

**TERRAIN STABILITY ASSESSMENT
&
SOIL EROSION ASSESSMENT**

**Proposed TSL TA0915
Blocks 1, 2 and 3**

**Smallwood Creek and Garrity Creek
Selkirk Forest District**

**Prepared for:
Atlas Information Management
&
British Columbia Timber Sales
Kootenay Lake Field Team**

**Prepared by:
Sitkum Consulting Ltd.
Project No. 20-1561**

July 13, 2020



Table of Contents

1.0	INTRODUCTION.....	1
2.0	METHODOLOGY.....	2
2.1	Office Assessment	3
2.2	Field Assessment	3
2.3	Limitations	4
3.0	BACKGROUND INFORMATION.....	4
3.1	General Physiography	4
3.2	Regional Terrain Stability Considerations.....	4
3.3	Site Location - General	6
4.0	OBSERVATIONS AND INTERPRETATIONS.....	8
4.1	TA0915-1.....	8
4.1.1	Existing Roads	9
4.1.2	Downslope	10
4.1.3	Landslide Hazard and Partial Risk Analysis.....	11
4.2	TA0915-2.....	12
4.2.1	Existing Roads	14
4.2.2	Proposed and Existing Trails	14
4.2.3	Downslope	15
4.2.4	Landslide Hazard and Partial Risk Analysis.....	18
4.3	TA0915-3.....	20
4.3.1	Existing Roads	25
4.3.2	Proposed Garrity 3110 Road.....	26
4.3.3	Proposed Trails	26
4.3.4	Existing Trails.....	26
4.3.5	Downslope	28
4.3.6	Landslide Hazard and Partial Risk Analysis.....	30
4.4	Soil Erosion Assessment.....	31
5.0	RECOMMENDATIONS	33
5.1	Road Recommendations	33
5.2	General Harvesting Recommendations.....	33
5.3	Specific Harvesting Recommendations	34
5.4	Field Reviews.....	35
6.0	CLOSURE.....	36
7.0	REFERENCES.....	37

List of Appendices

Appendix A – Risk Analysis Overview & Soil, Rock, and Slope Classification Tables
Appendix B – Soil Erosion Hazard Definition and Criteria Tables
Appendix C – Road Recommendations Summary Table and Typical Section Diagrams
Appendix D – Figures

List of Figures

Figure 1 – Overview Map (scale 1:20,000)
Figure 2 – Traverse Route Map (scale 1:10,000)
Figure 3 – TSA Map (scale 1:5,000)

July 13, 2020

Sitkum File No: 20-1561

Atlas Information Management
#101-1383 McGill Rd.
Kamloops, B.C.
V2C 6K7

Attention: Richard Cane, R.P.F.

Cc: Genevieve Lachance, R.P.F.
Practices Forester, BCTS Kootenay Lake Field Team

1.0 INTRODUCTION

At the request of Mr. Richard Cane, R.P.F. of Atlas Information Management (AIM), Sitkum Consulting Ltd. (SCL) has carried out a Terrain Stability Assessment (TSA) and Soil Erosion Assessment (SEA) for the proposed forest development of TSL TA0915. The development consists of three proposed fire mitigation cutblocks in the Smallwood Creek area, located approximately 11 km to 13 km west of Nelson, B.C. (refer to Figure 1).

The assessment was requested based on application of British Columbia Timber Sales (BCTS) Terrain Stability Assessment Decision and Documentation Tool, part of the BCTS Terrain Stability Management Model. A TSA has been completed due to the development being situated upslope of private property and dwellings. The soil erosion assessment was requested as the proposed development is located upslope of licensed water intakes used for domestic purposes.

The scope of the work, as requested by AIM, is:

- to identify potential terrain stability and soil erosion concerns associated with the proposed forest development;
- to evaluate the potential impact relating to slope stability and soil erosion of the proposed forest development on downslope elements at risk; and
- to make recommendations, where appropriate, with the intent to reduce the likelihood of landslides and soil erosion attributable to the proposed forest development.

The considered downslope elements at risk include private property and residences (includes human safety), point of diversion (POD) infrastructure, and water quality with respect to domestic water supply. Other potential downslope elements at risk which have not been specifically addressed by means of assigning risk ratings in this report include downslope forest roads and trails, wildlife habitat, visual resources, timber value, and soil productivity. Elements further downslope including public roads and Highway 3A, a rail line, and transmission lines also have not been individually risk rated, but have either been grouped as valley bottom elements or can be inferred to be less at risk than the more proximal elements which have been addressed.

This report is a revised version of a signed and sealed TSA and SEA dated February 26, 2020 that incorporates minor changes to reserve areas, machine free zones and/or wildlife tree retention areas in Block 1 and Block 3, reflects recent changes by the British Columbia

Geographic Warehouse to the Falls Community Watershed boundary, and reflects the recently completed road upgrades and road construction by BCTS within the development area.

2.0 METHODOLOGY

The TSA has been carried out in a method consistent with the *Guidelines for Terrain Stability Assessments in the Forest Sector* (AFPBC/APEGBC 2010). A partial risk analysis has been completed with specific definitions and an overview presented in Appendix A. Land Management Handbook 56, *Landslide Risk Case Studies in Forest Development Planning and Operations* (Wise et al. 2004) can be referenced for additional background information on partial risk analysis.

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

The likelihood of landslide initiation has been estimated in a primarily qualitative manner based on generally accepted geotechnical interpretations and assumptions, the experience of SCL, comparative observations of both natural and forest development related landslides in the southern Columbia Mountains, and results from regional landslide attribute studies (Jordan 2003). The likelihood ratings are considered incremental to the existing state (natural or otherwise) as a result of the proposed development. Unless otherwise stated, the likelihood ratings assume that generally accepted good forest development practices are used, including effective maintenance and deactivation measures.

Safety for workers relating to road layout and design considerations is addressed by the coordinating professional, along with work site safety standards and procedures. Worker and road user safety related to terrain stability is considered in this assessment by means of recommendations as required for constructing a stable road prism, as well as identification of upslope hazards where they may exist.

A table that provides a list of descriptive terms relating to soil drainage, soil texture and consistency, surface expression, and bedrock characteristics is presented in Appendix A.

Recommended cut and fill slope angles as presented in the Road Recommendations Summary Table in Appendix C are based on the experience of SCL considering site specific material properties and slope configurations in comparison with existing cut and fill slope angle performance in the local and regional area.

Figures 1 to 3 in Appendix D present water features based on Terrain Resource Information Management (TRIM) mapping with additional information gathered by AIM during layout. Some adjustments to downslope stream locations have also been made based on field observations and LiDAR data interpretation by SCL.

Information regarding the potential for acid rock drainage resulting from road construction and its impacts has been presented to assist land managers in their evaluation of risk to water quality. This level of assessment is consistent with the FREP Extension Note #42 Evaluating The Presence And Impact Of Acid Drainage From Industrial Roads In British Columbia (Maloney and Carson, 2018). No laboratory testing has been completed, and this does not represent a more

detailed metal leaching and acid rock drainage (ML/ARD) screening assessment as completed for larger quarries or mine sites.

2.1 Office Assessment

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

- *TA0915 – Smallwood Blocks 1, 2 & 3; SMA-016A, SMA-018 & SMA-017; Assignment #2019-03 Terrain Specialist Assignment Form* dated September 27, 2019;
- *BCTS Terrain Stability Assessments Decision and Documentation Tool, Blocks SMA-016A, SMA-018 and SMA-017* dated August 26, 2019;
- AIM 1:5000 scale Harvest Plan Maps (TRIM based contour map, LiDAR hillshade, and orthomosaic maps) for Block 1 (dated September 19, 2019), Block 2 (dated September 18, 2019) and Block 3 (dated December 10, 2019);
- SCL 1:5,000 scale LiDAR based 5 m contour topographic map, Bare Earth surface model (hillshade), and slope themed maps with proposed development features and TSIL C terrain stability mapping;
- AIM Garrity 3110 Road Appraisal Notes, June 18, 2019;
- *Terrain Stability Assessment and Soil Erosion Assessment, Proposed Smallwood 2000 FSR, Garrity 1800 FSR and Garrity 3100 FSR*, report prepared for BCTS by Sitkum Consulting Ltd. (SCL project #19-1508), September 13, 2019;
- *Smallwood 2000 FSR, Garrity 1800 FSR, Garrity 3100 FSR, June 9, 2020 Final Construction Field Review*; report prepared for BCTS by Sitkum Consulting Ltd. (SCL project #20-1508), June 16, 2020;
- *Preliminary Terrain Stability Office Review of Smallwood Creek Fire Mitigation Areas, SMA-15-55, SMA-016, SMA-016A, SMA-017, and SMA-018 in RDCK Wildfire Urban Interface*, report prepared for BCTS and RDCK by Sitkum Consulting Ltd. (SCL project #19-1477b), June 21, 2019;
- *Hydrologic Assessment, Blocks SMA 15-55, SMA-016, SMA-016A, SMA-017, SMA-018 and SMA-019*, report prepared for BCTS by Statlu Environmental Consulting (Project #18-190), March 28, 2019;
- *Smallwood FSR Maintenance Prescriptions*, prepared for BCTS by Sitkum Consulting Ltd. (SCL project #16-1305), November 2016;
- *Terrain Stability Assessment and Soil Erosion Assessment, Proposed TSL A68929, Blocks 2, 3, and 4, Smallwood Creek*, report prepared for Atlas Information Management by Sitkum Consulting Ltd (SCL project #12-923), June 19, 2013;
- GoogleEarth (GE) and iMapBC web applications (for fish status, water license data, BEC mapping, and geology mapping); and
- ClimateBC_Map (UBC Centre for Forest Conservation Genetics).

2.2 Field Assessment

On October 24 and October 30, 2019, Jeremy Major, P.Geo. of SCL completed the initial field assessments of Blocks 1, 2 and 3. On November 7, 2019, Mr. Major and Tedd Robertson, P.Geo. Eng.L. of SCL reviewed select areas within and downslope of Blocks 2 and 3. Mr. Major

returned to Block 3 with Murray Peck, FIT of AIM on November 22, 2019 to mark out the special management zone and skid trails upslope of the proposed Garrity 3110 road.

The combined field traverses by SCL took approximately 28 person hours to complete. The weather at the time of the assessments ranged from sunny to mostly cloudy, with temperatures from -7°C to 8°C. There was no significant precipitation during the field traverses and the ground was entirely snow free.

Observations and interpretations presented within this report also take into account field traverses by Mr. Robertson and Mr. Major described in the above referenced TSA report that were completed as part of the assessment of the proposed Smallwood 2000 FSR, Garrity 1800 FSR and Garrity 3100 FSR (SCL Project #19-1508). Those field traverses were completed on July 3, July 9 and July 11 of 2019, and took approximately 27 person hours to complete.

Refer to Figure 2 for approximate traverse routes from all field traverses. Field positions were established based on p-line survey flagging, handheld GPS (iPad Mini with Bad Elf external GPS) and recognizable land features (creeks, slope breaks, etc.).

2.3 Limitations

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

3.0 BACKGROUND INFORMATION

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

3.1 General Physiography

The proposed development is situated in the Kokanee Range within the Selkirk Mountains of the Columbia Mountain System. The general physiography of the region consists of serrated ridges and peaks above 2000 m elevation and rolling topography with rounded ridge crests and steep valley sides below 2000 m. Summit levels are between 2000 m and 2500 m elevation, and local relief of 800 m to 1500 m is typical. The study area is located near the southern edge of the Kokanee Range where the terrain is more subdued. Rounded ridge crests are generally between 1300 m to 2000 m elevation and are typically forested, with local relief of 600 m to 1000 m.

3.2 Regional Terrain Stability Considerations

Landslides within B.C. occur both naturally and as a result of forest development. Landslide attribute studies completed in the region report an increase in landslide occurrence where forest development exists (Jordan 2003). Jordan reports slope steepness, terrain type, the presence of gullies, and the presence of natural landslides as significant terrain variables when looking at development related landslides. In general, landslide frequency was found to be much lower than average in areas with slopes less than 20° (35% gradient), and increase with slope steepness to a maximum in the 35° to 40° category (70% to 84% gradient), with a decrease in the > 40° category (likely due to the presence of steep yet stable bedrock slopes in this category). Landslide frequency was found to be greater in gullied terrain in comparison with non-gullied.

Glaciofluvial and kame deposits were found to have the greatest landslide frequency of all the surficial material types, with thick morainal materials being second. Development-related landslides were also more frequent in areas with existing natural slope failures.

In the southern interior of B.C., roads have been shown to be a much more significant factor than harvesting for landslides attributable to forest development. Landslide attribute studies in the Nelson Forest Region indicate approximately 80% of forest development-related landslides are caused by roads (Jordan et al. 2010). Landslides caused by roads are primarily due to drainage diversions or unstable fill slopes, with cut slope failures being much less common overall. As a result of improved road construction methods and standards in recent years, fill slope failures are much less common on newer roads, with drainage now being the most frequent cause (Jordan 2003, Jordan et al. 2010).

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

In the southern interior of B.C., studies indicate that harvesting alone rarely results in landslides, with only 2% of forest development-related landslides attributable to clearcutting alone in a terrain study completed in the Nelson Forest Region (Jordan et al. 2010). Trails constructed during harvesting operations are a more significant factor than tree removal, with trails found responsible for approximately 13% of forest development-related landslides (Jordan et al. 2010). These studies also indicate that landslides caused by trails are mostly drainage-related, as opposed to cut or fill slope instabilities. With good development practices, harvesting-related landslides are very rare on slopes less than 50%, rare on slopes between 50% and 70%, and are still uncommon but occur most frequently on slopes between 70% and 84%. In many cases, harvesting can contribute to development-related landslides by increasing local runoff that can be intercepted by roads and trails.

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

Most downslope drainage related landslides in the region are debris slides or debris avalanches, although many become channelized debris flows if gullies are present. Channelized debris flows

generally initiate either by a destabilizing impact to a gully channel from a smaller initial landslide, or from a critical high flow reached in a stream channel which causes localized destabilization of the bedload and/or stream banks (Geertsema 2010). Either mode of initiation can result in progressive channel destabilization and entrainment of debris. The former is by far the most common cause of debris flow initiation within the region. The latter is generally associated with significantly increased stream flows due to widespread watershed disturbances such as wildfires. Other contributing factors to in-channel debris flow initiation can be significant runoff concentration or redirection from resource roads or trails which greatly increase effective drainage areas, redirected stream flows, extreme runoff events, or stream flow blockage failures (e.g. short lived landslide dam).

Most road prism landslides are less than approximately 1000 m³ in volume, and commonly remain small in size (50 m³ to 500 m³) unless they enter a gully and cause a channelized debris flow as described above. They are generally limited in magnitude by source area volume and potential for entrainment of downslope materials. Drainage-related landslides are commonly larger, dependent on the length and steepness of slope, type and amount of material available for entrainment, and water discharge at the site. The concept of yield rate can be used to estimate potential event magnitude, taking into account the likely area and depth of scour (Hung et al. 2005).

Factors that can increase the length of runout and/or decrease the angle of deposition include, but are not limited to, increased event volume^{1,2,3}, increased vertical relief^{1,2}, slope geometry², increased water supply⁴, finer textured materials^{3,4}, confinement^{1,2,4}, and lack of obstructions or topographical constraints^{1,2,3,4}. Hung et al. (2005) reports variable published deposition angles for relatively coarse grained debris flows in B.C. ranging from 12% to 25%, with lower angles for finer textured materials. Jordan et al. (2011) reports on three specific long runout events that recently occurred in the southern interior of BC, and identifies fine textured materials, specifically those with substantial clay content, as an important contributing factor to the long runout. No detailed empirical-statistical analysis of runout distance specific to the region is available; however, consideration of the above factors combined with field observations of past landslide events in the area can provide context for the qualitative estimate of potential landslide runout distances.

The above findings are generally consistent with field observations of SCL over the past 20 years assessing terrain stability in the region. Much previous forest development has occurred within the Smallwood Creek and Garrity Creek drainages over the last century, and the local effects on terrain stability have been observed to be generally consistent with regional landslide attribute studies as discussed above. These local and regional terrain stability considerations, along with professional judgment and the experience of SCL, provide a basis for the supporting rationale of the conclusions and recommendations presented in this report.

3.3 Site Location - General

The proposed blocks are located on primarily south aspect slopes upslope of private land with residential development, Highway 3A, a railway line, a power transmission line, and the

¹ Corominas 1996

² Hunter and Fell 2003

³ Jordan et al. 2011

⁴ VanDine 1996

Kootenay River (refer to Figure 1 in Appendix D and Image 1 below). There are also numerous Points of Diversion (POD's) located downslope; the POD's relating to each block will be discussed individually within Section 4.

According to the referenced Biogeoclimatic Ecosystem Classification (BEC) mapping, the proposed blocks are primarily situated within the West Kootenay variant of the dry warm subzone of the Interior Cedar Hemlock Biogeoclimatic zone (ICHdw1) which is present on the lower to mid-elevation slopes in the area. The highest elevation portions of Block 2 and Block 3 are situated near the transition to the Ymir variant of the moist warm subzone of the ICH Biogeoclimatic zone (ICHmw4). Available climate model data estimates mean annual precipitation in the vicinity of the proposed blocks of approximately 750 mm to 1100 mm depending upon elevation.

