope face and the excavation equipment and no equipment should be working above the crest of the cutslope while workers or other equipment are located below.

7.4 Road Prism Recommendations

Construction on moderately steep to steep gradient terrain (>65%) will generally require full bench cut with some areas of $\frac{3}{4}$ bench. Where $\frac{3}{4}$ bench cuts are prescribed the fillslope must be constructed of placed and keyed-in coarse angular rock or compacted sand and gravel mineral soils. This material must be placed upon an excavated, blasted or natural bench at least 2m wide and flat or slightly out-sloped. The bench must be founded in bedrock or competent (undisturbed) mineral soils. If natural benches are not present and excavation or blasting of a bench is not achievable the road prism should be shifted into a full bench cut. The placed rock fill should be designed and constructed at an angle no steeper than 1V to 1H. Placed and compacted granular material should be designed and constructed at an angle no steeper than 1V to 1.5H. The slope length of the fill should be restricted to the reach of the excavator to ensure that the material can be carefully placed, keyed in and compacted where applicable.

Road subgrade material should not be placed on water-softened or saturated slopes (i.e. slopes where considerable seepage and/or significant hydrophobic plants are present). All water softened material should be excavated to expose the compact till materials and/or bedrock. Unsuitable material will have to be spoiled in lower slope areas and not incorporated into the structural road prism.

7.5 Road Drainage Recommendations

Cross drain culverts are indicated in the traverse notes for this road where the road crosses S6 streams and NCDs. Additional cross drain culverts may be required to reduce the potential for drainage concentration by the road.

The following Tables 7.1 to 7.3 contain site descriptions, a partial risk analysis, and construction recommendations for the assessed sections of the proposed roads.

The Branch 17.6E road will require full bench cut with endhaul construction along the majority of the alignment due to its location on a steep gradient ridge. It is anticipated that most of the cut will occur in competent rock.

Table 7.1 Branch 17.6 Road – Summary of Observations, Risk Analysis, and Construction Recommendations											
Road Section		Terrain Characteristics			Landslide Likelihood P(H) ¹² and Description	Elements at Risk and P(S:H) ¹³	Partial Risk P(HA) ¹⁴	Road Construction Recommendations			Residual Hazard P(H)
Start Δ ¹⁵	End Δ	Surficial Materials and Slope Morphology	Estimated Bedrock Depth	Drainage				Bench	Endhaul (%) ¹⁶	Construction Recommendations and Design Cut and Fill Angles	
0+000	1+549	Road alignment switchbacks up through existing cutblock on 45 to 55% slopes. Road follows old trails for portions of the alignment. Deep deposits of silty sand and gravel till transitioning to a thin blanket to veneer of till overlying a gently sloping bedrock surface on the upper slopes. Surficial materials are loose to dense at depth	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill constructionEnsure adequate cross drain culverts are installed to reduce the potential for drainage concentration and diversion. Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low
1+549	1+576	Town approach to large draw at 1+576 Steep gradient (80 to 90%) sidewall slopes extend 15 to 20m upslope of the alignment and 10 to 20m downslope. Expect deep deposit of silty sand till with organic enriched imperfectly drained upper horizon. Slope breaks over to 35% above the road. Stream channel is 3m wide by 0.2m deep at HWM. 25 to 35% gradient Likely snow avalanche path	1-3m	Imperfect	High Small to medium (<250m ³) fill slope or cutslope failure, potential for runout to Stream A downslope.	Fisheries resource in Bigmouth Creek Low	Moderate	Full	100%	<ul style="list-style-type: none">Full bench cut with endhaul from approximately 1+549 to 1+560Transition to fillslope construction at approximately 1+560 with full fill road prism by 1+570.Construct keyed in rock fill in the draw and install <u>1200mm culvert</u>Maximize fill construction to reduce required cut.Ensure fill is not placed on water softened or saturated material. Cut: 100% in silty sand and gravel till 400% in bedrock Fill: 100% for keyed in rock fill	Low
1+576	1+638	Woods approach to large draw Moderately steep gradient slopes Slight bowl, possible old draw sidewall slump Expect significant seepage in cut. Expect deep deposit of silty sand till with organic enriched imperfectly drained upper horizon.	1-3m	Imperfect	High Small to medium (<250m ³) cutslope failure, potential for runout to Stream A downslope.	Fisheries resource in Bigmouth Creek Low	Moderate	½ to ¾	50%	<ul style="list-style-type: none">½ to ¾ bench construction with keyed in rock fillsIf significant seepage is encountered the cutslope will likely require sloping back and armouring with coarse rock to reduce potential for slumping. Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low
1+638	2+409	Road alignment switchbacks up through proposed cutblock on generally 45 to 55% slopes. Deep deposits of silty sand and gravel till and glaciofluvial materials Surficial materials are loose to dense at depth	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill constructionEnsure adequate cross drain culverts are installed to avoid altering natural drainage patterns to escarpment slope downslope of 2+050 to 2+310 Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low
2+409	2+599	Moderately steep gradient straight to slightly convex uniform slope Sand and gravel glaciofluvial materials, likely overlying denser till.	2-3m	Well	Moderate Small to medium (<250m ³) fill slope failure, potential for runout up to 150m to moderate slopes below	Soil and timber resources on terrain downslope (less than 0.1 hectare disturbance) High Fisheries resource in Bigmouth Creek Low	High Low	¾	50-75	<ul style="list-style-type: none">¾ Bench cut construction Cut: 100% in sand and gravel materials 400% in bedrock Fill: 70% to 100% for keyed in coarse rock or compacted sand and gravel fill	Low

