Appendix 5-C

Terrain Mapping and Geohazards

HARPER CREEK PROJECT:
TERRAIN MAPPING AND GEOHAZARDS

Prepared for:

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July 2014
Polar File: 930101

FINAL
REPORT

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Mr. Mark Branson
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Dear Mr. Branson:

Re: Final Report: Harper Creek Project; Terrain Mapping and Geohazards

Polar Geoscience Ltd. is pleased to provide this final report summarizing the Terrain and Geohazards for the Harper Creek Project located near Vavenby, BC. This report is in support of Harper Creek Mining Corporation's Application for an Environmental Assessment Certificate and specifically addresses the Terrain, Landform, Surficial Materials and Geohazard portions of Application Information Requirements (AIR) 81, 88, 89, and 91. We look forward to your comments and will finalize the report upon your direction.

Yours truly,

Polar Geoscience Ltd.

Original hard copy signed and sealed

Polly Uunila, P.Geo.
Senior Geoscientist

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

On May 2, 2014 ERM Rescan retained Polar Geoscience Ltd. (Polar) to conduct an assessment (including mapping) of the terrain, landforms and geohazards associated with the proposed Harper Creek Project (the Project), located near Vavenby, BC. This report supports Harper Creek Mining Corporation's (HCMC) application for an Environmental Assessment Certificate and specifically addresses the following Application Information Requirements (AIR):

- 81, description of local terrain and landforms;
- 88, terrain and landforms for the regional study area (RSA) and local study areas (LSA);
- 89, geohazard assessment for the RSA and LSA; and
- 91, overview of the terrain and surficial materials within and around the Study Area

This report provides an inventory of geohazards, specifically mass movement processes. The scope of this assignment did not include determination of magnitude, frequency, and/or consequence of the geohazards, and thus it is not to be considered a geohazard risk assessment. The geohazards mapped in this assignment are a "snapshot in time" view of the distribution of mass movements based on the visual evidence from the air photos. Knowledge of where existing geohazards and potentially unstable terrain are located provides direction to focus future detailed geohazard and slope stability studies.

This report principally discusses the methods and results of the mapping of terrain, terrain stability and geohazards associated with the Harper Creek Project. Appendix A provides a detailed description of the terrain symbols used on the maps. Appendix B is the statement of General Conditions. Map 1 consists of the Terrain and Geohazards Map and Map 2 is the Terrain Stability and Soil Erosion Potential Map.

1.2 PROJECT TERMS AND DEFINITIONS

The project infrastructure referred to in this report is based on digital files dated May 12, 2014. The term "local" from item 81 of the AIR is defined as under and immediately adjacent to project infrastructure (refer to Section 6.0). The LSA used for this assignment is the same as the one used