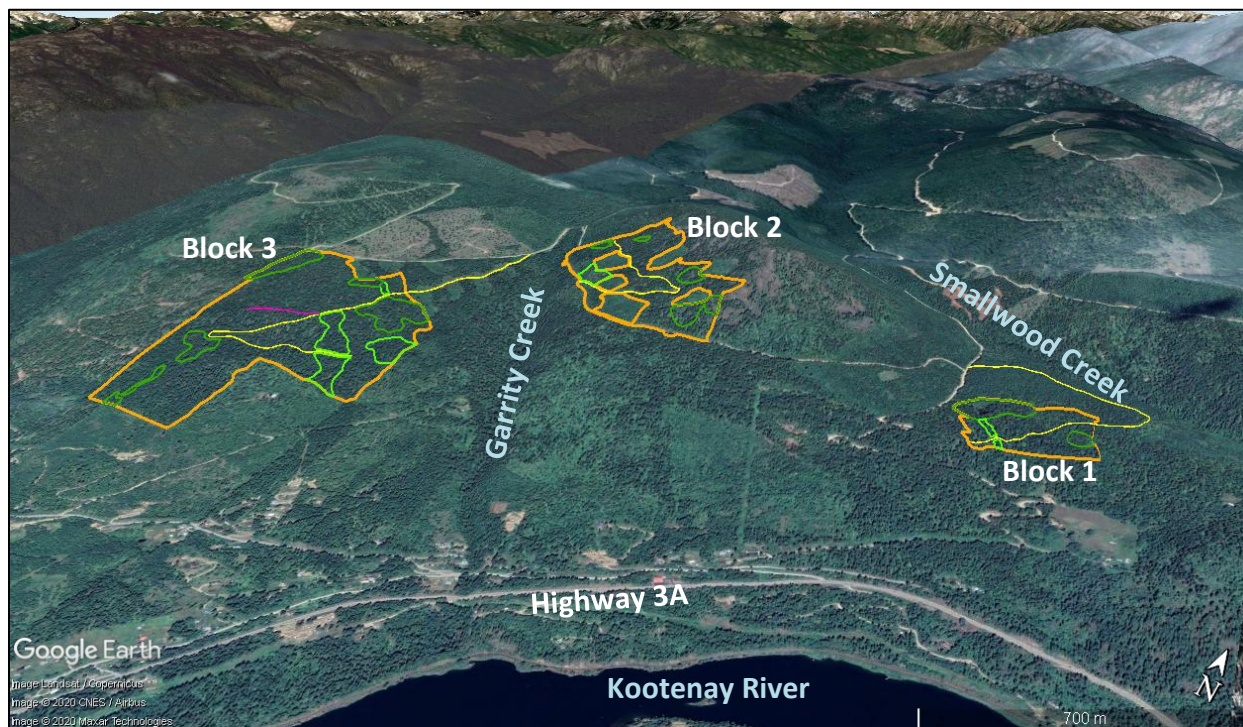


Image 1: Oblique aerial view using Google Earth imagery dated July 15, 2019, looking northwest across the Kootenay River at the proposed development of TSL TA0915. Proposed harvest boundaries are outlined in orange, wildlife tree retention area (WTRA) and reserve area boundaries are outlined in dark green and light green respectively, existing roads in yellow and proposed roads in pink.

Four distinct geologic units have been delineated by the regional geologic mapping in the area of the proposed blocks. Dioritic intrusive rocks of the Eagle Creek Plutonic Complex are mapped within the lower elevation portion of Blocks 2 and 3, and the area downslope of all three blocks to valley bottom. Sedimentary rocks of the Ymir Group, typically limestone, slate, siltstone, and argillite, are mapped within and surrounding Block 1, as well as the middle and upper elevations of Blocks 2 and 3 respectively. Underlying the most western portion of Block 2 and straddling Garriety Creek to the area upslope of Block 3 are basaltic volcanic rocks of the Rossland Group, Elise Formation. And lastly, the northern most portion of Block 2 is underlain by Middle Jurassic aged granodioritic intrusive rocks of the Nelson Batholith that encompasses the majority of the Kokanee Range to the north and east. In general, diorite believed to be part of the Eagle Creek Plutonic Complex was observed over a greater areal extent than mapped within Blocks 2 and 3.

Observations of bedrock were limited in Block 1; except for basaltic volcanic rock downslope of the eastern harvest boundary, contrary to the mapped sedimentary rocks.

Copper, silver and gold was mined between 1907 and 1961 at the Queen Victoria mine, located approximately 500 m southwest of Block 1, and a similar distance southeast of Block 2. Ore mineralization at the mine occurs as skarn hosted by limestone, dark grey quartzite and argillite of the Ymir Group at and near the contact with the granodiorite of the Nelson Batholith (MINFILE Record Summary, No. 083FSW082). While there are no known adverse effects from metal leaching or acid rock drainage (ML/ARD) relating to the existing mine site or resource roads in the area, in part due to the lack of connectivity between rock exposed at these sites and sensitive watercourses or elements at risk, there is some potential for rock susceptible to ML/ARD to be encountered in the area based on the presence of sulphide mineralization occurrences at and near the minesite. This potential for ML/ARD concern was also identified in the Statlu Environmental Consulting 2019 Hydrologic Assessment listed in Section 2.1, and is further discussed in the section of this report describing the proposed Garrity 3110 road.

Refer to Statlu 2019 report for additional background information on the area including a hydrology review and findings from a historical air photo review.

4.0 OBSERVATIONS AND INTERPRETATIONS

The following sections include observations and interpretations relating to the proposed forest development, including landslide hazard and partial risk analysis.

4.1 TA0915-1

Block 1 (planning number SMA-016A) is 10.3 ha gross area in size, with 6.4 ha of net merchantable area. The block is scheduled to be harvested by conventional ground based methods with a partial cut silviculture system. Access will be provided by Smallwood 2000 FSR (refer to Image 2 below and Figure 3 in Appendix D).

The proposed cutblock is located on a south to southeast aspect slope between approximately 850 m and 915 m elevation, directly upslope of private land. The TSIL C terrain stability mapping indicates the block is situated on terrain mapped as stable; primarily terrain stability class I, except for the southeast and southwest harvest areas which are located within the upper portions of class II and class III polygons respectively.

The block is situated on the south side of a very broad, gentle gradient ridge that divides the drainage areas of Smallwood Creek from the south aspect face occupied by the block. A wildlife tree retention area (WTRA) encompasses gentle terrain upslope that includes a wetland area and a licensed POD for irrigation purposes (PD27201, Nygaard Swamp). A plastic waterline 3" in diameter crosses southeast through the block from the POD to the private land downslope, as shown on Figure 3. The waterline is located intermittently on surface or shallowly buried; a designated machine free zone (MFZ) surrounds the waterline within the proposed harvest area. The waterline is not currently in use; however, where crossed by the recently constructed Smallwood 2000 FSR the waterline was cut and rebuilt through the road prism within a casing to prevent damage to the line.

Slope gradients within the block are typically between 10% and 35%. Steeper slopes up to 60% gradient less than 15 m in length are present upslope of Smallwood 2000 FSR. The surface configuration is uniform to slightly irregular, with a few shallow, broad swales. An NCD flows

from the wetland upslope within a 1 m to 2 m deep gully through the block (NCD-1). The gully ends near the lower harvest boundary and signs of surface flow disappear within 20 m on unconfined, moderate gradient terrain. The NCD and gully are surrounded by a machine free zone and are also included within a reserve. According to information provided by AIM, the TSL holder may extract Douglas Fir Beetle impacted stems within the reserve.

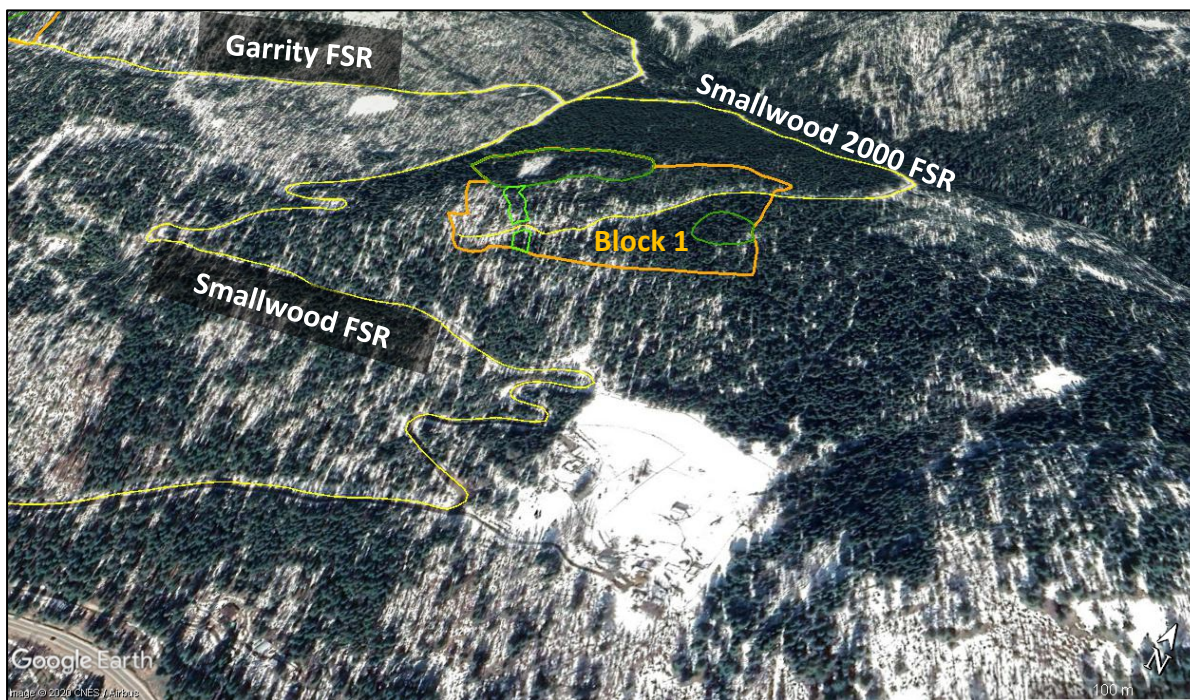


Image 2: oblique aerial view northwest at Block 1 using Google Earth imagery dated March 17, 2020. The block is located upslope of the switchbacks on Smallwood FSR and developed private land. The proposed block boundary is shown in orange, WTRA and reserve area boundaries in dark green and light green respectively, and existing roads in yellow.

Surficial materials within the block form a blanket estimated to range from 1 m to 3 m in depth. The predominant material appears to be basal till with a typical composition of compact silty sand with some gravel, trace cobbles, boulders and clay, and a coarse fragment content (CFC) ranging from 15% to 25%. The till is generally moderately well drained to well drained. Loose sandy material that is mostly well drained was observed in the northeast portion of the block, comprised of uniform silty sand with 5% to 15% CFC, possibly glaciofluvial or ablation till deposits on the broad, gentle gradient ridge upslope. There are two areas of seepage identified by AIM on gentle to moderate gradient terrain near the upper harvest boundary. A machine free zone surrounds the seep that is adjacent to the WTRA.

4.1.1 Existing Roads

Smallwood 2000 FSR was previously assessed in a separate TSA and construction of this road was completed by BCTS in the spring of 2020 (SCL Project #'s 19-1508 and 20-1508). The final 120 m of the road, from Hub 82 to the point of termination (POT) was constructed as a temporary road and is planned to be rehabilitated following development of Block 1. Refer to the Road Recommendations Summary Table in Appendix C for general recommendations relating to rehabilitation of the temporary road section.

The road alignment descends from Smallwood FSR along the broad, gentle gradient ridge upslope of Block 1 followed by a continued descent from northeast to southwest across the proposed harvest area to the end of the permanent road at Hub 82. The short temporary road section has a rolling grade and crosses the shallow gully containing NCD-1.

4.1.2 Downslope

Private land is present immediately downslope of the block. Slope gradients within this area range from primarily gentle downslope of the southeast corner, to moderate and moderately steep downslope of the central portion (including a section with 50% to 60% gradients over a length of approximately 50 m), and steepest downslope of the southwest corner, where 60% to 70% gradient slopes for approximately 50 m length exist before easing to moderate gradient slopes downslope towards Smallwood FSR. The area has been mapped as stable by the available TSM (Class II and III) and there are no significant gullies.

Surficial material over most of this area is till with a typical composition of compact silty sand with some gravel, and trace cobbles and boulders (20% to 25% CFC). The till is of varying thickness, as indicated by bedrock outcrops that include dark green to black volcanic rocks and weathered or altered rock that may be diorite. Some colluvial material is present on and downslope of the steepest slopes, where bedrock is near surface.

A partially overgrown machine trail located downslope of the western portion of the block climbs steeply from a broad swale at Smallwood FSR where an existing culvert is located, towards the northeast. The trail has almost no cut or fill and is not significantly redirecting runoff.

Smallwood FSR switchbacks five times on the face downslope of Block 1. The nearest buildings include a residence located on gentle gradient terrain located east of the switchbacks, approximately 275 m downslope of the lower harvest boundary.

Approximately 450 m downslope of the southwest portion of the block is a POD with a current licence for both domestic use and irrigation (PD27203, Harley Spring). Flint Spring (PD28326) is a POD near PD27203, licensed for irrigation. Another proximal POD licensed for domestic and irrigation use is at Bear Spring (PD27202), located approximately 350 m southeast of the southeast corner of Block 1; however, this POD appears to be outside of the direct influence of the proposed block.

A small debris slide, estimated to have involved 200 m³ of material, occurred 85 m downslope of Block 1 approximately five years ago, depositing some material on Smallwood FSR (refer to Figure 3 for location, and Image 3 below). While the cause is unconfirmed, the debris slide appears likely related to a waterline break associated with PD27201, as indicated by a broken 3" diameter plastic pipe that is shallowly buried at the top of the headscarp. The landslide scoured a path that averages 5 m wide and 1 m deep down the 50% gradient slope.

As part of previous work in the area (SCL Project #16-1305, listed in Section 2.1), five small debris slide scars were observed 200 m to 300 m southwest of Block 1. These slides are dormant and revegetated with an estimated age of > 30 years. All failures terminated along or prior to an existing trail < 75 m down slope of Smallwood FSR, and none appeared to have an adverse effect on down slope water license locations or private land. It is likely that these slope failures were a result of redirected runoff along Smallwood FSR, as they initiate immediately down slope of the road.



Image 3: View down the path of the debris slide that impacted Smallwood FSR approximately 5 years ago; the road is visible in the distance.

4.1.3 Landslide Hazard and Partial Risk Analysis

Taking into account the observations presented above, along with the regional terrain stability considerations presented in Section 3.2, the likelihood of a hazardous in-block landslide attributable to the proposed harvesting of TA0915-1 is estimated to be Very Low. Landslides attributable to harvesting on similar terrain using similar methods within the region are very rare following generally accepted good development practices.

- **P(H) harvesting related, in-block: VL**

Hazardous downslope drainage related landslides have occurred on similar downslope terrain if significant redirected runoff is concentrated onto steeper downslope terrain, as shown by the recent small debris slide that impacted Smallwood FSR downslope of Block 1. Continuous adverse grades, such as those present along the permanent section of Smallwood 2000 FSR can redirect or concentrate runoff over long distances; however, the potential for such an occurrence is limited due to the lack of drainage features and moderately well drained to well drained soils along the alignment. The proposed drainage plan will provide for effective dispersal of runoff, and in conjunction with effective road maintenance and seasonal deactivation, significantly concentrated runoff is unlikely to occur downslope. Redirection of NCD-1 from harvesting is also unlikely to occur due to the confinement within a gully and designated machine free zone and reserve area. As a result, considering the above factors and small harvest area which limits the potential for compounding effects, the likelihood of a hazardous drainage related landslide downslope of Block 1 is estimated to be Very Low.

- **P(H) downslope drainage related: VL**

In the event of a hazardous in-block or downslope drainage related landslide, considering the site specific terrain conditions and in comparison with other forest development related landslides in the region, it would most likely be a debris slide or debris avalanche on the order to 200 m³ to 1000 m³ in size.

A debris slide or debris avalanche would likely be on the smaller end of the size range due to the limited slope lengths of steeper terrain, similar to the event that occurred approximately 5 years ago. A similar type of event is unlikely to continue a significant distance downslope due to the lack of confinement, multiple road crossing (Smallwood FSR and private roads), as well as extensive gentle gradient terrain, especially near the residence and other building just east of the switchbacks on Smallwood FSR.

Due to the proximity of private land, the likelihood of an impact to the private land is estimated to be equivalent to the likelihood of the drainage related downslope landslide occurring, or Very Low. The gentle gradient terrain surrounding the residences on this private land, combined with the lack of gully connectivity leading to the residences, significantly reduces the likelihood of an impact to a residence in the unlikely event of a downslope drainage related landslide. As a result, the likelihood of a damaging impact to residences is estimated to be orders of magnitude lower than the upper limit of Very Low. Due to the lack of watercourses and considering the downslope terrain configuration, the POD's to the south including PD27202, PD27203, and PD28326 are very unlikely to be affected. Similarly, considering the extent of intervening gentle gradient terrain the valley bottom elements at risk including the Highway, Railway, and Kootenay River are very unlikely to be affected.