¹² **P(H) Probability of occurrence of a specific hazardous landslide** following conventional sidecast road construction in this section.

¹³ **P(S:H)** The probability that there will be a spatial effect, given that a specific hazardous landslide occurs, **i.e. the probability that the landslide will impact the specific element at risk**

¹⁴ **P(HA) = P(S:H) x P(H) = The probability of occurrence of a specific hazardous landslide and the probability of it reaching or otherwise affecting the site occupied by a specific element**

¹⁵ Road stations are referenced as P-Line stations from the digital Roadeng survey notes which may or may not represent marked field locations

¹⁶ Refers to the approximate percentage of the total cut volume that will require endhauling off site.

Table 7.1 Branch 17.6 Road – Summary of Observations, Risk Analysis, and Construction Recommendations											
Road Section		Terrain Characteristics			Landslide Likelihood P(H) ¹² and Description	Elements at Risk and P(S:H) ¹³	Partial Risk P(HA) ¹⁴	Road Construction Recommendations			Residual Hazard P(H)
Start Δ ¹⁵	End Δ	Surficial Materials and Slope Morphology	Estimated Bedrock Depth	Drainage				Bench	Endhaul (%) ¹⁶	Construction Recommendations and Design Cut and Fill Angles	
2+599	3+014	Road alignment switchbacks up through proposed cutblock on generally 45 to 55% slopes. Deep deposits of silty sand and gravel till and glaciofluvial materials Surficial materials are loose to dense at depth	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill construction Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low

Table 7.2 Branch 17.6A Road – Summary of Observations, Risk Analysis, and Construction Recommendations											
Road Section		Terrain Characteristics			Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Road Construction Recommendations			Residual Hazard P(H)
Start Δ	End Δ	Surficial Materials and Slope Morphology	Estimated Bedrock Depth	Drainage				Bench	Endhaul (%)	Construction Recommendations and Design Cut and Fill Angles	
0+000	0+455	Road alignment located on generally 45 to 55% planar slopes with some short steeper pitches. Planar slopes are dissected by relic meltwater gullies. Deep deposits of silty sand and gravel till Surficial materials are loose to dense at depth	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill constructionBuild up fill from placed and keyed in rock in the draws crossed at 0+268, 0+331, and 0+416. Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material 100% for keyed in rock fill	Low
0+455	0+502	Relic gully headwall area Several small gullies begin above the road and converge below centreline	1-3m	Imperfect	Moderate Small to medium (<500m ³) cutslope failure, potential to compromise drainage structures and result in a fillslope failure.	Fisheries resource in Bigmouth Creek Low	Low	½	0	<ul style="list-style-type: none">Cut and fill construction with fill built up from placed and keyed in rock in the drawsIf significant seepage is encountered the cutslope will require sloping back and armouring with coarse rock to reduce potential for slumping. Cut: 100% in silty sand and gravel till 400% in bedrock Fill: 70% for sidecast fill of local material 100% for keyed in rock fill	Low
0+502	0+654	Road alignment located on generally 45 to 55% slopes with some short steeper pitches. Deep deposits of silty sand and gravel till Surficial materials are loose to dense at depth	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill construction Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low
0+654	0+694	Large gully-like draw with S6 stream 55% channel gradient 72% gradient on sidewalls for at least 70m Dry, open ridge on woods side	1-3m	Well	Moderate Small to medium (<500m ³) cutslope failure, potential to compromise drainage structures and result in a fillslope failure.	Fisheries resource in Bigmouth Creek Low	Low	Full to ½	50	<ul style="list-style-type: none">Full bench cut on approaches transitioning to fill constructionStrip organics from base and key in coarse rock at the toe of the fillBuild up granular fill in compacted liftsInstall 600mm CMP with well armoured outlet Cut: 100% in silty sand and gravel till 400% in bedrock Fill: 70% for sidecast fill of local material 100% for keyed in rock fill	Low