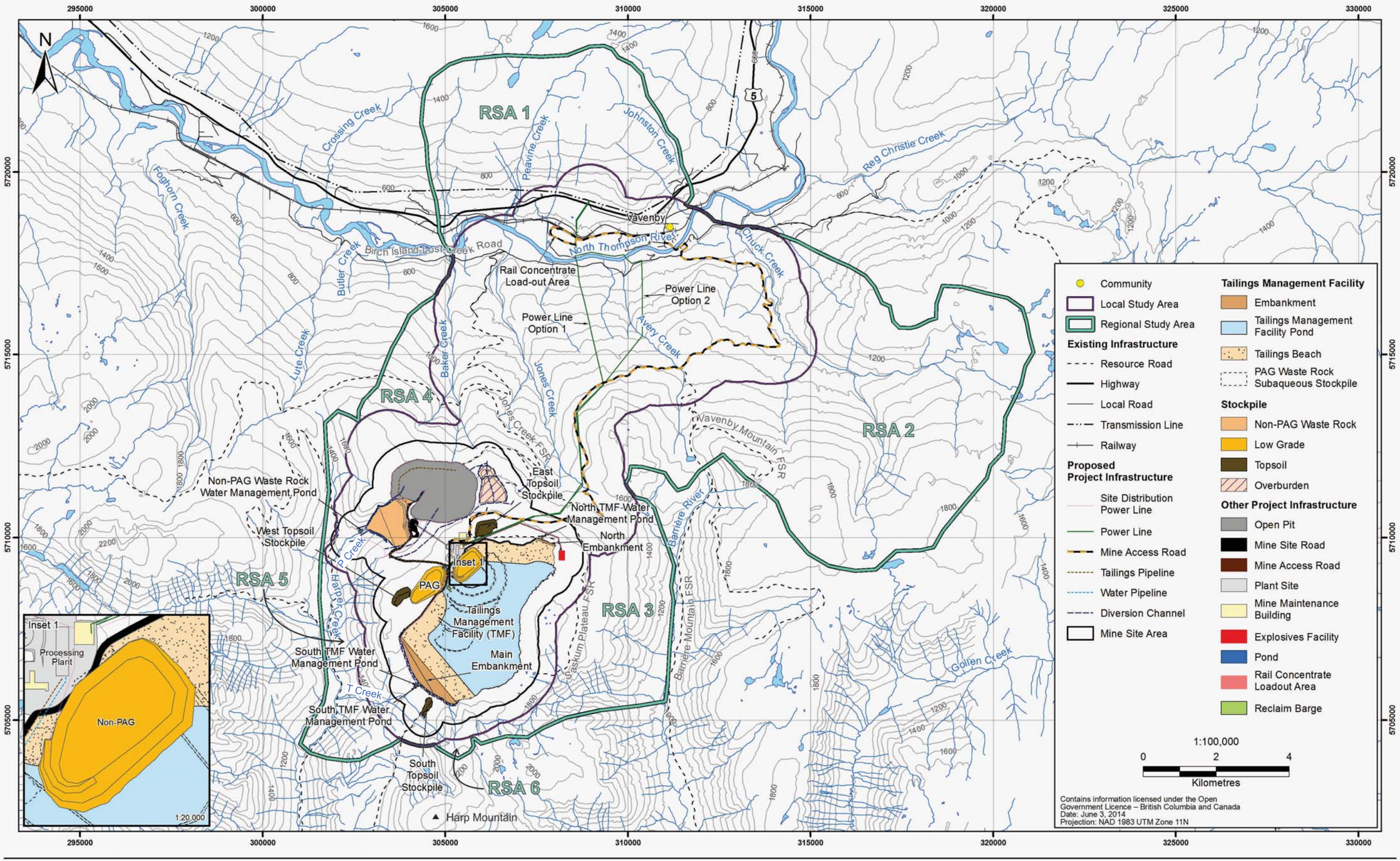
for the Terrestrial Ecosystem Mapping (TEM) and soils phases of the AIR (see Figure 1.1). A watershed-based Terrain and Geohazards RSA (see Figure 1.1) was identified for the purposes of this assignment to address the existing and potential geohazards to the Project and potential geohazards that can impact areas downslope from the Project. In order to simplify analysis and reporting, six (6) separate RSA Units were identified (Figure 1.1):

1. RSA Unit 1: This unit includes slopes to the height of land above the northern edge of the LSA. This unit was reviewed in order to identify potential geohazards that could affect project infrastructure.
2. RSA Unit 2: Chuck Creek and Avery Creek watershed to the heights of land that extent beyond the boundaries of the LSA. This unit was reviewed in order to identify potential geohazards that could affect project infrastructure.
3. RSA Unit 3: This unit extends from the LSA to the Barriere River valley bottom. This unit was reviewed in order to identify potential geohazards downslope of the Project that could affect the Barriere River.
4. RSA Unit 4: This unit includes a portion of the Baker Creek watershed missing from the LSA. This unit was reviewed in order to assess potential for geohazards that could affect project infrastructure.
5. RSA Unit 5: This unit extends from the LSA to the Harper Creek valley bottom. RSA Unit 5 was reviewed in order to identify potential geohazards downslope of the Project that could affect Upper Harper Creek.
6. RSA Unit 6: This includes a small area at the southern edge of the LSA to the height of land near Harp Mountain. RSA Unit 6 was reviewed to identify potential geohazards that could affect project infrastructure.