- **P(HA_{proximal private land}) downslope drainage related: VL**
- **P(HA_{proximal residences}) downslope drainage related: VL**
- **P(HA_{valley bottom elements}) downslope drainage related: VL**
- **P(HA_{POD's}) downslope drainage related: VL**

4.2 TA0915-2

Block 2 (planning number SMA-018) is 30.9 ha gross area in size, with 23.6 ha of net merchantable area with a partial cut silviculture system. The block is scheduled to be primarily harvested by conventional ground based methods (20.8 ha), with 2.8 ha of cable harvest in the southeast portion of the block. There is one reserve area 1.3 ha in size where it is understood that Douglas Fir Beetle impacted stems may be extracted at the discretion of the TSL holder. Access to the block will be provided by Garrity FSR which follows the lower harvest boundary and the in-block Garrity 1800 FSR.

The proposed cutblock is located on a south to southwest aspect slope between approximately 1050 m and 1275 m elevation (refer to Image 4 and Figure 3). Five patch cuts approximately 1 ha to 4 ha in size harvested in the early 1990's are present within and immediately upslope of the block. The patch cuts were accessed by Garrity 1800 FSR as well as additional spur roads and trails, some of which were rehabilitated.

Drainage from majority of Block 2 is towards Garrity Creek to the southwest, while drainage from the eastern portion is towards the south onto the face unit east of Garrity Creek (refer to the drainage divide on Figure 3). For the purpose of this assessment Garrity Creek has been assumed fish bearing. Stability and erosion control prescriptions have been made based on the downstream water resources, and because of the downstream domestic water use the prescribed level of works would not be changed even if Garrity Creek were to be proven non-fish bearing.

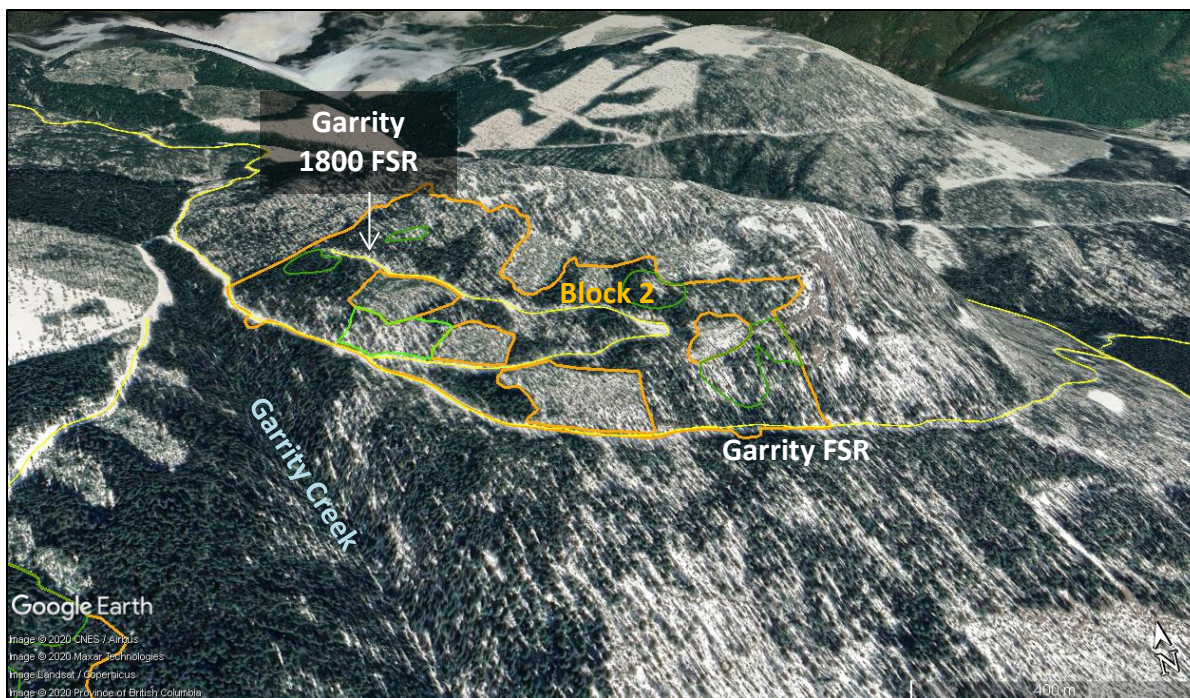


Image 4: oblique aerial view north at Block 2 using Google Earth imagery dated March 17, 2020. The proposed block boundary is shown in orange, WTRA and reserve area boundaries in dark green and light green respectively, and existing roads in yellow. Note the existing patch cuts within and immediately upslope of the block.

The lower to middle elevations within the block have been mapped as stable (Class II and III) by the TSIL C terrain stability mapping. Slope gradients within this area are primarily gentle to moderate gradient (typically 15% to 40%), underlain by a till veneer to blanket (typically 1 m to 2 m thick, but ranging from 0 m to 3 m), with a uniform to slightly irregular surface configuration. The typical till is comprised of compact to dense silty sand with some gravel, trace cobbles, boulders and clay, and a CFC of 20% to 25%. Soils are moderately well drained to well drained. Steeper terrain is generally limited to isolated areas of short slopes (15 m to 35 m length) with gradients of 45% to 60%. The proposed cable harvest area in the southeast portion of the block consists of an area extending 25 m to 170 m upslope of Garrity FSR where slope gradients are typically 50% to 65% (up to 75% in the upper portion near the eastern boundary), and includes two broad dry gullies. Localized bedrock outcrops are present among the well drained till mantle on this slope, with no signs of instability. An old trail is also present on this slope, but where observed in the field it was overgrown, out-sloped, and approximately 3 m wide with no evidence of significant runoff interception or redirection. Steeper terrain that includes a significant extent of exposed bedrock is present within the WTRA upslope of the cable harvest area.

Approximately 4.5 ha of the upper elevation, northwest portion of the block and 0.5 ha of the easternmost block area (near FC2 and FC3) are situated within a potentially unstable (Class IV) polygon that extends upslope to ridge top. Slope gradients within these portions of the block range from gentle to moderately steep, in contrast to the primarily steep rocky terrain upslope of the block. Surficial material is primarily a till veneer to thin blanket, with colluvial cobbles and boulders downslope of moderately steep to steep rocky slopes. There is one steep slope between lower gradient benches, located south of FC8, that is 70% to 80% gradient and 30 m in length

with bedrock bluffs (diorite) and a colluvial veneer, including talus. Within the small portion of the eastern harvest area located in the Class IV polygon, the lower harvest boundary follows a rocky ridge diagonally upslope, and in-block slope gradients are typically 50%, becoming 65% gradient within 15 m of the upper harvest boundary. Surficial materials in this eastern area are well drained till and colluvial veneers with bedrock bluffs 1 m to 2 m high. No signs of recent instability were observed within the proposed block.

4.2.1 Existing Roads

Garrity FSR is a long-term permanent road maintained by BCTS. A drainage review of the road was completed as part of the assessment for the proposed upgrade and extension of Garrity 1800 FSR, taking into consideration the planned development of Block 2 (SCL Project #19-1508, and Project #20-1508 for the associated post-construction field review).

In some areas along Garrity FSR evidence of significant seasonal flow was observed downslope of culvert outlets due to relatively long ditch runs, or from runoff forced onto the road bed due to bedrock obstructing the ditch. While these situations were not currently causing any instability, seven ditch relief culverts were added along Garrity FSR in the spring of 2020 in the vicinity of Block 2, taking into consideration the proposed road construction and harvesting upslope. The intent of the additional culverts is to disperse runoff as much as practical given the sensitivity of the terrain downslope. These culverts are located at PM100, PM44, PM94, PM40, PM71, PM92 and PM90, as shown on Figure 3.

Garrity 1800 FSR is an existing road that was upgraded and extended by a length of 775 m by BCTS in the spring of 2020. The road begins at 1100 m elevation with level to rolling grades over the initial 225 m, then ascends to the switchback. The road continues towards the northwest with mostly favourable grades to the POT at approximately 1185 m elevation.

4.2.2 Proposed and Existing Trails

A proposed skid trail continues upslope from the POT of Garrity 1800 FSR (refer to Figure 3). The proposed trail ascends the northwest portion of the block by following gentle to moderate gradient terrain, below some steeper rocky sections.

There are two main existing trails present within the block, beginning near the switchback of Garrity 1800 FSR, that ascend to the northwest and northeast. Two additional spur trails begin from the trail heading northwest. In most areas, the trails are frequently outsloped and are not presently redirecting runoff (refer to Image 5); however, use of these trails by heavy equipment during harvesting could alter the present drainage patterns. Refer to the specific recommendations in Section 5.3 regarding recommended deactivation of existing trails if used during the harvesting of Block 2.



Image 5: looking southwest, down the existing trail in the northeast portion of Block 2. Outsloping of the trail presently prevents the significant redirection of runoff down the steep grade.

4.2.3 Downslope

Downslope of Block 2 and Garrity FSR to the west-southwest is the gully sidewall approaching Garrity Creek. The gully sidewall ranges from approximately 50 m long at the north end of the block, to 200 m in length at the south end, and has been mapped as unstable (Class V) by the TSM. This moderately steep to steep gully sidewall typically ranges from approximately 50% to 70% gradient, but is between 75% and 90% gradient in some sections. The surficial material on the sidewall is primarily thick till that is typically moderately well drained with localized imperfect drainage and seepage. The larger gully sidewall has many smaller gullies on it, and is subject to some gully erosion processes including small to medium sized debris slides, slumps, and toe slope erosion (refer to Image 8 on the next page). Several debris slides within the range of 50 to 100 years old based on vegetative indicators were identified downslope of the northwest portion of Block 2, as well as a smaller debris slide estimated to be only 10 to 20 years old. These debris slides typically have headscarps 5 m to 10 m wide and 1 m to 2 m deep. Some of these past landslides appear to be naturally occurring, but some are likely associated with past occurrences of significant redirected runoff from previous upslope forest development.

Where Garrity Creek was observed in the field near 1100 m elevation the channel gradient is 10% to 17% gradient, with commonly a 5 m to 10 m wide floodplain in the gully bottom (refer to Images 6 and 7). No signs of debris flows were observed within Garrity Creek at this site despite impact from the gully side wall failures upstream.



Images 6 and 7: looking downstream (left) and upstream (right) at the gentle gradient Garrity Creek within the broad gully bottom near 1100 m elevation, downslope of the northern portion of Block 2.

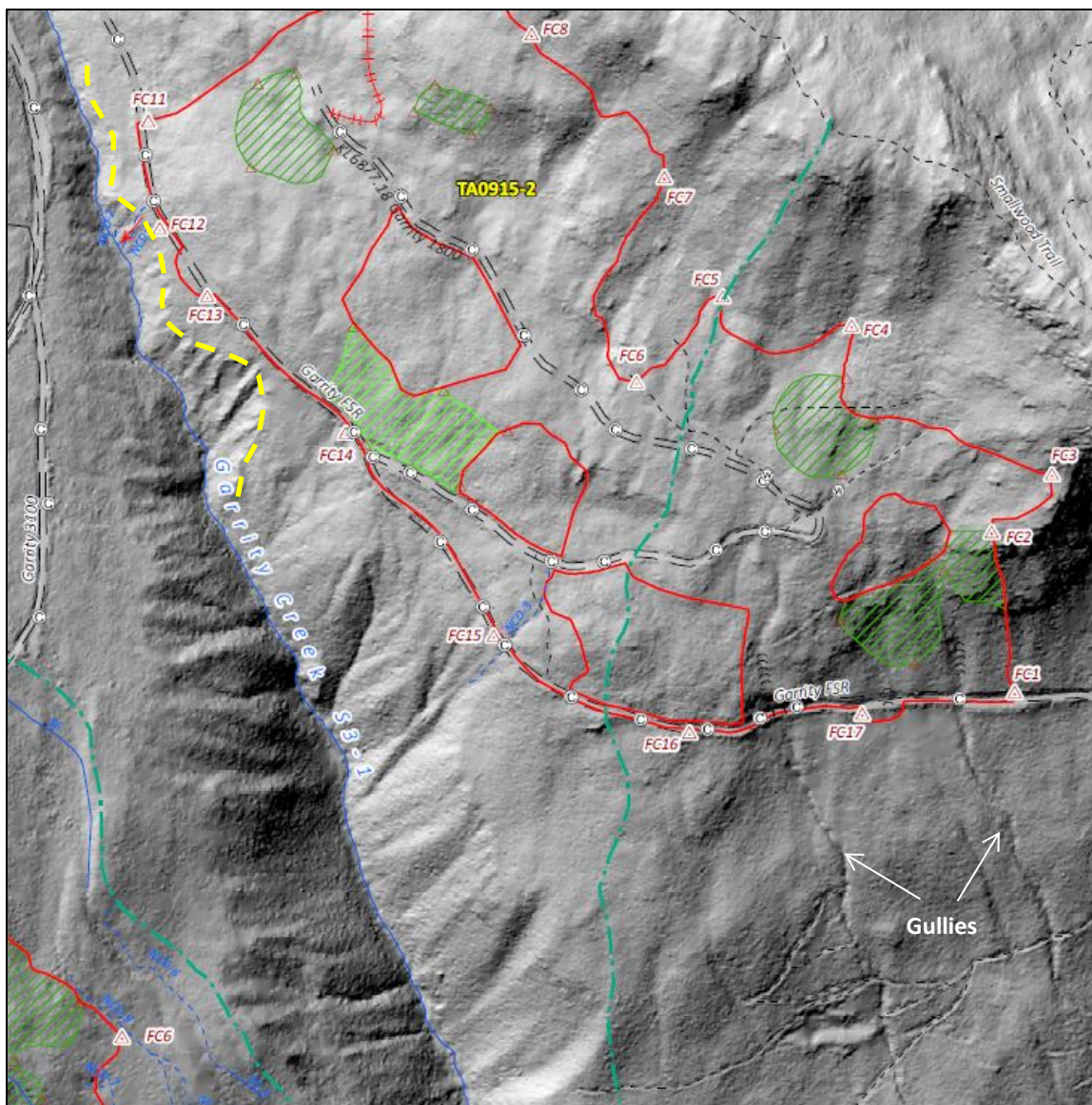


Image 8: LiDAR hillshade image showing the gullied terrain on the sidewall of Garrity Creek downslope of Block 2, as well as the gullies downslope of the eastern portion of the block. The green dashed line denotes the drainage divide between Garrity Creek and the face unit to the east. The dashed yellow line in the upper left of the image denotes the slope break where multiple headscarps are present from landslides that have occurred in the 50 to 100 years on the sidewall of Garrity Creek. Note the multiple roads and trails crossing the gully downslope of the area between FC16 and FC17. Actual culvert locations on Garrity FSR differ slightly from culvert locations shown on the image.

Garrity Creek remains in a well-confined gully downstream of Block 2 prior to the confluence with the Kootenay River. Based on the available LiDAR data, the Garrity Creek channel gradient averages 23% from 1100 m to 1000 m elevation, 30% from 1000 m to 900 m elevation, 22% from 900 m to 800 m elevation, 26% from 800 m to 700 m elevation, and 21% from 700 m to 640 m elevation at the Beasley Road crossing approximately 80 m upstream of Highway 3A (~1600 m slope distance between approximately 1100 m elevation and 700 m elevation within the gully polygon classified as unstable by the TSM). A final steeper gradient reach (> 60%) exists between Beasley Road and the rail line adjacent to the Kootenay River. There is no significant fan at the valley bottom, and no private residences situated within the gully. A 1200

mm culvert protected by three steel posts, as well as a 1000 mm overflow culvert is located at Beasley Road, with the road grade located a few metres above the channel at the uphill side of crossing. A 1200 mm (possibly 1400 mm) culvert is located at the Highway 3A crossing with a similar steel trash rack as well as a roughly 3 m vertical back up perforated intake spout connected to the culvert in case of blockage. The highway grade is located approximately 8 m vertical above the gully bottom at the uphill side of the road fill.

Garrity Creek has 11 water licences for domestic consumptive and irrigation uses from four POD's. The nearest POD is located at approximately 710 m elevation and 300 m upstream of Beasley Road (PD28315, for domestic purposes).

The face located east of Garrity Creek and downslope of Garrity FSR consists of predominantly moderate gradient terrain with slope gradients typically ranging from 25% to 50% for the majority of the approximately 1100 m distance to Beasley Road. Localized areas of moderately steep to steep gradient terrain (up to approximately 80%) appear to be associated with near surface bedrock or occur on the sidewalls of two gullies located on the middle to lower slope. This terrain has been mapped as stable by the available TSM (Class II and III). A few gullies exist on this slope, with one beginning within the western portion of the cable harvest area of Block 2, between FC16 and FC17, and continuing in a southerly direction to valley bottom (refer to Image 8 above). This gully does not contain a stream near the Garrity FSR, but does contain Victoria Brook with one POD approximately 900 m south of the lower harvest boundary (PD28317 with three licences; two for domestic use and one for irrigation). A residence is located approximately 60 m downslope of the mapped POD PD28317 location on an excavated bench.

The gully located between FC16 and FC17 was traversed for a distance of 400 m downslope of Garrity FSR across an area with multiple old roads and trails, many of which are overgrown. The roads and trails branch from a road extending west from the Smallwood FSR switchback at 890 m elevation and appear to be associated with mineral exploration in the area. The gully downslope of Block 2 is typically 1 m to 2 m deep, with gradients ranging from 28% to 50% and intermittent signs of seasonal flow. There is no apparent deposition of landslide debris such as levees along the margins of the shallow gully in an area of reduced gradient near 1000 m elevation; however, slightly irregular terrain in an area of significantly reduced confinement at approximately 940 m elevation may be a result of deposition from a historic debris flow (hundreds to thousands of years old). Based on observations from the length of gully traversed, past erosion may be a result of ongoing gully processes over time or a singular debris flow long ago and the gully does not appear to be susceptible to periodic debris flows or significant erosion events. There are three road/trail crossings of the gully, two of which redirect seasonal flow out of the gully due to steep trail grades and no drainage structures (e.g. culverts or waterbars). The more obvious redirection occurs at the lowest crossing, down the grade towards the southwest for approximately 35 m before runoff appears to disperse onto uniform, moderate gradient terrain downslope due to a slight outslope of the road surface. No apparent instability was observed associated with the trail crossings or redirected runoff. These trails, located 300 m to 400 m from the block are not expected to be affected by any significant changes to drainage patterns resulting from the development of Block 2. Furthermore, the amount of runoff contributed by the ditch on Garrity FSR to this gully will be reduced with the addition of ditch relief culverts recently installed up the grade at PM44 and PM100.