Table 7.2 Branch 17.6A Road – Summary of Observations, Risk Analysis, and Construction Recommendations											
Road Section		Terrain Characteristics			Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Road Construction Recommendations			Residual Hazard P(H)
Start Δ	End Δ	Surficial Materials and Slope Morphology	Estimated Bedrock Depth	Drainage				Bench	Endhaul (%)	Construction Recommendations and Design Cut and Fill Angles	
0+694	0+788	Road crosses broad ridge and broad bowl beyond Frequent boulders on surface Dry, rocky ground	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill constructionGood rock source for construction of required rock fills backchain. <div>Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock</div> <div>Fill: 70% for sidecast fill of local material</div>	Low
0+788	0+842	Large avalanche chute / gully with S6 stream Stepped bedrock channel Expect thin organics overlying dense silty sand and gravel or bedrock 45 to 55% channel gradient	1-3m	Well	Moderate Small to medium (<500m ³) cutslope failure, potential to compromise drainage structures and result in a fillslope failure.	Fisheries resource in Bigmouth Creek Moderate	Moderate	Full to ½	50	<ul style="list-style-type: none">Full bench cut on approaches transitioning to fill constructionStrip organics from base and key in coarse rock at the toe of the fillPlaced rock fillInstall 800mm CMP with well armoured outlet <div>Cut: 100% in silty sand and gravel till 400% in bedrock</div> <div>Fill: 100% for keyed in rock fill</div>	Low
0+842	0+917	Steep gradient slopes on woods side draw sidewall Expect 1-2m of organic rich sand and gravel colluvium overlying dense silty sand and gravel till or bedrock Seepage present	1-3m	Imperfect	Moderate Small to medium (<500m ³) fillslope failure, also potential for cutslope failure compromise drainage structures and result in a road prism failure.	Fisheries resource in Bigmouth Creek Moderate	Moderate	Full	100	<ul style="list-style-type: none">Full bench cut with endhaul of material back to waste site on moderate slopes <div>Cut: 100% in silty sand and gravel till 400% in bedrock</div> <div>Fill: NA</div>	Low
0+917	1+052	Moderate to moderately steep gradient slopes Frequent boulders on surface Dry, rocky ground	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill constructionGood rock source for construction of required rock fills backchain. <div>Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock</div> <div>Fill: 70% for sidecast fill of local material</div>	Low
1+052	1+276 =POT	Moderately steep (65 to 70%) slopes Sand and gravel till with boulders	1-3m	Imperfect	Moderate Small to medium (<500m ³) fillslope failure, also potential for cutslope failure compromise drainage structures and result in a road prism failure.	Fisheries resource in Bigmouth Creek Moderate	Moderate	3/4	50	<ul style="list-style-type: none">¾ Bench cut with placed rock fill and endhaul of excess cut material <div>Cut: 100% in silty sand and gravel till 400% in bedrock</div> <div>Fill: NA</div>	Low

Table 7.3 Branch 17.6D Road – Summary of Observations, Risk Analysis, and Construction Recommendations											
Road Section		Terrain Characteristics			Landslide Likelihood P(H) and Description	Elements at Risk and P(S:H)	Partial Risk P(HA)	Road Construction Recommendations			Residual Hazard P(H)
Start Δ	End Δ	Surficial Materials and Slope Morphology	Estimated Bedrock Depth	Drainage				Bench	Endhaul (%)	Construction Recommendations and Design Cut and Fill Angles	
0+000	0+518	Road alignment located on generally 45 to 55% slopes with some short steeper pitches. Deep deposits of silty sand and gravel till. Surficial materials are loose to dense at depth. Large incised draw of Stream A crossed at 0+323 and Stream B at 0+352. Streams have gradients of less than 40% and flow within well defined meltwater channel like draws.	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill constructionBuild up fill from placed and keyed in rock in the draws crossed at 0+323 and 0+352. Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low
0+518	0+605	Moderately steep (60 to 70%) slopes through broad swale. Sand and gravel till with boulders. NCD at 0+580, expect localized seepage.	1-3m	Imperfect to well	Moderate Small to medium (<500m ³) fillslope failure, also potential for cutslope failure compromise drainage structures and result in a road prism failure.	Fisheries resource in Bigmouth Creek Low	Low	¾	50	<ul style="list-style-type: none">¾ Bench cut with placed rock fill and endhaul of excess cut material Cut: 100% in silty sand and gravel till 400% in bedrock Fill: 100% for keyed in rock fill	Low
0+605	0+716	Road alignment located on generally 45 to 55% slopes with some short steeper pitches. Deep deposits of silty sand and gravel till. Surficial materials are loose to dense at depth.	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill construction Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low
0+716	0+833	Moderately steep (60 to 70%) slopes of draw sidewall and adjacent ridge/bowl beyond. Sand and gravel till with boulders. NCD at 0+766, expect localized seepage.	1-3m	Imperfect to well	Moderate Small to medium (<500m ³) fillslope failure, also potential for cutslope failure compromise drainage structures and result in a road prism failure.	Fisheries resource in Bigmouth Creek Low	Low	¾	50	<ul style="list-style-type: none">¾ Bench cut with placed rock fill and endhaul of excess cut material Cut: 100% in silty sand and gravel till 400% in bedrock Fill: 100% for keyed in rock fill	Low
0+833	0+886 = POT	Road alignment located on generally 45 to 65% slopes with some short steeper pitches. Deep deposits of silty sand and gravel till. Surficial materials are loose to dense at depth.	1-3m	Well	Low Small to medium (<500m ³) fill slope failure, runout limited by moderate gradient slopes	NA	NA	½	0	<ul style="list-style-type: none">Cut and fill construction Cut: 70% in silty sand and gravel till and/or colluvium 400% in bedrock Fill: 70% for sidecast fill of local material	Low

8.0 Snow Avalanche Assessment

General Discussion

An assessment of the terrain within and adjacent to the proposed cutblocks was completed to determine the potential for snow avalanche initiation. The assessment follows procedures presented in the document: “Land Management Handbook 55 – Snow Avalanche Management in Forested Terrain.” (LMH55) (Weir 2002), published by the BC Ministry of Forests, Forest Science Program.

The proposed development is located in an area receiving heavy snowfall during winter months that results in heavy snow packs for a significant portion of the winter. Climate records from the Goldstream River/Stitt Creek confluence weather station approximately 24km south at an elevation of 700m show a mean maximum water equivalent depth of 452mm. The Mica Creek station (32km northwest at elevation of 580m) indicates a mean maximum water equivalent depth of 590mm.

According LMH55 the majority of destructive avalanches initiate on terrain with a concave profile (either down or across slope) with a slope gradient of greater than 58% (approx 30 degrees). The Bigmouth Creek watershed is located in mountainous terrain where this slope profile is prevalent. Significant signs of recent and historic snow avalanche activity are present in the form of numerous snow avalanche chutes located on the valley walls.

This assessment is intended to estimate the snow avalanche hazard pertaining to the proposed cutblocks: (i) to determine the potential for avalanche hazard initiation and runout resulting from the development and (ii) to determine the incremental hazard to the cutblock area from existing snow avalanche activity. The partial risk stated in this assessment is to stationary resource values as outlined by (FRPA) and does not take into consideration any other potential elements at risk that are not explicitly stated within this report. This assessment is not in any way intended as analysis or risk management for workers working within the proposed development during the winter or spring period. To address the Worksafe BC requirements for snow avalanche safety BCTS must retain a qualified avalanche technician to develop an avalanche safety plan during operations.

8.1 Active Snow Avalanche Terrain – Discussion and Conclusions

The northwest falling boundary of Cutblock K671 between approximately FC 4 and FC 7 is situated adjacent to a snow avalanche runout zone. The avalanche path has a start zone located in the alpine well above the block elevation and appears to host up to size Class 4 avalanches¹⁷. The runout zone consists of 15 to 25% gradient slopes and vegetated with alder and other deciduous species. Layout is such that the runout zone is not included in the proposed harvest area and a buffer of timber 20 to 40m wide has been left along the edge of the runout zone. The terrain within the buffer adjacent to the terminus of the runout zone has similar slope gradient as the runout zone. As natural avalanches tend to runout on an average gradient of around 17% (10 degrees) it is not expected that the runout would extend significantly into the buffer area.