Other similar gullies exist on this face unit to the east, and where observed in the field these

gullies appeared inactive and likely a result of past gully erosion processes on the order of hundreds to thousands of years old. Several other POD's are located downslope of the eastern portion of Block 2 at similar or greater distances as PD28317, none of which have surface flow connectivity to the block based on field observations of surface flow patterns along Garrity FSR and downslope.

4.2.4 Landslide Hazard and Partial Risk Analysis

Taking into account the observations presented above, along with the regional terrain stability considerations presented in Section 3.2, the likelihood of a hazardous in-block landslide attributable to the proposed harvesting of TA0915-2 is estimated to be Very Low. Landslides attributable to harvesting on similar terrain using similar methods within the region are very rare following generally accepted good development practices.

- **P(H) harvesting related, in-block: VL**

The proximal terrain downslope of Garrity 1800 in the 200 m to 250 m distance between the upper road section and the lower harvest boundary of Block 2/Garrity FSR within the Garrity Creek drainage area is generally stable and not likely to be sensitive to small changes in runoff patterns. Along the Garrity 1800 FSR the planned drainage control and lack of expected seepage or surface water features crossed limits the potential for significant redirected runoff, despite the predominantly continuous favorable road grades. Downslope of Garrity FSR the terrain becomes more sensitive, with evidence of past gully sidewall instability as described in Section 4.2.3. Small to medium sized gully sidewall failures have occurred along this lower slope in the past century, at least one of which appears related to road drainage, but the majority likely predate the road. Similar failures should be expected to occur in the future, but the frequency and magnitude of failures is not expected to significantly increase following the proposed development of Block 2. Seasonal runoff along Garrity FSR may increase following harvesting due to the reduced canopy resulting in increased snow accumulation and more rapid spring melt on this mid-elevation southwest aspect. However, the additional drainage control installed in the spring of 2020 along the existing Garrity FSR will reduce the amount of concentrated runoff affecting the more sensitive gully sidewall adjacent to Garrity Creek in comparison with the previous condition. As a result, taking the above factors into consideration the incremental increase in the likelihood of a hazardous downslope drainage related landslide within the Garrity Creek drainage area following the development of Block 2 is estimated to be Low.

- **P(H) downslope drainage related, Garrity Creek drainage: L**

In the event of a downslope drainage related landslide on the gully sidewall of Garrity Creek, it is most likely to be a small to medium sized (200 m^3 to 1000 m^3) debris slide or debris avalanche based on comparison with past landslides on this slope. Due to the generally consistent moderately steep slope gradient on the gully sidewall, such an event would likely result in an impact to Garrity Creek that would deliver an input of both fine and coarse debris to the channel causing temporarily elevated turbidity at and downstream of the point of impact. Some localized changes to channel morphology from the input of coarse material and woody debris could also occur. Due to the gentle channel gradients within this portion of Garrity Creek and typically broad gully bottom, a debris flow is unlikely to initiate, as indicated by landslides that have occurred on the gully sidewall and reached the Garrity Creek channel in the past century. The likelihood of a debris flow initiating and continuing downslope to reach POD PD28314 or further downslope elements at risk is substantially less than the likelihood of a hazardous

landslide initiating. Under adverse conditions, it is assumed that temporarily elevated turbidity levels could affect water quality in Garrity Creek, but a significant impact to the POD system by a more destructive debris flow is highly unlikely. In the case of adverse effects to water quality in Garrity Creek, temporarily elevated turbidity could result for a period of weeks with reoccurring turbidity during periods of high runoff for a few years following the event due to erosion of the landslide surface and remobilization of sediment in the stream. As a result, the partial risk to water quality and other downslope elements at risk within the drainage area of Garrity Creek are estimated to be:

- **P(HA_{water quality in Garrity Creek}) downslope drainage related: L**
- **P(HA_{POD infrastructure}) downslope drainage related: VL**
- **P(HA_{private land}) downslope drainage related: VL**
- **P(HA_{valley bottom elements}) downslope drainage related: VL**

The face unit to the east of the Garrity Creek drainage consists of some steeper slopes between Garrity 1800 FSR and Garrity FSR. As discussed in the Section 4.2, the steepest short pitches are associated with bedrock outcrops, and no signs of instability were observed in the field; however, this terrain would be sensitive to significant changes in runoff if affected. The likelihood of significant redirected runoff affecting this in-block terrain is limited considering the planned drainage control, lack of seepage or water features intercepted, and a high point planned in the Garrity 1800 FSR road grade near the Garrity Creek drainage divide.

The terrain downslope of Garrity FSR and Block 2 on the face unit to the east of Garrity Creek is mostly moderate gradient and uniform for at least 150 m, with isolated steeper areas on gully sidewalls or associated with bedrock outcrops on open slopes. This terrain is typically less sensitive than the steeper terrain present upslope of Garrity FSR. Similar to Garrity 1800 FSR, the likelihood of significant redirected runoff affecting this downslope terrain is limited considering the planned drainage control (including the additional culverts described in Section 4.2.1) and moderately well drained to well drained soils and lack of water features intercepted.

As a result, the incremental increase in the likelihood of a hazardous downslope drainage related landslide on the face east of the Garrity Creek drainage area following the development of Block 2 is estimated to be Low.

- **P(H) downslope drainage related, east of Garrity Creek drainage: L**

In the event of a downslope drainage related landslide on the face unit east of the Garrity Creek drainage, it is most likely to be a small sized (200 m³ to 500 m³) debris slide or debris avalanche based on comparison with past landslides in the region on similar terrain, and considering local conditions. There is a shallow gully that extends downslope south of the Garrity FSR to valley bottom in this area as discussed in Section 4.2.3. For comparison, where previously redirected runoff on the Smallwood FSR has caused small landslides to impact similar gullies on this face unit to the east, larger debris flow events did not initiate or continue to valley bottom. Considering these local observations and the extent of gentle to moderate gradient terrain with areas of minimal gully confinement, the likelihood of a debris flow initiating within or downslope of Block 2 and continuing downslope to reach private land or the POD location is substantially less than the likelihood of a hazardous landslide initiating. Under adverse conditions, it is assumed that temporarily elevated turbidity levels could affect water quality in

Victoria Brook, but a significant impact to the POD system or private land and residence by a more destructive debris flow is highly unlikely. In the case of adverse effects to water quality in Victoria Brook, temporarily elevated turbidity could result for a period of weeks with reoccurring turbidity during periods of high runoff for a few years following the event due to erosion of the landslide surface and remobilization of sediment in the stream. As a result, the partial risk to water quality and private land on the face unit east of Garrity Creek are estimated to be:

- **P(HA_{PD28317 on southeast aspect face}) downslope drainage related: L**
- **P(HA_{private land}) downslope drainage related: VL**
- **P(HA_{private residence}) downslope drainage related: VL (orders of magnitude lower than upper limit)**
- **P(HA_{valley bottom elements}) downslope drainage related: VL (orders of magnitude lower than upper limit)**

4.3 TA0915-3

Block 3 (planning number SMA-017) is 59.2 ha gross area in size, with 44.3 ha of net merchantable area with a partial cut silviculture system. Proposed harvest methods in the block include conventional ground based (27.1 ha), modified ground based (hoe chuck, 4.4 ha), skyline (10.9 ha, primarily in the southwest portion of the block in order to yard long distances upslope) and cable (1.8 ha). There are four reserve areas totaling 4.4 ha in size in the eastern portion of the block where it is understood that Douglas Fir Beetle impacted stems may be extracted at the discretion of the TSL holder. Garrity 3100 FSR will provide the primary access to the block, although timber from the northern most portion of the block is planned to be skidded upslope to Garrity FSR, which follows part of the upper harvest boundary (refer to Image 9 and Figure 3).

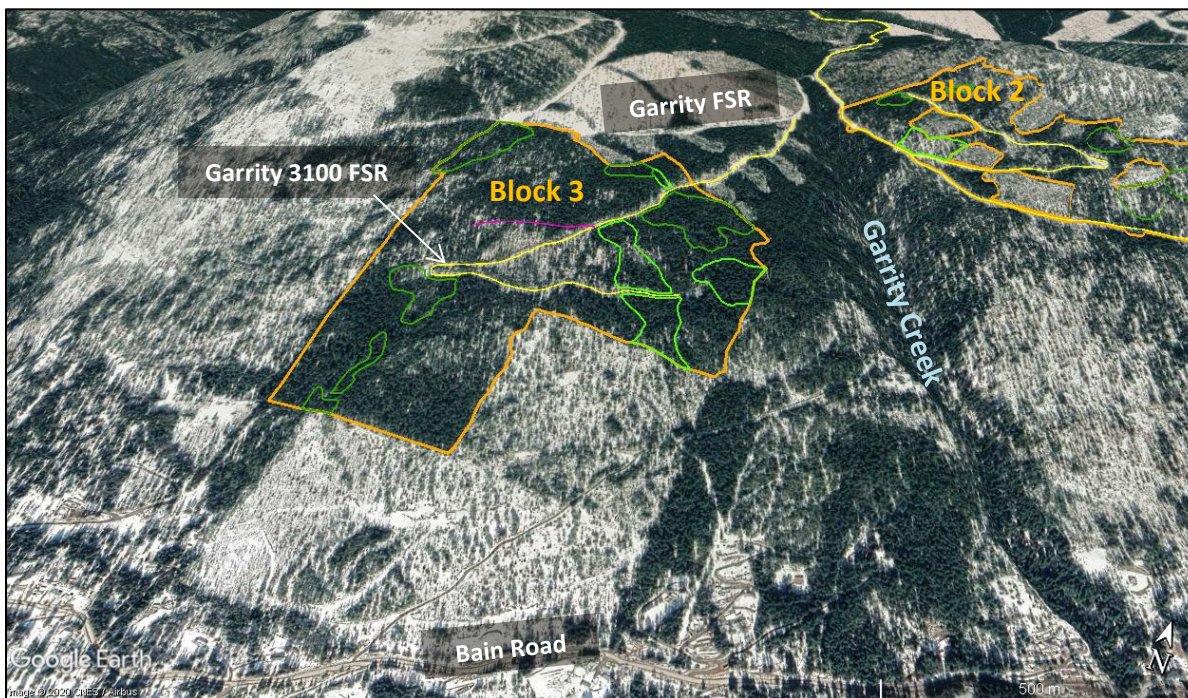


Image 9: oblique aerial view northwest at Block 3 using Google Earth imagery dated March 17, 2020. The proposed block boundary is shown in orange, WTRA and reserve boundaries in dark green and light green respectively, existing roads in yellow, and the proposed Garrity 3110 road in pink.

The proposed cutblock is located on a south to southeast aspect slope between approximately 850 m and 1185 m elevation on the face unit west of Garrity Creek. The Falls Creek Community watershed is located immediately west of Block 3, as shown on Figure 1. The recent hydrologic assessment completed for the proposed development (Statlu 2019) confirms that there is no harvesting or new road construction planned within the Falls Creek Community watershed, although a recent update by the British Columbia Geographic Warehouse to reflect refinements to the boundary using the LiDAR data acquired by BCTS indicates a spatial overlap in the mapping of less than 0.2 ha. No further consideration to the Falls Creek Community Watershed is considered necessary in this assessment given the very minor overlap in mapping, the lack of concern identified in the hydrologic report, and the lack of terrain stability or soil erosion concerns associated with harvesting along this watershed boundary.

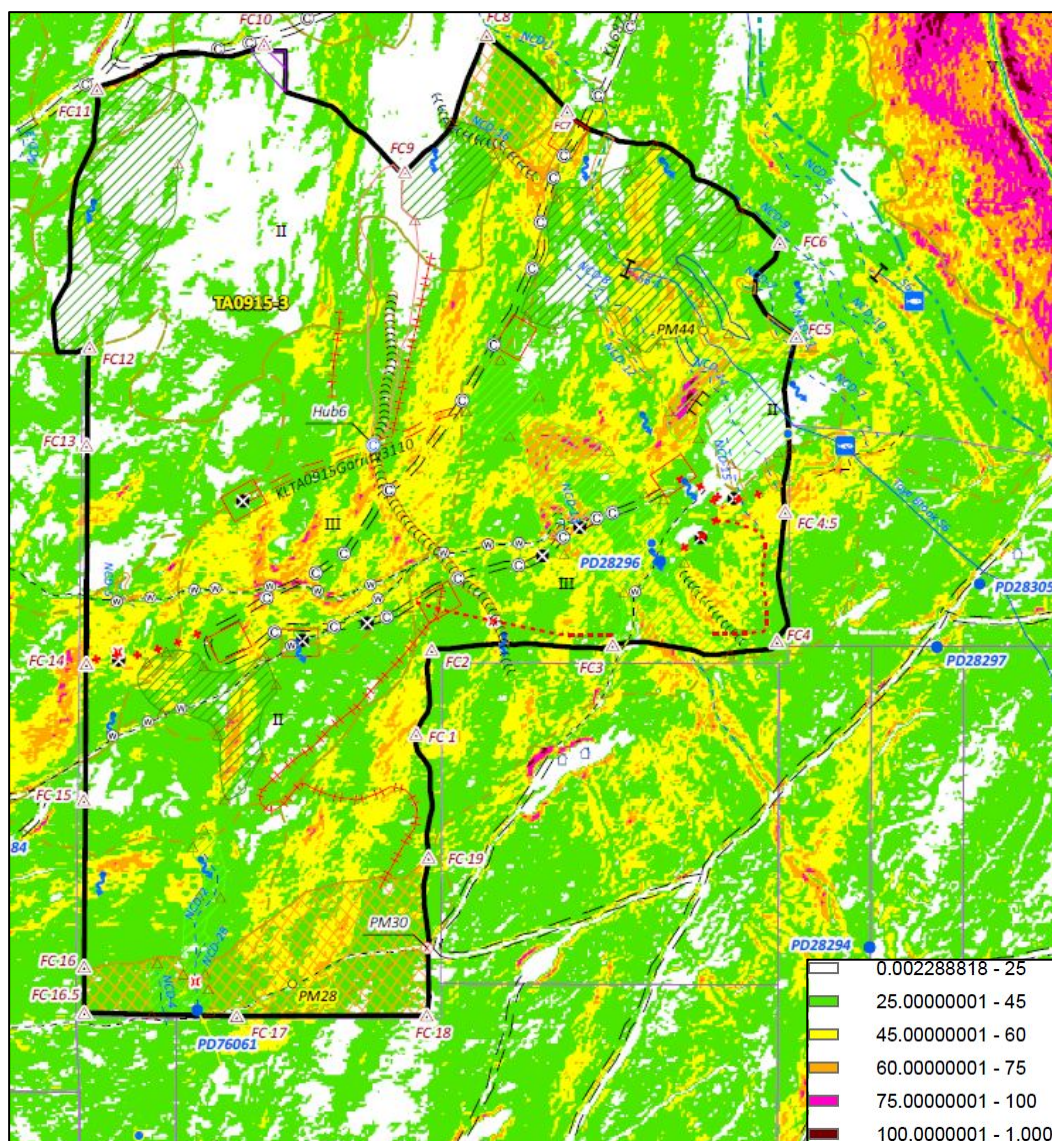


Image 10: LiDAR slope themed image of Block 3. Colour shaded areas depict slope gradient ranges as shown by the legend in the lower right. Note the areal extent of terrain less than 25% and 45% gradient (white and green respectively) within the block and downslope.

The TSIL C terrain stability mapping indicates the block is situated on terrain mapped as stable (class II and III). Some of these terrain polygons also include proximal areas of the private land directly downslope, but for the most part the downslope terrain is outside of the TSM project boundary.

The upper portion of the proposed cutblock consists of large areas of gentle to moderate gradient terrain (typically 15% to 35%; refer to Image 10 above). This occurs upslope of a northeast-southwest trending line between approximately FC8 and FC14. Short, steeper slopes within this area occur primarily as a result of a north-south oriented bedrock ridge west of FC9.

The remaining portion of the block downslope of the area described above consists of benched terrain resulting from variable slope gradients over distances of 30 m to 70 m. Within the conventional harvest area, gradients of 25% to 40% are common, with occasional gentle benches as well as slopes of 40% to 60%; small areas of steeper terrain are reserved. The cable harvest areas typically have slope gradients of 50% to 65% while the skyline harvest units are more typically 40% to 50% gradient with short slopes to 65% gradient.

The surface has a uniform to slightly irregular configuration that is incised by occasional swales and gullies. The gullies are typically 2 m deep, except within the southeast corner of the block between approximately FC3 and FC4.5 where they are up to 5 m deep. These larger gullies end or transition to shallow swales on lower gradient terrain near the lower harvest boundary, with the exception of one gully that continues downslope for at least 275 m towards POD PD28294 (Wilkins Brook) and residences further downslope. An NCD is present within the 2 m to 3 m deep, 35% gradient gully immediately downslope of Block 3. To limit the potential for the proposed development to adversely affect stability or water quality within this gully, the entire portion of the gully within the block was included within a proposed reserve area following the field assessment, as shown on Figure 3.

The surficial material in the block is predominantly a thick blanket of till with a typical composition of compact to dense silty sand with some gravel, trace cobbles, boulders and clay and a CFC of 20% to 25%. Thinner materials are locally present, more commonly in the western portion of the block at slope breaks or ridge features, and consist of a mix of till and colluvium, with higher coarse fragments contents (up to 40% to 50%). Soils are typically moderately well drained to well drained; however, localized areas of imperfect drainage are present throughout the block as indicated by seepage and wet site indicator plants such as wild ginger. Some of the swales and gullies within the harvest area have short sections with seasonal flow that have been mapped as NCDs. More extensive areas of imperfectly drained soils are present on gentle gradient terrain within a reserve and WTRA in the eastern portion of the block. There are also numerous watercourses that are variably confined within the eastern portion of the block that have primarily been reserved or included in WTRAs. Machine free zones have been designated and flagged in the field along all sections of watercourses that lie within the harvest area. Reserve areas are also treated as machine free zones; however, it is understood that machine use may occur within reserve areas to extract Douglas Fir Beetle impacted stems if suitable rationale is provided and machine impacts can be effectively managed.

There are two licensed POD's for domestic use located within the block. In the southeast, PD28296 (Ellis Spring) consists of a covered dug well with a buried waterline extending to a private residence located approximately 245 m to the southwest (refer to Image 11). There is no surface flow input to the POD, limiting the potential impact of the proposed harvesting on water

quality in terms of potential erosion and sediment delivery. The area surrounding the POD and extending 275 m upslope has been reserved from the harvest area. As identified in the TSA and Soil Erosion Assessment of Garrity 3100 FSR, of greater concern would be the effect of the proposed road construction on shallow subsurface flow. In order to reduce the potential for significant changes to subsurface flow in proximity to the POD, the alignment has been designed in a way to take advantage of an existing trail as much as practical, reducing the amount of cut required.



Image 11: Looking downslope at the covered well of licensed POD PD28296, located in a gully within Block 3, approximately 70 m downslope of the final section of Garrity 3100 FSR.

The second licensed POD within the block is located in the southwest portion, near FC17 (PD76061, Picton Spring); however, no signs of any water intake or related infrastructure (e.g. waterline) were observed during the TSA field assessment or during layout within this area. The mapped location of the POD is in line with NCD-2 that is variably confined on gentle to moderate gradient terrain within the lower harvest area. The area surrounding NCD-2 as well as the smaller NCD-4 has been excluded from the harvest area, within two WTRAs, except for a narrow corridor with a proposed skid crossing to provide machine access across NCD-2. NCD-2 crosses an existing trail immediately downslope of the block at a low point in the grade that is scoured from seasonal flow. The adjacent NCD-4 crosses the same trail at a more subtle low point.

Stream S6-1 flows through the eastern portion of the block and continues to two POD's licensed for domestic use situated 270 m and 420 m distance downstream of the lower harvest boundary (Toye Brook, PD28305 and PD28302). Within the block, the stream is largely within a reserve and WTRA, except along a 40 m length where repeated crossing will be required to bring timber felled from the area near FC5 and FC6 to the landing at the POT of Garrity 3100 FSR (refer to Image 12). Short sections of the tributary NCDs to this stream are also present within the upper harvest area (NCD-1 and NCD-16). Refer to the specific recommendations in Section 5.3 regarding crossings of the stream and NCD tributaries. As noted above, machine free zones have been designated along all watercourses (including NCDs) within the harvest area. A machine free zone has also been designated along S6-1 within the reserve area (which is already treated as MFZ) to emphasize the additional consideration required in working around this stream due to the connectivity to domestic PODs.

A traverse of Toye Brook from the water intake of PD28305 was completed by SCL in September 2012 as part of a TSA for an upslope block (SCL project #12-923); the following observations and interpretations are primarily based on that assessment, with additional observations from field traverses completed in 2019.



Image 12: looking northeast across the shallow gully containing S6-1 (Toye Brook). This portion of the stream is within the proposed harvest area and has direct surface flow connectivity to domestic water intakes downstream.

Downslope of Garrity FSR and upslope of Block 3 the southernmost tributary NCD of Toye Brook crosses a gentle bench with thicker soils that are moderately well drained with no visible channel in a broad swale, although surface flow connectivity is possible during peak flow. This swale becomes better defined on moderate gradient terrain within the upper portion of Block 3 and is included in a small reserve area (NCD-16 on Figure 3), to where it is joined by the southern end of a man made trench at approximately 1060 m elevation (~50 m downslope of Garrity 3100 FSR). This man-made trench containing the northern tributary NCD of Toye Brook (NCD-1 on Figure 3) is crossed by Garrity 3100 FSR just outside of the block and trends diagonally across the slope within the block in a roughly north-south orientation. It is typically 1 m to 2 m deep with 15% to 34% channel gradients, and is filled with abundant small woody debris but lacking in older large woody debris. Downstream of the confluence of the two NCDs the channel bed material transitions from organics and woody debris with some sand, silt and trace boulders and cobbles, to an S6 stream with a step-pool channel composed of gravel, cobbles, and boulders with woody debris and some sand. Channel gradients down to the water intake range from 38% to 60%, interrupted by a broad, imperfectly drained gentle gradient bench at approximately 970 m elevation where the channel is poorly confined within the reserve area in the eastern portion of Block 3. An unlicensed POD is present at the lower boundary of this reserve, between FC4.5 and FC5, that appears to be non-functioning. A small vegetated cone of material is located where the channel meets the gentle gradient bench, likely a result of significant upstream erosion at the time of excavation of the man-made channel section. No indications of debris flows or recent instability were observed within the channel between Garrity FSR and the downstream private land. At the water intake of PD28305 is a perennial S6 stream with variable channel confinement to a maximum of 0.5 m deep. The notable presence of wet indicator plants within 5 m of the stream channel on a relatively low elevation (approximately 900 m to 950 m) south aspect indicates a significant component of subsurface

flow. At the time of the assessment in 2012 the first surface flows were encountered just below 1060 m elevation (similar to observations in 2019), and by 1000 m elevation stream flow was estimated to be a similar rate to the water intake location at approximately 900 m elevation. This suggests that the majority of the low flow water at the water intake in Toye Brook is derived from groundwater emerging from the slope into the stream channel between approximately 1060 m and 1000 m elevation. Within the proposed block, this elevation range is mostly included in a WTRA, with the exception of the narrow harvest area between 1000 m and 1020 m elevation (PM44 on Figure 3). Refer to the Soil Erosion Assessment in Section 4.4 for a discussion of the potential for sedimentation within Toye Brook with respect to the proposed harvesting.

A special management zone has been marked in the field surrounding a swale and gentle gradient basin upslope of Hub 6 on Garrity 3110, extending upslope to the upper harvest boundary at FC9. A machine free zone has also been designated along the remainder of the swale through the block to the lower harvest boundary. The special management zone and machine free zone were added based on a recommendation following the initial field assessment as precautionary measures to minimize ground disturbance in the gentle basin and swale that continues through the block to private land downslope. Surficial materials in the gentle gradient basin consists of a moderately well drained till blanket, with no signs of shallow subsurface flow. The small basin feeds into the swale, which is typically 1 m to 2 m deep through the block, except for a gullied section 2 m to 3 m deep between the lower segment of Garrity 3100 to the lower harvest boundary. Seasonal flow is evident within the swale based on minor scour observed; seepage also emerges within the swale near the lower harvest boundary. The intention of the special management zone and machine free zone, in combination with the planned retention of the partial cut silviculture system, is to reduce the potential for increased or accelerated runoff within the swale following development. Refer to Section 5.3 for specific recommendations regarding the special management zone and machine crossings of the swale.

4.3.1 Existing Roads

Garrity 3100 FSR consists of an existing road to which an additional 1402 m in length was recently constructed by BCTS to facilitate harvesting within Block 3. The extension was previously assessed in a separate TSA and a field review of the final construction was completed (SCL Project #'s 19-1508 and 20-1508). Within Block 3, Garrity 3100 FSR descends with generally consistent adverse grades that are typically 7% to 12% and one switchback. An approximately 100 m long section of the road near the point of termination follows the route of an existing trail.

Garrity FSR is located upslope of the block, briefly following the upper harvest boundary near FC10. Drainage along this road was reviewed in detail by SCL in 2012 as part of the TSA and Soil Erosion Assessment for TSL A68929 Block 2 (SCL project #12-923 referenced in Section 2.1), located north of TA0915 Block 3. Additional culverts were installed by BCTS prior to the sale of TSL A68929 with the intent of reducing the length of ditch runs where cut slope seepage or ditch scour was noted, and also to better maintain historic drainage patterns within the Toye Brook drainage area. The road was briefly reviewed by SCL in July 2019 and drainage control appeared to be functioning as intended. Seasonal deactivation measures including back-up cross ditches and intermediate waterbars were in place and the ditch had been recently cleaned.

4.3.2 Proposed Garrity 3110 Road

Garrity 3110 is a proposed temporary licensee-construct road within the central portion of Block 3. The alignment has a consistent favourable grade over the majority of its length, ascending upslope of Garrity 3100.

The initial 75 m of the proposed road, from the POC to Hub 5, is on 50% to 60% gradient side slopes. Surficial material in this area is a moderately well drained till blanket estimated to be 2 m to 3 m thick. Side slopes ease within a broad gully at Hub 6 (no visible channel) and for the remainder of the road are typically 30% to 40% gradient. Material thickness west of the gully varies from 0.5 m to 2 m; some rock excavation may be required exiting the gully as a result of diorite bedrock near surface. Fractured diorite is occasionally present on the surface between Hub 10 and the POT at Hub 14. A proposed landing and tower setting is located at end of the proposed road, directly upslope of a 50% to 55% gradient slope. Refer to the Road Recommendations Summary Table in Appendix C for general and specific recommendations relating to road construction and rehabilitation.

Diorite bedrock observed along the western portion of the Garrity 3110 alignment is similar to the bedrock and colluvium observed along Garrity 3100 downslope. The absence of visible sulphide minerals, iron staining or other chemical alteration to the rock suggests there is limited potential for the exposure of acid generating rock in this area during construction. Where rock excavation is anticipated the lack of seepage expected or surface water connectivity between the alignment and downslope watercourses limits the potential for affected drainage, if any, to reach elements at risk (fish habitat or domestic water intakes).

4.3.3 Proposed Trails

Three designated skid trails, three yarder trails, and two backspars are proposed to facilitate harvesting within the block. The proposed temporary trails are primarily within the steeper, lower half of the block in contrast to the upper half where random skidding is more feasible or where greater options exist to locate temporary trails on primarily gentle gradient slopes. The proposed trails typically take advantage of the terrain to avoid steeper slopes or areas with exposed bedrock.

Three designated skid crossings have been incorporated into the harvest plan following the field assessment, as shown on Figure 3. The first is located at the proposed yarder trail extending west from the switchback of Garrity 3100 FSR, where it crosses a gully with an NCD upslope (NCD-5) and seepage downslope. The second recommended skid crossing is located near the lower harvest boundary where the proposed backspars trail crosses the mapped swale that continues downslope of the special management zone; additional crossings of this swale should be similarly managed as recommended in Section 5.3. The third recommended skid crossing is where the proposed yarder trail located southeast of the POT of Garrity 3100 crosses NCD-15.

Three additional skid crossings are proposed as discussed in Section 4.3 and shown on Figure 3. These crossings are not associated with designated trails, but are recommended where machine access is required across watercourses S6-1, NCD-1 and NCD-2 to facilitate harvesting.

4.3.4 Existing Trails

Old machine trails are present within the middle to lower elevations of the proposed cutblock and are identifiable on the LiDAR hillshade image (refer to Image 13).

One existing trail enters the block from private land near FC3, passes the shallow well and water intake of PD28296 and ascends to a switchback near the POT of Garrity 3100. Two trails are present east of the switchback on gentle ground while the main trail continues to ascend west across the block. Another spur descends from the main trail across the western portion of the block, crossing the harvest boundary north of FC15. In most cases these old trails are not currently redirecting runoff; however, it is likely occurring during periods of high runoff in some locations and there is potential for the trails to interfere with the intended drainage from culverts on the new section of Garrity 3100 FSR. As a result, waterbars or constructed swales at gully crossings were recommended in the TSA report for Garrity 3100 FSR to eliminate the potential for redirected runoff in the vicinity of the road. These drainage structures have been shown as existing on Figure 3 as they are to be installed by BCTS prior to the timber sale. Refer to the specific recommendation in Section 5.3 to maintain or restore these drainage structures during and following harvesting.

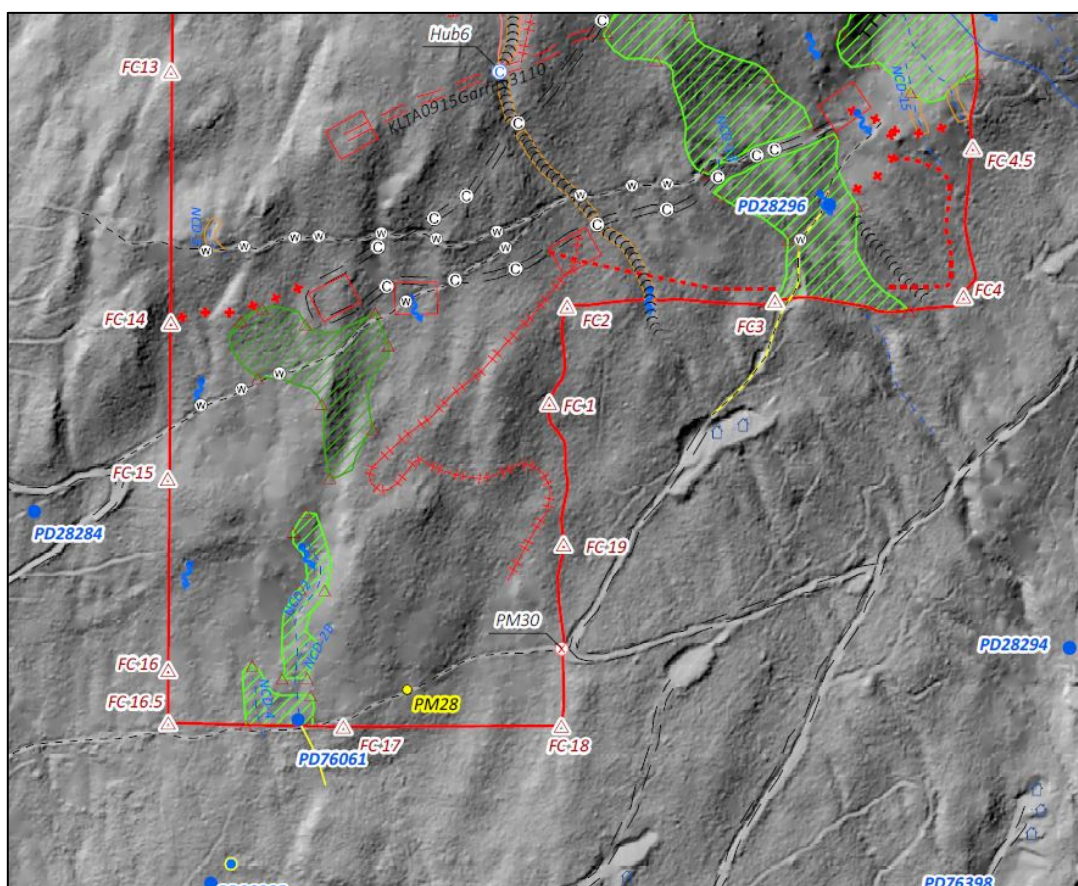


Image 13: LiDAR hillshade image showing the existing trails within the middle to lower elevations of Block 3 and downslope.

Another bladed trail is present within the lower harvest area that connects private roads east and west of the block. The eastern junction is located at a switchback on the private road (located at PM30 on Figure 3 and Image 13). There is a cross-ditch at the junction that serves two functions: to take ditch water from the steep grade of the private road and discharge it off the switchback, while also preventing any runoff along the trail from flowing onto and down the private road (refer to Images 14 and 15). The cross-ditch is shallow and has been partially filled with

transported sediment and as a result, some runoff escapes the cross ditch onto the private road. The existing trail has no ditch and there is noticeable erosion of the trail surface over the final 50 m from seasonal runoff that is redirected down the 10% grade prior to the junction with the private road. Most of the redirected runoff flows downslope just before the junction due to a subtle outslope; however, it appears that some of the redirected runoff continues to the road junction. Given the southerly aspect and mid-slope elevation, a localized increase in spring runoff following harvesting may occur which in turn could result in an increase in the amount of runoff redirected down the section of road within the block. Also, subtle drainage paths like this are easily disrupted, especially if this trail is used during harvesting. Refer to the specific recommendations in Section 5.3 for recommended improvement of the cross ditch at the road junction as well as additional waterbars along the trail to disperse runoff.



Image 14: looking northeast up the steep grade of the private road from the switchback immediately east of Block 3 (PM 30 on Figure 3).



Image 15: looking downslope at the shallow cross-ditch at the start of the trail that heads west from the switchback of the private road (PM 30 on Figure 3).