Cutblocks K672 and K670 are separated by a large avalanche track in a well defined draw. The runout zone for this avalanche track is located downslope of the southeast corner of Cutblock K672 in an area adjacent to an

¹⁷ Weir P.W. 2002 *Handbook for Management of Snow Avalanche Prone Forest Terrain* Ministry of Forests Research Program Victoria BC. (LMH55)

existing cutblock situated downslope of Cutblock K672 (see Figure 3). The avalanche track is well confined in a topographic draw. The track becomes confined adjacent to FC 9 of Cutblock K672. At this point young hemlock is growing nearly completely across the track and only a narrow bedrock channel approximately 3m wide and incised 10 to 15m is present. This indicates that the frequency of very large destructive events that descend to the valley bottom is low enough that the 15 to 25 year old stand has been able to develop. Due to the well incised nature of the draw that this avalanche path follows it is judged that the proposed harvesting will have no significant impact on the runout potential or aerial extent of avalanches that descend this track following the proposed harvesting

Cutblock K68Q is not adjacent to any significant avalanche paths.

8.2 Potential Snow Avalanche Terrain – Discussion and Conclusions

The proposed cutblocks in this development all contain areas with slopes greater than 58% with a moderate downslope concave profile (terrain described in LMH55 as being prone to snow avalanche initiation). Further potential contributing factors to avalanche initiation that would be expected to be increased following logging activities include a depth of winter snow that is expected to be greater than the height of surface features (i.e., stumps or slash), and an increase in exposure to wind loading (LMH55). Table 8.1 summarises the factors in assessing avalanche hazard for the block in the proposed development.

Table 8.1: Factors in assessing avalanche hazard for the proposed development

Cutblock	K68Q	K672	K670
Elevation (m) of potential starting zone	1200	1150	1150
Estimated mean maximum water equivalent depth	750	720	720
20 year water equivalent (est)	1195	1165	1165
Start zone angle	100% (45°)	67% (33.5°)	77% (37.5°)
Start zone area	3000m ² (max)	9000m ² (max)	10000m ² (max)
Path length	150 m	500 m	550 m
Runout Angle	50% (26.5°)	50% (26.5°)	26% (15°)
Potential size	1-2	1-2 (potentially to 3)	2-3
Wind loading	High	Low	Moderate in draw
Potential impact to	Timber / plantation	Timber / plantation	Timber /plantation Bigmouth FSR

8.2.1 Cutblock K670

Discussion

As described in the previous sections, Cutblock K670 has steep gradient terrain in the upper portion of the cutblock. The Branch 17.6A Road traverses moderate to moderately steep slopes that break over steeper below the road location. The slopes above this road, particularly downslope of FC 21 to FC 18 are broken and deposits of coarse blocky colluvium are present (increased surface roughness). An incised draw is present downslope of FC 17, this draw has timber within it in the upper portion of the cutblock but becomes open midway down through the cutblock and may host small (size class 1-2) avalanches. This draw extends well

upslope of the cutblock and may be a transport zone for avalanche events initiating well upslope of the cutblock. Several narrower but deeply incised and bedrock controlled draws are present in the eastern portion of the cutblock. These draws also extend well upslope of the cutblock and may be transport zones for events initiating well upslope of the cutblock. Defined fan landforms, likely formed immediate post glacial are present downslope of the gullied draws at the valley bottom.

The mean maximum snow water equivalent depth (720 annual / 1165 for a 20 year period) exceeds the threshold for avalanche initiation as described in McClung (2001)¹⁸ and LMH55. The potential for wind loading in the central draw is assessed as moderate, due to the natural rolling over of terrain into this feature.

The potential starting zone – the upper portion of the block in and around the central draw, has slope angles to 77%, well within the threshold for avalanche initiation. The confined gulley extends down to the moderate gradient slopes approximately 500-550 m to the Bigmouth FSR.