4.3.5 Downslope

Private land is present immediately downslope of the majority of the block, except for the easternmost portion (near FC5 and FC6) where some intervening terrain is present prior to the private land. The downslope terrain typically consists of gentle to moderate gradient slopes with few gullies or swales (refer to LiDAR imagery shown in Images 10 and 13). Surficial material is primarily a thick till blanket that is well drained to moderately well drained where observed on open slopes. The majority of the terrain extending several hundred metres downslope has been previously harvested, notably a large parcel south of FC4 and extending west to the north-south lot boundary west of FC17. Existing private roads and old trails can be seen on the hillshade model image presented in Image 13. There are no identifiable landslides on the private land as a result of the harvesting or presence of the existing roads and trails.

The most proximal private residences are located approximately 135 m downslope of the lower harvest boundary. Numerous additional private residences are located further downslope prior to Bain Road, Garrity Road, Beasley Road, and Highway 3A.

The first proximal residence is downslope of FC18, separated from the block by gentle to moderate gradient terrain (typically 35%) downslope of a subtle ridge feature that divides drainage from the block towards the east and west of the residence.

The second proximal residence is located downslope of the area between FC2 and FC3; terrain separating the residence from the block is predominantly moderate gradient (typically 35% to 45% gradient). A shallow swale (typically 0.5 m to 1 m, except briefly 2 m deep where the slope gradient increases slightly) continues from the block to the cut slope of the large excavated bench where the buildings are situated. The swale meets the cut slope approximately 10 m to 15 m west of the actual residence. The trail leading to this residence's water intake (PD28296) is on top of the large cut, ascending northeast. The swale is continuous for approximately 430 m within Block 3, originating within the special management zone described in Section 4.3. The gully within the lower harvest area transitions to a shallow swale with a notable area of reduced confinement at the lower harvest boundary where the swale turns southwest briefly and is poorly confined on the east. There is no scour or other signs of significant seasonal flow within the swale downslope of the block, in contrast to the swale or gully upslope within Block 3 where seasonal flow is evident in some sections based on the presence of minor scour.

As noted in Section 4.3, the gullies present within the area of moderate to moderately steep gradient terrain in the southeast corner of the block, between FC3 to FC4.5, end or transition to shallow swales on lower gradient terrain near the lower harvest boundary, with the exception of the gully that continues downslope for at least 275 m towards POD PD28294 (Wilkins Brook) and residences further downslope. An NCD is present within the 2 m to 3 m deep, 35% gradient gully immediately downslope of Block 3. Residences 50 m to 250 m downslope of the POD appear to be situated on excavated benches adjacent to the gully; the gully gradient and confinement decrease significantly within this area.

POD PD28285 (Husum Spring) is licensed for domestic use and is located 135 m downslope of the southwest corner of the block. There are two dug wells approximately 10 m apart, one covered and one mostly uncovered (refer to Image 16). There is no apparent surface flow input to the wells; wet site indicator plants are present on the gentle gradient bench between the two wells. POD PD28297 (Craft Spring) is licensed for domestic and irrigation uses and is located approximately 250 m downslope of the eastern harvest boundary.



Image 16: looking east at the uncovered well at PD28285, located approximately 135 m downslope of the southwest portion of Block 3. The photo was taken from the location of the covered well that is also present.

Several other POD's are located downslope of the block at a further distance, none of which have surface flow connectivity to the block based on field observations of surface flow patterns near the block.

4.3.6 Landslide Hazard and Partial Risk Analysis

Taking into account the observations presented above, along with the regional terrain stability considerations presented in Section 3.2, the likelihood of a hazardous in-block landslide attributable to the proposed harvesting of TA0915-3 is estimated to range from Very Low to Low. Landslides attributable to harvesting on similar terrain as the majority of the block area using similar methods within the region are rare following generally accepted good development practices. The Low rating applies to the isolated areas of moderately steep terrain.

- **P(H) harvesting related, in-block: VL to L**

Road prism landslides are unlikely to occur along the proposed Garrity 3110 temporary road when constructed using generally accepted good construction practices and favourable surficial material properties (e.g. free draining, non-cohesive). Taking into account the observations presented above and the regional terrain stability considerations presented in Section 3.2, the likelihood of a hazardous road prism landslide following conventional sidecast fill construction on the proposed temporary road is estimated to be Very Low to Low. The Low rating applies to the initial 75 m of the proposed road with slope gradients of 50% to 60% where wood supported fill has been recommended to improve fill slope stability and reduce the effort required for rehabilitation by reducing fill slope lengths.

- **P(H) road prism Garrity 3110: VL to L**

Hazardous downslope drainage related landslides in the region are rare on gentle to moderate gradient terrain similar to the majority of the downslope area. This type of terrain is generally not particularly sensitive to small changes in runoff regimes associated with upslope forest development when good practices are employed. Some drainage related landslides have occurred in similar situations if significant concentrated or redirected runoff is directed onto isolated areas of steeper downslope terrain, as shown by the small drainage related landslides in the vicinity of Smallwood FSR described in Section 4.1.2. These examples on adjacent terrain remained small in size and did not result in larger debris flow events or continue to valley bottom.

In general, there is limited potential for significant concentrated or redirected runoff affecting downslope terrain as a result of the proposed development, based on the:

- generally linear drainage patterns within the block on a face unit with no significant catchment areas where cumulating effects of harvesting and road construction are more likely to result;
- presence of reserves, WTRA's and special management areas in key areas intended to reduce the potential for increased surface flow or redirection of watercourses;
- planned drainage control including seasonal deactivation on Garrity 3100, as well as typically moderately well drained to well drained soils with only isolated areas of seepage anticipated;
- designated skid crossing of Toye Brook which is confined within a gully for the short section that is included in the harvest area; and

- high level of development supervision and post-harvest field reviews intended to ensure drainage patterns have been maintained.

As a result, considering the limited potential for significant concentrated or redirected runoff and the limited sensitivity of the downslope terrain, the likelihood of a hazardous downslope drainage related landslide following the development of Block 3 is estimated to be Very Low.

- **P(H) downslope drainage related: VL**

In the event of a hazardous in-block, road prism, or down slope drainage related landslide, based on comparison with past landslides in similar terrain configurations within the region, it is likely to be a small to medium sized (200 m^3 to 1000 m^3) debris slide or debris avalanche. A debris flow is less likely to occur due to the lack of continuous gully confinement with streamflow that is generally required to facilitate debris flow initiation and transport in similar situations. Where watercourses are present, there are gentle gradient areas without gully confinement that would most likely arrest a landslide. The potential for a damaging effect to the several downslope POD's and two proximal residences from a hazardous landslide is also very limited due to the discrete location of the elements, and considering the specific conditions surrounding these elements including slope profile. Due to the proximity of the private land to Block 3, an impact to the private land is conservatively assumed to be equivalent to the likelihood of the landslide initiating within the block near the lower harvest boundary or downslope. As a result, the likelihood of a spatial effect on all down slope elements at risk is estimated to be equivalent or less than the likelihood of a downslope drainage related landslide initiating:

- **P(HA_{private land}) downslope drainage related: VL**
- **P(HA_{private residences}) downslope drainage related: VL (orders of magnitude lower than upper limit)**
- **P(HA_{PD28296 and PD76061}) downslope drainage related: VL**
- **P(HA_{PD28305 and PD28302; Toye Brook}) downslope drainage related: VL**
- **P(HA_{PD29294; Wilkins Brook}) downslope drainage related: VL**
- **P(HA_{PD28285 and PD28297}) downslope drainage related: VL**

Risk ratings for the most proximal POD's have been presented based on shared characteristics where present (e.g. PD28296 and PD76061 are located within the block boundary). All other downslope POD's can be inferred to be less at risk due to the greater separating distances of gentle to moderate gradient slopes without continuous surface flow or gully confinement.

4.4 Soil Erosion Assessment

Soil erosion hazard criteria are based on the classification presented in Soil Erosion Hazard Criteria for Watershed Assessments in the Southern Interior-final report (Jordan 2000), assuming a moist climate regime. Presented in Appendix B are summary tables relating to the soil erosion rating system applied, which is primarily based on research completed in the Nelson Forest Region by the B.C. Ministry of Forests. An important note to make is the correlation between the specific ratings used in this report and the corresponding management implications of this specific system. Other soil erosion rating systems (for example, one used in terrain mapping) may have different management implications and therefore these ratings should not be directly compared with those using alternative systems, unless the differences in rating definitions and management implications are taken into consideration.

It has been well documented that the majority of soil erosion resulting from forest development is caused by roads and trails as opposed to timber harvesting. The criteria system used takes this into consideration by using soil depth (shallow soils will often have bedrock exposed for a portion of the cut slope and ditch line) and hill slope gradient (steeper side slopes generally require larger road cuts) in the hazard rating criteria table. Soil drainage is a key factor in determining soil erosion hazard and has a strong influence on the rating where drainage is imperfect or wetter. Matrix textures (relative proportions of sand, silt, and clay) as well as coarse fragment content (generally more significant than matrix textures) are also taken into account in addition to road grades.

In general, the till soils along the majority of the roads and trails within the development area can be susceptible to erosion based on the material properties. This is also the case for the sandy material (possibly ablation till or glaciofluvial material) along portions of the Smallwood 2000 FSR alignment in the northeast portion of Block 1. Where encountered, the colluvial soils are typically coarser textured, thinner, and better drained resulting in a road prism that is less susceptible to erosion. Based on the Jordan 2000 criteria, **the soil erosion hazard rating would be High to Very High for the road and trail sections through till and glaciofluvial materials, and primarily Moderate to High for the sections through colluvial materials.**

The primary areas of concern with respect to erosion and sediment delivery to watercourses are:

- NCD-3 within Block 2, where crossed by Garrity FSR and Garrity 1800 FSR, due to possible seasonal surface flow connectivity to Garrity Creek;
- Garrity 3100 FSR adjacent to and within Block 3 where the alignment crosses NCD-1 and NCD-16 that converge downslope and lead to domestic water intakes (Toye Brook);
- Bladed trails crossing S6-1 (Toye Brook) or its tributaries NCD-1 and NCD-16 within Block 3; and
- the proposed crossing of NCD-2 within Block 3 to provide machine access to the southwest portion of the block, 35 m upslope of the legal location of PD76061.

Efforts should be made to control erosion at the source as opposed to controlling sediment once erosion has occurred; in practice the latter is generally more costly and less effective. Erosion and sediment control measures should be focused where the potential for sediment delivery to watercourses is greatest, such as adjacent to watercourse crossings and where surface water features are in close proximity to roads and trails. In the event of erosion and subsequent sediment delivery to a watercourse, there is the potential for elevated turbidity levels to reach downstream resources including domestic water use.

Erosion and sediment control strategies have been recommended in the General and Specific Recommendations in Section 5 and in the Road Recommendations Summary Table in Appendix C, which should be implemented along with appropriate additional works which may be required based on conditions encountered during development. **Based on comparison with similar forest development in the region, and assuming preventative erosion and sediment control measures are implemented at the time of development according to the recommendations presented in this report, the residual likelihood of long-term significant soil erosion and sediment delivery resulting in elevated turbidity levels reaching downstream elements is estimated to be Low.**

It is important to note that the soil erosion hazard ratings presented consider long-term or chronic soil erosion. Adverse effects to domestic water quality from POD's, most notably in Toye Brook, could occur during and/or immediately following harvesting if adverse weather or ground moisture conditions are encountered and insufficient preventative measures are employed. A commitment by forest development personnel to manage runoff appropriately and implement preventative measures concurrent with harvesting will be necessary to reduce the potential for significant adverse effects.

5.0 RECOMMENDATIONS

The following recommendations are intended to reduce the likelihood of landslide initiation, erosion, and sediment delivery to watercourses and should be followed in order to maintain the risk ratings presented in this report.

5.1 Road Recommendations

Recommendations related to road construction, maintenance, and deactivation are included in the Road Recommendations Summary Table presented in Appendix C.

5.2 General Harvesting Recommendations

1. **Operations should be modified or suspended when there is abundant hill slope runoff occurring at the site**, which is likely to occur during times such as spring break-up or from prolonged heavy precipitation. This is intended to reduce the likelihood of concentrated or redirected drainage as well as erosion and sediment delivery.
2. **Machine use should be limited** to areas where excessive scour, rutting, or compaction is avoidable. This would generally restrict machine use from areas of moderately steep or steeper slopes as well as areas of wet, soft, or very loose soils. Some modified machine use (e.g. hoe-chucking) may be possible in these areas if excessive disturbance is avoidable.
3. **All natural drainage patterns** (including all NCDs and S6 streams as well as dry swales and gullies) should be maintained and left free of excess debris (slash or soil) that could result in a redirection of seasonal surface runoff.
4. **Excavated or bladed trail construction** should be minimized as practical, and avoided in areas of seepage or where shallow subsurface runoff is likely to be intercepted.
5. **All trails⁵** should be fully rehabilitated upon completion of use and concurrent with operations, ideally prior to the next spring freshet. If any trails are to overwinter then additional precautions should be taken including pulling back all watercourse crossings and any potentially unstable fill slopes, and installing frequent cross-ditches in order to limit the potential for redirected runoff.
6. **If stumping is prescribed**, the additional machine use should follow the recommendations above with the intent of limiting the potential for disturbance that could result in shallow subsurface or surface runoff interception, concentration, diversion, or acceleration. Stumping should be avoided in machine free zones.

⁵ "all trails" requiring rehabilitation include all bladed or excavated trails as well as any other machine paths that have resulted in the scouring of the ground surface which may result in the concentration and/or redirection of runoff. **Full rehabilitation** implies decompaction, re-contouring, constructing waterbars on the re-contoured surface where appropriate, and seeding with an appropriate seed mix, or replanting. This applies to all similar references throughout this report.

5.3 Specific Harvesting Recommendations

Block 1:

No specific recommendations.

Block 2:

1. Existing trails used during harvesting should be deactivated with frequent waterbars (e.g. 25 m spacing, and at all natural drainage features) to prevent redirected runoff.

Block 3:

1. Watercourse crossings with trails or machinery should be minimized as practical with the intent of reducing the potential for redirection or adverse effects to water quality.
2. Skid crossings (temporary drainage structures) should be installed at all machine crossings of watercourses, and other features as described in Recommendations 3 and 4 below. There are 6 proposed skid crossings located at: NCD-1, S6-1, NCD-15, NCD-2, downslope of NCD-5, and the mapped swale downslope of the special management zone, as shown on Figure 3.
3. A single designated skid crossing of S6-1 (Toye Brook) is recommended to access the harvest area east of the stream; the exact location can be determined by the timber sale licensee (the general location is at PM44 on Figure 3) considering practical harvesting constraints, access, and erosion and sediment control strategies. A single designated skid crossing, is also recommended across NCD-1 (tributary to S6-1) to access the small harvest area southeast of the NCD. NCD-1 and S6-1 have direct surface flow connectivity to domestic water intakes downstream, as a result, extra precautions to protect water quality are recommended at the crossings, and may include the use of geotextile fabric in conjunction with the temporary crossing structure (e.g. bundled logs) if considered beneficial for maintaining water quality.
4. Machine crossings of the mapped swale that continues downslope of the special management zone (e.g. the proposed backspar trail near the lower harvest boundary shown on Figure 3) should:
 - a. be minimized as practical;
 - b. have skid crossings installed; and
 - c. have no excavation within the gully bottom to avoid intercepting shallow subsurface flow.
5. Bladed or excavated trails are not recommended within the special management zone (SMZ) surrounding the broad swale and gentle gradient basin upslope of Hub 6 of Garrity 3110. It is also recommended to avoid repeated skidding along common routes within the SMZ to avoid soil compaction and to minimize ground disturbance.
6. Waterbars and constructed swales on existing trails within the block (as shown on Figure 3) should be maintained or restored as necessary during and following development, with the intent of providing effective long-term drainage control.
7. Existing trail within the lower harvest area:
 - a. improve the cross ditch at the start of the trail (PM30 on Figure 3), to prevent any runoff from the trail from flowing onto the private road and to maintain the continuity of the ditch line on the private road; and

- b. construct waterbars across the full width of the trail within Block 3 between the subtle high point near PM28 and the junction with the private road, a distance of ~150 m. Two or three waterbars of sufficient width and depth to disperse runoff from the trail surface while allowing for minimal disruption to any recreation use of the trail would be suitable given the lack of well-defined drainage features and moderately well drained to well drained soils. The intent of the waterbars is to disperse runoff that is presently redirected down the trail towards the private road.

5.4 Field Reviews

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

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

A post-harvest field review by a qualified registered professional (QRP) is recommended to ensure that natural drainage patterns have been maintained, that seasonal watercourses have not been impacted in a way that is likely to result in redirection or adverse effects to downstream water quality, and that the intent of the TSA recommendations are met.

6.0 CLOSURE

The discussions and recommendations presented above are based on a visual field assessment and additional information, which was reviewed at the time of the assessment. This report has been prepared for use by Atlas Information Management and British Columbia Timber Sales – Kootenay Lake Field Team, which includes distribution as required for purposes for which the assessment was commissioned. The assessment has been carried out in accordance with generally accepted geotechnical practice. Geotechnical judgment has been applied in developing the recommendations in this report. No other warranty is made, either expressed or implied.

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

Respectfully submitted,

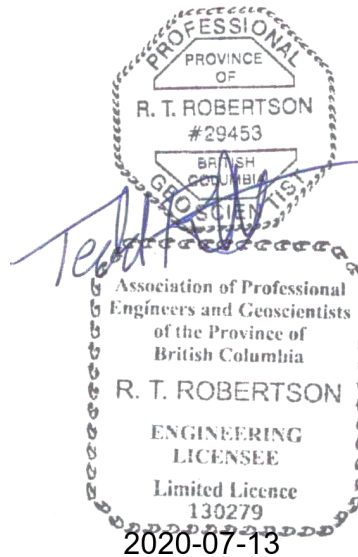
Sitkum Consulting Ltd.

Prepared by:

Prepared and Reviewed by:



Jeremy Major, P.Geo.
Geoscientist



Tedd Robertson, P.Geo. Eng.L.
Geoscientist

7.0 REFERENCES

- AFPBC/APEGBC 2010. Guidelines for terrain stability assessments in the forest sector. Association of Professional Engineers & Geoscientists of British Columbia (APEGBC), Burnaby B.C.
- B. C. Ministry of Forests, Lands, and Natural Resource Operations. 2016. Biogeoclimatic Ecosystem Classification Subzone/Variant Map for the Kootenay Lake Subunit, Selkirk Resource District, Kootenay/Boundary Region, 1:250,000 scale.
- Corominas, J. 1996. The angle of reach as a mobility index for small and large landslides. *Can. Geotech. J.* 33: 260-271. NRC Research Press (1996).
- Geertsema, M., Schwab, J., Jordan, P., Millard, T., and Rollerson, T. 2010. Hillslope Processes. Chapter 8 in *Compendium of forest hydrology and geomorphology in British Columbia*. Pike, R.G., Redding, T.E., Moore, R.D., Winker, R.D., Bladon, K.D. (editors.) B.C. Min. For. Range, For. Sci. Prog., Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops B.C. Land Manag. Handb. 66.
- Grainger, B. 2002. Terrain stability assessments in “gentle-over-steep” terrain of the southern interior of British Columbia. *in* Terrain stability and forest management in the Interior of British Columbia workshop proceedings, May 23-25, 2001 Nelson, BC. Jordan, P. and J. Orban (eds.) Res. Br., B.C. Min. For., Victoria, B.C. Tech Rep. 003.
- Hungr, O., McDougall, S., and Bovis, M. 2005. Entrainment of material by debris flows. Chapter 7 in *Debris Flow Hazards and Related Phenomena*. Jacob, M. and Hungr, O. (editors). Springer Praxis, Berlin. pp. 135-158.
- Hunter, G. and Fell, R. 2003. Travel distance angle for “rapid” landslides in constructed and natural soil slopes. *Can. Geotech. J.* 40: 1123-1141. NRC Research Press (2003).
- Jacob, M. 2005. Debris flow hazard analysis. Chapter 17 in *Debris Flow Hazards and Related Phenomena*. Jacob, M. and Hungr, O. (editors). Springer Praxis, Berlin. pp. 411-443.
- Jordan, P. 2003. Landslide and Terrain Attribute Study in the Nelson Forest Region. Final report to Ministry of Forest Research Branch. FRBC Project Number: KB97202-ORE1. Unpublished report.
- Jordan, P. 2002. Landslide Frequencies and Terrain Attributes in Arrow and Kootenay Lake Forest Districts; *in* Terrain stability and forest management in the Interior of British Columbia workshop proceedings, May 23-25, 2001 Nelson, BC. Jordan, P. and J. Orban (eds.) Res. Br., B.C. Min. For., Victoria, B.C. Tech Rep. 003. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr003.htm
- Jordan, P. 2001. Regional Incidence of Landslides; *in* Watershed Assessment in the Southern Interior of British Columbia: Workshop Proceedings, March 9-10, 2000 Penticton, B.C. Toews, D.A.A. and Stephen Chatwin (eds.) Res. Br., B.C. Min. For., Victoria, B.C. Work Pap. 57/2001. www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp57.htm
- Jordan, P. 2000. Soil Erosion Hazard Criteria for Watershed Assessments in the Southern Interior-final report. FRBC Research Award no. KB97225-ORE.
- Jordan, P., Nicol, D., and Turner, K. 2011. Debris flow hazards in the southern interior of British Columbia: the problem of events with unusually long runout. *GeoHazPaper124*. Proceedings of the 5th Canadian Conference on Geotechnique and Natural Hazards; Kelowna, May 15 to 17, 2011.
- Maloney, D. and Carson, B., 2018. Evaluating the presence and impact of acid drainage from industrial roads in British Columbia. Forest and Range Evaluation Program (FREP) Extension Note #42.
- Massey, N.W.D, D.G. MacIntyre, P.J. Desjardins, and Cooney, R.T., 2005. Digital Geology Map of British Columbia: Tile NM11 Southeast B.C., B.C. Ministry of Energy and Mines, Geofile 2005-3.
- Ministry of Forest, Lands and Natural Resource Operations, 2016. Biogeoclimatic Ecosystem Classification Subzone/Variant Map for the Kootenay Lake Subunit, Selkirk Resource District, Kootenay Boundary Region, 1:250,000 scale.
- Pike R.G., T.E. Redding, R.D. Moore, R.D. Winkler and K.D. Bladon (editors). 2010. *Compendium of forest hydrology and geomorphology in British Columbia*. B.C. Min. For Range., For. Sci. Prog., Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops B.C. Land Manag. Handb. No. 66. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm
- Statlu Environmental Consulting, 2019. Hydrologic Assessment: Blocks SMA 15-55, SMA-016, SMA-016A, SMA-017, SMA-018 and SMA-019, Taghum/Beasley, West Arm. Unpublished technical report for BC Timber Sales, Project Number 18-190.
- VanDine, D. F., 1996. Debris flow control structures for forest engineering. Res. Br., B.C., Min. For. Victoria, B.C., Workshop Paper no. 22
- Wise, M.P., Moore, G.D., and VanDine, D.F. (editors). 2004. Landslide risk case studies in forest development planning and operations. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handbook. No. 56

Appendix A

**Risk Analysis
&
Soil, Slope, and Rock Classification
Definitions and Overview**

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

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

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

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

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

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

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

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

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

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

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

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

In general terms, risk is defined as the product of probability of occurrence and consequence ($R=PXC$). In the consideration of consequence to a specific element at risk, the vulnerability or robustness of the specific element must be understood. The vulnerability of specific elements is

generally best assessed by specialists (e.g. biologists, foresters, utility engineers) with a greater knowledge of the element than the terrain stability professional may have.

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

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

Table 1: Qualitative description of the likelihood of occurrence, and related quantitative probability ranges¹

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

1) Modified from Wise et al (2004), Table 2, pg 14; and B.C. MoF (2002), Appendix 10.2., and refers to a 1 km segment of road or a specified area of development.

2) Assumes a 20 year+ design life.

3) Time period between logging and establishment of a new-growth forest (generally on the order of 20 to 30 years).

4) Annual probability of occurrence does not consider the design life of the road.

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

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

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

*1 ha = 10,000 m²

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

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

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

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

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

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

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

References

B.C. Ministry of Forests 2002. Forest road engineering guidebook. For. Prac. Br., B.C. Min. For., Victoria, B.C. Forest Practices Code of British Columbia Guidebook.

Wise et al 2004. Landslide risk case studies in forest development planning and operations. B.C. Min. For., Res. Br., Victoria, B.C. Land Manage. Handb. No. 56.
<<http://www.fro.gov.bc.ca/hfd/pubs/Docas/Lmh/Lmh56.htm>>

Soil, Slope, and Rock Classification

Course Grained Soils ¹ (Cohesionless):

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

Fine Grained Soils ¹ (Cohesive):

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

Rock Strength ¹:

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

Spacing of Discontinuities in Rock ¹:

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

Soil Description¹⁴:

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

Soil Thickness^{2,3}:

Thickness	
Blanket	>1.0 m
Veneer	<1.0 m

Soil Drainage⁵(adapted):

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

Slope Gradient:

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

Surface Configuration ² (modified):

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

Slope Shape ³ (modified) and Features

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

Qualitative landslide magnitude ratings⁷

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

REFERENCES:

1. Canadian Geotechnical Society, Canadian Foundation Engineering Manual, 3rd Edition, *Identification and Classification of Soil and Rock*, 1992.
2. Ministry of Forests, A Guide for Management of Landslide Prone Terrain in the Pacific Northwest, 2nd Edition, *Land Management Handbook #18*, 1994.
3. Ministry of Environment, Terrain Classification for British Columbia, Revised Edition, *Manual # 10*, 1998
4. Ministry of Forests, Forest Road Engineering Guidebook, 2nd Ed., 2002.
5. Ministry of Environment Lands and Parks and Ministry of Forests, Field Manual for Describing Terrestrial Ecosystems, LMH#25, 1998.
6. Ministry of Forests, Gully Assessment Procedures Guidebook 1995
7. Ministry of Forests, Landslide Risk Case Studies in Forest Development Planning and Operations, LMH#56, 2004.

Appendix B

Soil Erosion Hazard Definition and Criteria Tables

Soil Erosion Hazard Definition and Criteria Tables

Soil Erosion Hazard Criteria*¹

Soil Drainage Class	Soil Depth	Hillslope Gradient	Texture and Consolidation	Road Grade	Coarse Fragment Content and Bedrock			
					<20%	21-50%	51-80%	>80% or Bedrock
Imperfect or Wetter or evidence of seepage	≤ 1 m	All	All	< 12%	VH	H	M	L
				> 12%	VH	H	H	L
	> 1 m	All	All	all	VH	VH	VH	M
Moderately Well or Drier; seepage absent	≤ 2 m	All	All	< 12%	VH	H	M	L
				> 12%	VH	H	H	L
	> 2 m	<50%	All	< 12%	VH	H	M	L
				> 12%	VH	H	H	L
		≥50%	Si, S, LS/ Loose	All	VH	H	H	L
			Other	< 12%	VH	H	M	L
				> 12%	VH	H	H	L

* adapted from *Soil Erosion Hazard Criteria for Watershed Assessments in the Southern Interior, Final Report*. Jordan, P. 2000. and *Assessing Surface Erosion Hazard on Forest Roads (DRAFT)*. Thompson, S. 2001, assuming a moist climate regime.

Soil Erosion Hazard – Generalized Management Implications*

Hazard Class	Interpretation
Low	Low levels of erosion expected. No special measures are required.
Moderate	Low levels of erosion are expected and can usually be controlled with standard road construction and maintenance practices. Significant problems may develop on a site specific basis, but can generally be avoided with preventative measures in place. Evaluate critical locations where sediment delivery potential is high following road construction.
High	Moderate levels of erosion are expected, but can usually be controlled with standard road construction practices and high maintenance standards. Significant problems may develop on a site specific basis, and may require a both preventative and adaptive control measures. A review of the entire road immediately following construction is recommended to confirm if preventative measures are sufficient, and if additional measures are warranted based on as-built condition.
Very High	High levels of erosion are expected without effective control measures in place. Special measures will be required to control erosion from the road surface, cut slope and ditch. Mitigation strategies should be incorporated into the road design and revised following construction. Continuous monitoring immediately following construction and during the first spring runoff is recommended. Higher standards of road maintenance and deactivation will be required to control erosion from the road surface. Erosion of the road surface may impair operational use of the road without preventative measures such as a high level of drainage control and/or surfacing with a suitable non-erosive material.

*adapted from *Soil Erosion Hazard Criteria for Watershed Assessments in the Southern Interior, Final Report*. Jordan, P. 2000.

¹ Hazard ratings may be bumped up one category where polygon specific conditions warrant (e.g. concave slope configurations or severely gullied terrain). Hazard ratings may be bumped down one category where polygon specific conditions warrant (e.g. irregular bedrock controlled terrain, convex ridge top slope positions).

Appendix C

Road Recommendations Summary Table & Typical Section Diagrams

<u>Drainage:</u>	Smallwood Creek and Garrity Creek	<u>Field Assessment:</u>	October 24, 2019
<u>Road Section:</u>	TSL TA0915 Garrity 3110, and existing access	<u>Prescription Type:</u>	Road Recommendations
<u>Proposed Access:</u>	Temporary (≤2 year term)	<u>Prepared by:</u>	J.M./T.R.

Road Recommendations Summary Table: TSL TA0915

Refer to related Terrain Stability Assessment (SCL# 20-1561) and TSA Maps for additional recommendations and background information. **Use of this table and associated maps should not replace referencing the TSA**, as not all information is presented.

Construction should be modified or suspended when there is abundant hill slope runoff occurring at the site, which is likely to occur during times such as spring break-up or periods of high runoff from prolonged heavy precipitation. This is intended to reduce the likelihood of concentrated or redirected drainage, excessive erosion and sediment delivery, and potential instabilities associated with excavation and placement of saturated material.

Cut slopes should be constructed at 1H:1V for temporary roads, with a lower angle appropriate for areas of seepage or loose soils. **Cut slopes in bedrock** can generally be constructed at 0.25H:1V, but appropriate angles may range from vertical to 0.5H:1V dependent on rock properties encountered during excavation.

Fill slopes should be constructed at 1.5H:1V, with allowance for steeper fills of 1.1H:1V to 1.25H:1V where sufficient sound wood support or keyed rock is used. The use of sound wood support in fills and woody debris placement in the road sub-grade is only acceptable for roads with a term of less than 5 years, and provided it is done consistent with typical good construction practices (road use and stability not adversely affected). **Sound wood supported and/or keyed rock fills are recommended for temporary road sections crossing side slopes of 50% or greater**, in order to reduce benching requirements and fill slope lengths while increasing fill slope stability and reducing effort required for rehabilitation. Refer to the typical section diagrams depicting these construction types.

Road Drainage Systems: Drainage structures have been prescribed based on a field traverse of the proposed road alignments prior to construction, taking into account local drainage divides and anticipated subsurface conditions (refer to applicable *TSA Maps*). **Additional drainage control may be warranted** based on conditions encountered during construction. For temporary one season construction, cross drain requirements are also dependant on the season and time frame the road is to be in place prior to full rehabilitation. **For temporary roads, there is the option to use alternative functional cross drains and crossings** (e.g. skid culverts, bundled logs, wood box culverts, or other functional cross drains), as opposed to traditional round pipes. However, the following additional recommendations then apply:

- a) All prescribed culvert locations should have functional cross drain structures installed;
- b) All watercourse crossings must be appropriately sized to span the active channel and accommodate possible high flows;
- c) All watercourse crossings should be pulled prior to over-winter (not to be in place through the spring runoff), with the natural channel re-established and left free of debris (slash or soil); and
- d) All remaining ditch relief cross drains should be backed up or replaced with cross ditches prior to overwinter.

Post harvesting drainage management should be planned for if construction and/or harvesting are to take place in the fall and winter months – frozen road surfaces can be difficult to install cross-ditches on, but having effective drainage control in place for spring runoff is required for the risk ratings of the TSA to remain applicable.

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

Maintenance and Deactivation (recommended for proposed roads associated with the development, as well as existing roads used for access in the vicinity of the proposed development): Ditches and cross drains should be maintained functional and left free of excess slash or debris during and after harvesting. Seasonal deactivation measures (back up cross ditches and intermediate waterbars as appropriate) should be installed during periods of non-industrial use, including overwintering periods. Regular road inspections for additional required maintenance work (possible ditch cleaning, culvert cleaning, additional cross ditch placements, or cross ditch improvement) should be carried out during and subsequent to operations. Inspections should be semi-annually at minimum, once in the fall and once during the spring freshet, for the first two years following construction, taking into account the results of previous inspections. The intent is for timely identification and mitigation of stability or drainage related concerns to avoid more significant terrain stability concerns.

Full rehabilitation is recommended for all temporary roads within a 2 year term, with seasonal deactivation measures implemented as appropriate prior to rehabilitation. Rehabilitation will require removal of all culverts, decompaction of the road bed, and recontouring of the road prism to its original slope profile. The construction of swales on the re-contoured surface is recommended to re-establish drainage at natural drainage features. The intent of slope recontouring is to restore natural subsurface drainage patterns as much as practical in order to limit down slope hydrological effects of the road drainage systems.