Results

It is expected that small scale avalanches (i.e. size class 1-2 – mass to 100t, and impact pressures to 10kPa) could initiate in the cutblock following harvest activities, however the extent of the potential runout is likely to be confined by the gulley. Slope gradients in the lower portion of the cutblock are gentle to moderate on broad fan landforms where deposition of avalanche debris would likely take place. Deposition of avalanche debris would likely end at the road, and impact to the timber blow the block is unlikely.

8.2.2 Cutblock K671

Cutblock K671 is situated primarily on gentle to moderate slopes with no potential for post harvesting snow avalanche initiation. One small area less than 2 hectares in size is situated on steep gradient slopes that extend for approximately 120 to 140m from the upper boundary down to gentle slopes immediately below. It is expected that small scale avalanches (i.e. size class 1) could initiate in this portion of the cutblock following harvest activities. An avalanche in this area would likely be limited to the storm snow on the slope and would likely run out to the gentle terrain within the block downslope. Due to the small size of the initiation area it is not expected that a large scale destructive avalanche (i.e. size class 3 or greater) could be initiated on the slope following harvest activities.

8.2.3 Cutblock K672

Discussion

As described in the previous sections, Cutblock K672 is situated on predominantly planar, moderately steep to steep slopes dissected by occasional incised, timbered draws (refer to section 6.2 for a complete discussion of the terrain in this cutblock). The moderately steep to steep slopes are continuous for up to 500m before transitioning to moderate to gentle valley bottom terrain.

The cutblock is bounded upslope by moderately steep to steep terrain containing mature timber and no apparent signs of avalanche activity.

The mean maximum snow water equivalent depth (720 annual / 1165 for a 20 year period) exceeds the

¹⁸ McClung D.M. 2001 *Characteristics of terrain, snow supply and forest cover for avalanche initiation caused by logging*. Annals of Glaciology 32, 223-230.

threshold for avalanche initiation. Wind loading is likely to be minimal on the generally planar slopes in the block.

The potential starting zone – the upper portion of the block and the draw around FC12-13, has slope angles to 67%, which are just on the threshold for avalanche initiation. Slope gradients are long and generally planar but with benched terrain, which is likely to slow avalanche propagation within the block. Slope gradients at the bottom of the block are 50% at the timber edge.

Results

It is expected that small scale avalanches (i.e. size class 1-2 – mass to 100t, and impact pressures to 10kPa) may initiate in the cutblock following harvest activities. An avalanche initiating within this cutblock would likely be limited to the storm snow on the slope and is not likely to run out beyond the existing cutblock downslope. Runout is not expected to reach the Bigmouth FSR. The initiation of a large destructive avalanche on this slope (i.e. size class 3 or greater slab avalanche) following harvest activities is possible, but remote.

8.2.4 Cutblock K68Q

Discussion

As described in the previous sections, Cutblock K68Q is situated on predominantly planar, moderately steep to steep slopes. The majority of the terrain in the proposed cutblock slopes towards the incised draw that parallels the southern falling boundary. These slopes are generally 45 to 65% gradient and the steeper slopes are generally not continuous for more than 200m between gentle to moderate gradient benches that break up the slope. Stream A flows within a well defined, moderate gradient draw downslope of this terrain. This stream draw may host snow avalanche events that begin well upslope of the cutblock.

The cutblock is bounded upslope by steep terrain containing mature timber and no apparent signs of avalanche activity outside of the draw discussed above.

The area of concern in this block consists of the steep slopes below Spur17.6E. Slope gradients in the potential avalanche start zone area (below the spur) are to 100%, extending for 100-150m downslope to slopes of approximately 50%. This slope is well within the threshold for avalanche initiation.

The elevation of the area of concern is approximately 1200m. The mean maximum snow water equivalent depth (750 annual / 1165 for a 20 year period) exceeds the threshold for avalanche initiation. Additionally, the wind loading for this area is expected to be high, due to the convex (cross slope) shape of the area, and the presence of a broad ridge, to the south, which would be a source area for wind-transported snow.

Results

The likelihood of avalanche initiation in this area is estimated to be moderate to high, however because of the short slopes, (100-150m) it is unlikely that the size would exceed a class 1 to 2. An avalanche initiating in this area would likely impact but not significantly damage timber downslope, but may affect the plantation within the proposed cutblock. Penetration into and destruction of the timber below the falling boundary is considered unlikely due to the expected size class of any events that do initiate. Due to the small size of the anticipated initiation area(s) it is not expected that a large scale destructive avalanche (i.e. size class 3 or greater) could be initiated on these slopes following harvest activities.