Site Specific Recommendations

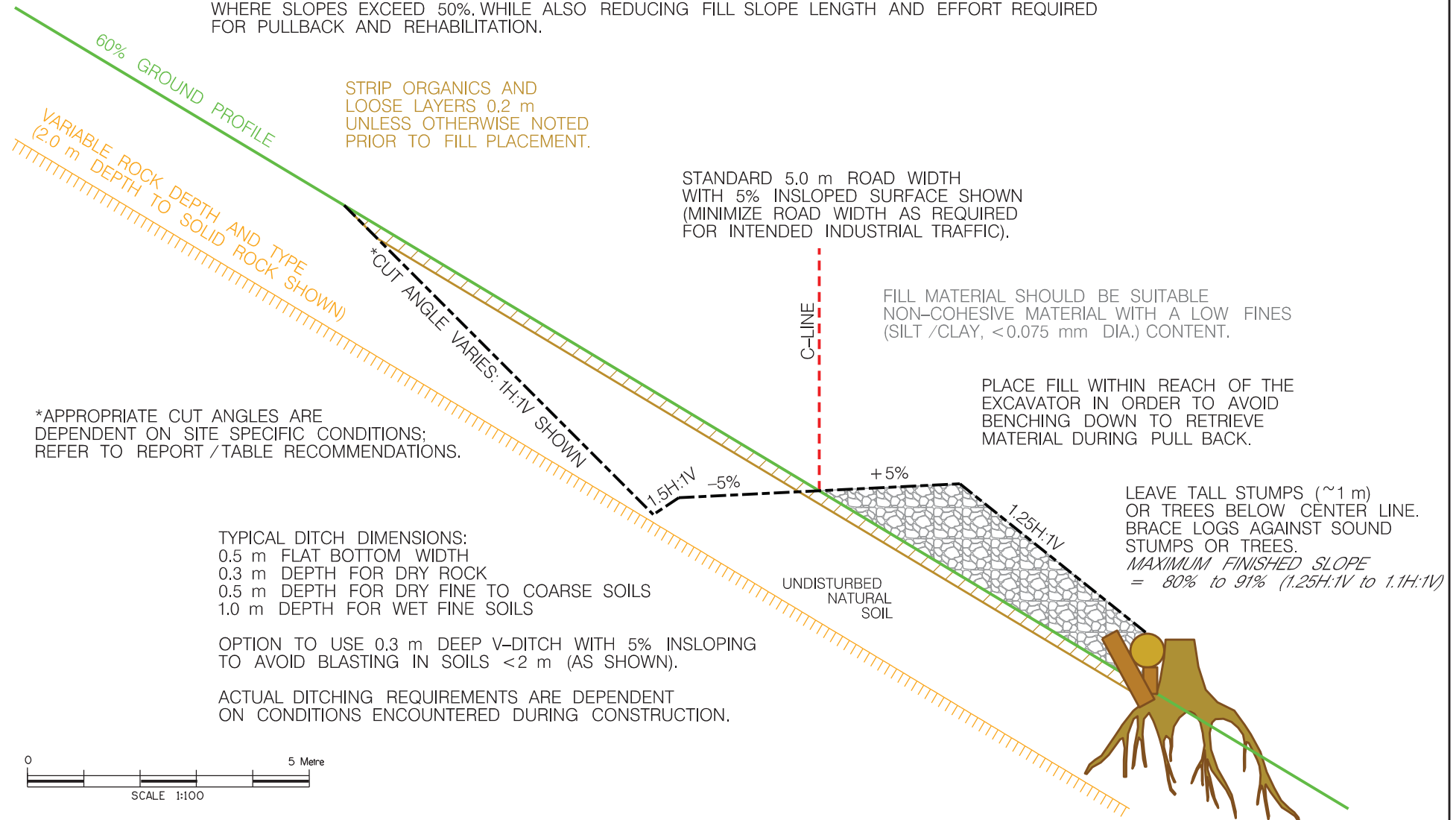
Smallwood 2000 Existing Temporary Road (Hub 82 to POT; Block 1):

- 1. Full rehabilitation as described above.

Garrity 3110 Proposed Temporary Road (Block 3):

- 1. The use of wood supported fill is recommended on side slopes of 50% to 60% gradient from the POC to Hub 5 to minimize cut and fill and improve rehabilitation opportunities.
- 2. Some rock excavation may be required between Hub 6 and 7, exiting the gully. Use wood and/or rock supported fill to minimize cut and fill and improve rehabilitation opportunities.
- 3. Full rehabilitation as described above.

THE INTENT OF WOOD SUPPORTED FILL IS TO REDUCE CUT DEPTH AND BENCHING REQUIREMENTS WHERE SLOPES EXCEED 50%. WHILE ALSO REDUCING FILL SLOPE LENGTH AND EFFORT REQUIRED FOR PULLBACK AND REHABILITATION.



PRODUCED FOR:



PROJECT TITLE:

TYPICAL CROSS SECTION
OF A WOOD SUPPORTED FILL
FOR TEMPORARY CONSTRUCTION
(< 2 YEAR ROAD TERM)

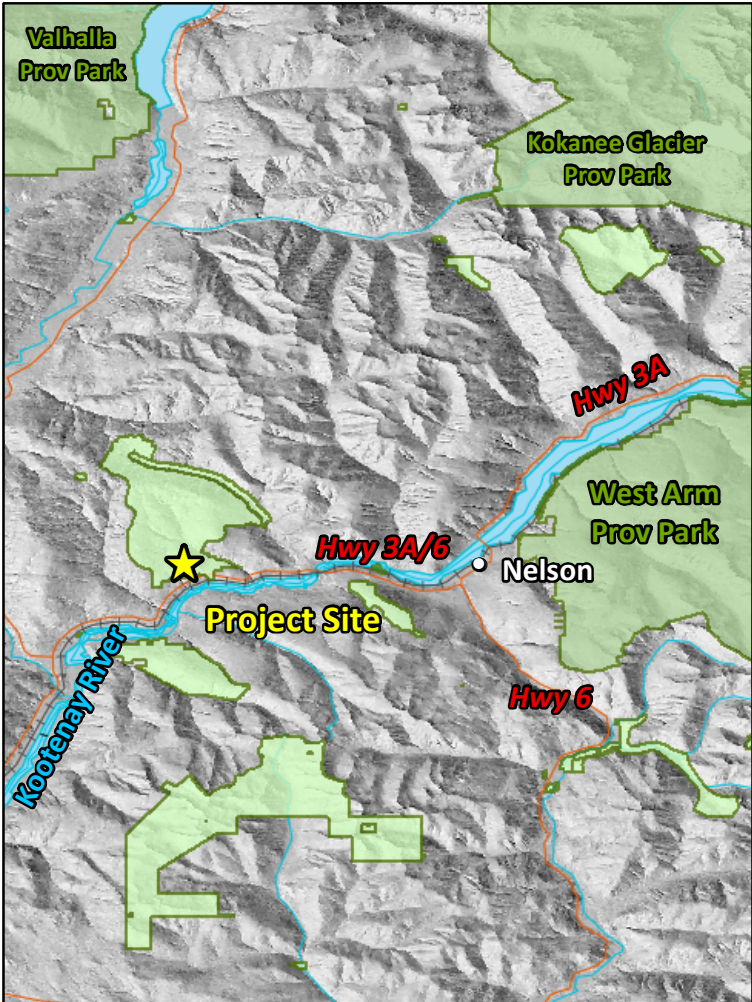
PRODUCED BY:



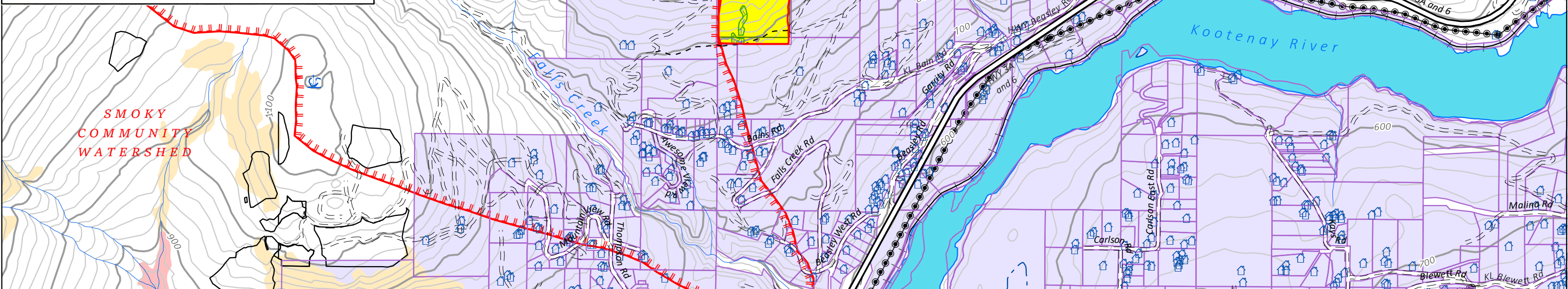
DRAWN: KA	DATE: July 7, 2020
REVIEWED:	PROJECT NO: 20-1561
APPROVED: JM	PAGE SIZE: Ansi A 8.5x11
FILENAME: CD_CSFC-WSF.dgn	Typical Section: 1

Appendix D

Figures



LOCATION INSET MAP
APPROXIMATE SCALE: 1: 500,000



SCALE: 1: 20,000

LOCATION: SMALLWOOD CREEK
MAPSHEET/OPENING NO: 82F043 / 82F053
UTM ZONE 11: 465,647E 5,482,364N NAD 83
DATA SOURCE(S): TRIM-BASE, ATLAS- BLOCKS & ROADS

PAGE SIZE: ANSI B 11"x17" DATE: JUL 6, 2020
PROJECT: 20-1561 DRAWN: CR
20_1561_FIGURE1.MXD CHECKED BY: JM, TR

LEGEND

BLOCK BOUNDARY:	EXISTING / PROPOSED	COMMUNITY WATERSHED / DOMESTIC WATERSHED	
ASSESSED BLOCK / ROAD		PROVINCIAL PARK / RECREATION SITE / PRIVATE LOT	
CONTOUR:	INDEX / INTERMEDIATE	STREAM / NON-CLASSIFIED DRAINAGE / DIVERTED WATER COURSE	
EXISTING ROAD: PAVED/SECONDARY/TEMP		STREAM CLASS / REACH BREAK / FISH BARRIER	
BCTS-CONSTRUCT ROAD:	PERM / TEMP	LAKE / SWAMP / WATER LICENCE INTAKE / STRUCTURE	
LICENSEE-CONSTRUCT ROAD:	PERM / TEMP	LINES:	
ROAD UPGRADE / EXISTING TRAIL		PIPE	
ROAD BRIDGE:	EXISTING / PROPOSED	TRANSMISSION	
LANDING:	EXISTING / PROPOSED	RAILWAY	
WILDLIFE TREE RETENTION AREA / RESERVE AREA		FENCE	
NON-PRODUCTIVE AREA			
		HEADSCARP / LANDSLIDE	
		AVALANCHE PATH / POTENTIAL AVALANCHE PATH	
		TERRAIN STABILITY MAPPING POLYGONS:	
		LEVEL C / D: POTENTIALLY UNSTABLE IV / P UNSTABLE V / U	

TSL TA0915

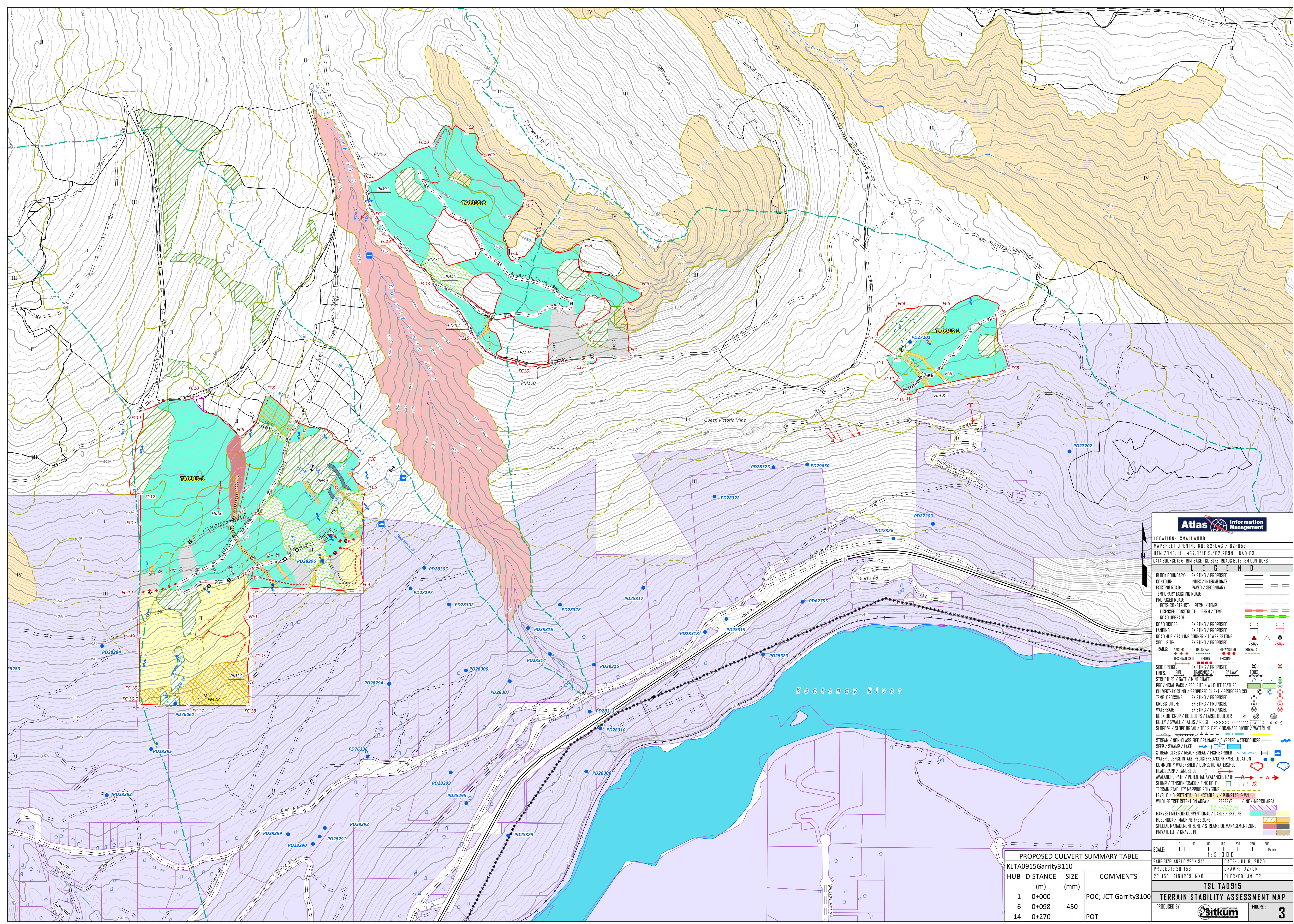
OVERVIEW MAP

PRODUCED BY:



FIGURE :

1



Atlas Information Management

LOCATION: SMALLWOOD
MAPSHEET OPENING NO: B2F043 / B2F053
UTM ZONE: 11 467.041E 5.482.289N NAD 83
DATA SOURCE (S): TRIM-BASE TCL-BLKS. ROADS BCTS-5M CONTOURS

LEGEND

BLOCK BOUNDARY: EXISTING / PROPOSED

CONTOUR: INDEX / INTERMEDIATE

EXISTING ROAD: PAVED / SECONDARY

TEMPORARY EXISTING ROAD:

PROPOSED ROAD:

BCTS CONSTRUCT: PERM. / TEMP.

LICENSEE CONSTRUCT: PERM. / TEMP.

ROAD UPGRADE:

ROAD BRIDGE: EXISTING / PROPOSED

LANDING: EXISTING / PROPOSED

ROAD HUB / FALLING CORNER / TOWER SETTING

SPOIL SITE: EXISTING / PROPOSED

TRAILS:

SKID BRIDGE:

PIPES:

TRANSMISSION:

RAILWAY:

FENCE:

PROVINCIAL PARK / REC. SITE / WILDLIFE FEATURE

CULVERT: EXISTING / PROPOSED CLIENT / PROPOSED SCL

TEMP. CROSSING: EXISTING / PROPOSED

CROSS-DITCH: EXISTING / PROPOSED

WATERBAR: EXISTING / PROPOSED

ROCK OUTCROP / Boulders / LARGE BOULDER

GULLY / SWALE / TALUS / RIDGE

SLOPE % / SLOPE BREAK / TDS SLOPE / DRAINAGE DIVIDE / WATERLINE

STREAM / NON-CLASSIFIED DRAINAGE / DIVERTED WATERCOURSE

SEEP / SWAMP / LAKE

STREAM CLASS / REACH BREAK / FISH BARRIER

WATER LICENCE INTAKE: REGISTERED / CONFIRMED LOCATION

COMMUNITY WATERSHED / DOMESTIC WATERSHED

HEADSCARP / LANDSLIDE

AVAILANCE PATH / POTENTIAL AVAILANCE PATH

SLOPP / TENSION CRACK / SINK HOLE

TERRAIN STABILITY MAPPING POLYGONS:

LEVEL 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 / 11 / 12 / 13 / 14 / 15 / 16 / 17 / 18 / 19 / 20 / 21 / 22 / 23 / 24 / 25 / 26 / 27 / 28 / 29 / 30 / 31 / 32 / 33 / 34 / 35 / 36 / 37 / 38 / 39 / 40 / 41 / 42 / 43 / 44 / 45 / 46 / 47 / 48 / 49 / 50 / 51 / 52 / 53 / 54 / 55 / 56 / 57 / 58 / 59 / 60 / 61 / 62 / 63 / 64 / 65 / 66 / 67 / 68 / 69 / 70 / 71 / 72 / 73 / 74 / 75 / 76 / 77 / 78 / 79 / 80 / 81 / 82 / 83 / 84 / 85 / 86 / 87 / 88 / 89 / 90 / 91 / 92 / 93 / 94 / 95 / 96 / 97 / 98 / 99 / 100

WILDLIFE: TREE RETENTION AREA / RESERVE / NON-MERCH AREA

HARVEST METHOD: CONVENTIONAL / CABLE / SKYLINE

HOEDUCK / MACHINE FREE ZONE

SPECIAL MANAGEMENT ZONE / STREAMSIDE MANAGEMENT ZONE

PRIVATE LOT / GRAVEL PIT

SCALE: 1:5,000

PROPOSED CULVERT SUMMARY TABLE

HUB	DISTANCE (m)	SIZE (mm)	COMMENTS
1	0+000	-	POC; JCT Garrity3100
6	0+098	450	
14	0+270	-	POT

PAGE SIZE: ANSI D 22" x 34"

DATE: JUL 6, 2020

PROJECT: 20-1561

DRAWN: AZ/CR

20_1561_FIGURE3_MXD

CHECKED: JM, TR

TSL TA0915

TERRAIN STABILITY ASSESSMENT MAP

PRODUCED BY:

FIGURE: 3