9.0 Closure

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

Factual data and interpretation contained within this report were prepared specifically for BCTS with whom Forsite has entered into a contract. No other party may rely upon this report without the express written permission of Forsite.

Sincerely,

Forsite Consultants Ltd.

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Attached: Figure 1 Location Map
 Figure 6 Overview Map

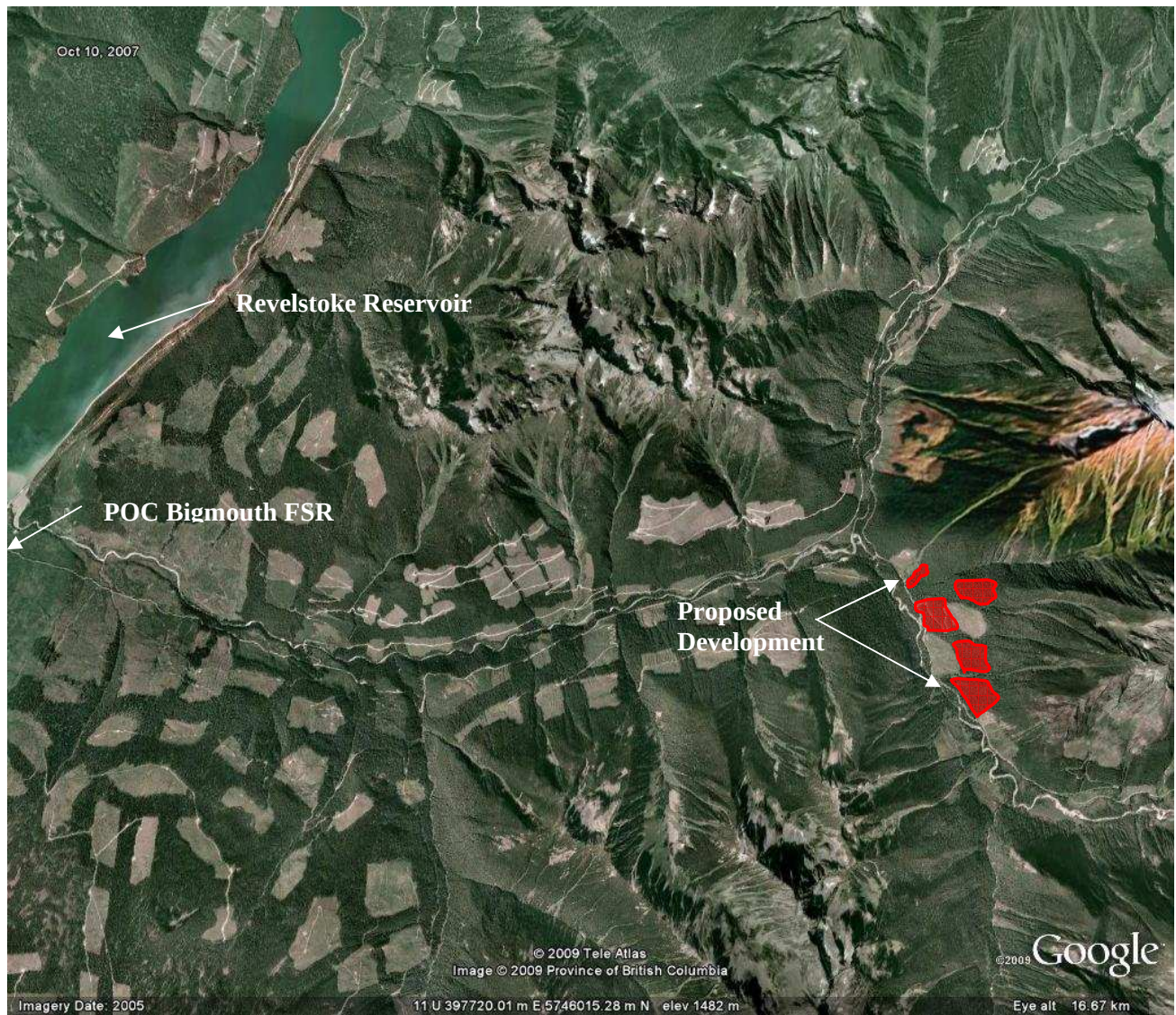


Figure 1: Location Map sourced from GoogleEarth February 2008.