In this report, the RSA and LSA combined are referred to as the Study Area.

Figure 1.1
Terrain Mapping and Geohazards Study Area

ERM



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Date: June 3, 2014
Projection: NAD 1983 UTM Zone 11N

2.0 OVERVIEW OF TERRAIN, SURFICIAL MATERIALS AND BEDROCK GEOLOGY

2.1 LANDSCAPE SETTING

The Study Area lies within the Shuswap Highlands, a subdivision of the Interior Plateau Physiographic Region (Holland, 1976). The Shuswap Highlands consists of a plateau, with rounded surfaces, separated by large valleys. Within the Study Area, the North Thompson River floodplain is at an elevation of 440 metres (m) with elevated fluvial and glaciofluvial terraces to 520 m (near location of the rail concentrate load-out facility). The side of the valley to the south of the North Thompson River consists of moderately steep terrain and is dissected by several steep-sided creeks including Jones, Avery and Chuck Creeks (near location of the mine access road and power lines). The valley sides level off to a gently sloping plateau from about 1,200 to 1,900 m (location of the Project Site Area[1]), and then the slopes steepen to the peak of Harp Mountain at 2,280 m located just beyond the southern boundary the Study Area.

On the north side of the North Thompson River, the valley side consists of moderately steep slopes which are dissected by steep-sided streams (all but Peavine and Johnston Creeks are un-named). At 1,200 m, the terrain levels off to gently sloping plateau.

2.2 BEDROCK GEOLOGY

The Study Area is underlain by the Kootenay terrane of the Omineca Complex (Massey et al., 2005). Bedrock outcrops along steep gully walls in many of the Study Area creeks, including Baker, Jones, Chuck, P and T Creeks as well as the valley wall of the Harper Creek and Barriere River valleys. Bedrock outcrops on the flanks of Harp Mountain at the southern edge of the Study Area. There are discontinuous bedrock outcrops on the crests of the undulating terrain of the plateau. Characteristics of the bedrock, such as mineral composition and structure determine the shape and texture of its weathered material. These characteristics influence the shape and size of clasts and the matrix texture of soils that are created.

[1] Project Site Area includes all of the tailings management facilities, all of the stockpiles, the open pit, and the plant site

Most of the Study Area is underlain by Lower Cambrian to Mississippian-aged, deformed and metamorphosed sedimentary and volcanic rocks of the Eagle Bay Assemblage and the southern portion of the Study Area is underlain by Cretaceous-aged intrusive rocks (Figure 2.1).

The Eagle Bay Assemblage is comprised of several units. The Slate Creek Unit, located along Jones and Avery Creeks in the centre of the Study Area, consists of sedimentary rocks including mudstone, siltstone, shale and fine clastic sedimentary rocks. Fine-grained sedimentary bedrock breaks down into silt and clay and, where bedded, the rock tends to fracture along bedding planes to produce slab-shaped clasts. A thin layer of weathered rock at the surface or underlying till is common where this rock type is present in the Study Area (Figure 2.2). Where this rock is fissile (fractures along bedding planes), it is weak and is prone to slides in cutslopes and gully walls. Where highly fractured, this rock tends to be weak and tends to be rippable with construction equipment.

The east and south-facing cliff faces in the Study Area consist of limestone, marble and calcareous sedimentary rocks (for example, polygons 551 and 657, Maps 1 and 2).

The north and eastern sides of the Study Area are underlain by greenstone and greenschist metamorphic rocks of the Forest Lake and Johnson Lake Units. These tend to break into pebble-sized rubble and flaggy slabs and consequently, boulders and blocks generally are not common. The rubble and slabs further weather into silt and fine sand and consequently result in a sandy silt matrix till. Where these rock types are highly foliated, they may be weak and prone to slides in cutslopes and gully walls.

Small areas of volcanic rocks of the Foghorn and Skwaam Bay Unit are located within the Study Area. The volcanic rocks break down into rubble and blocks which weather into silt and clay.

Figure 2.1
Geologic Setting for Harper Creek Project

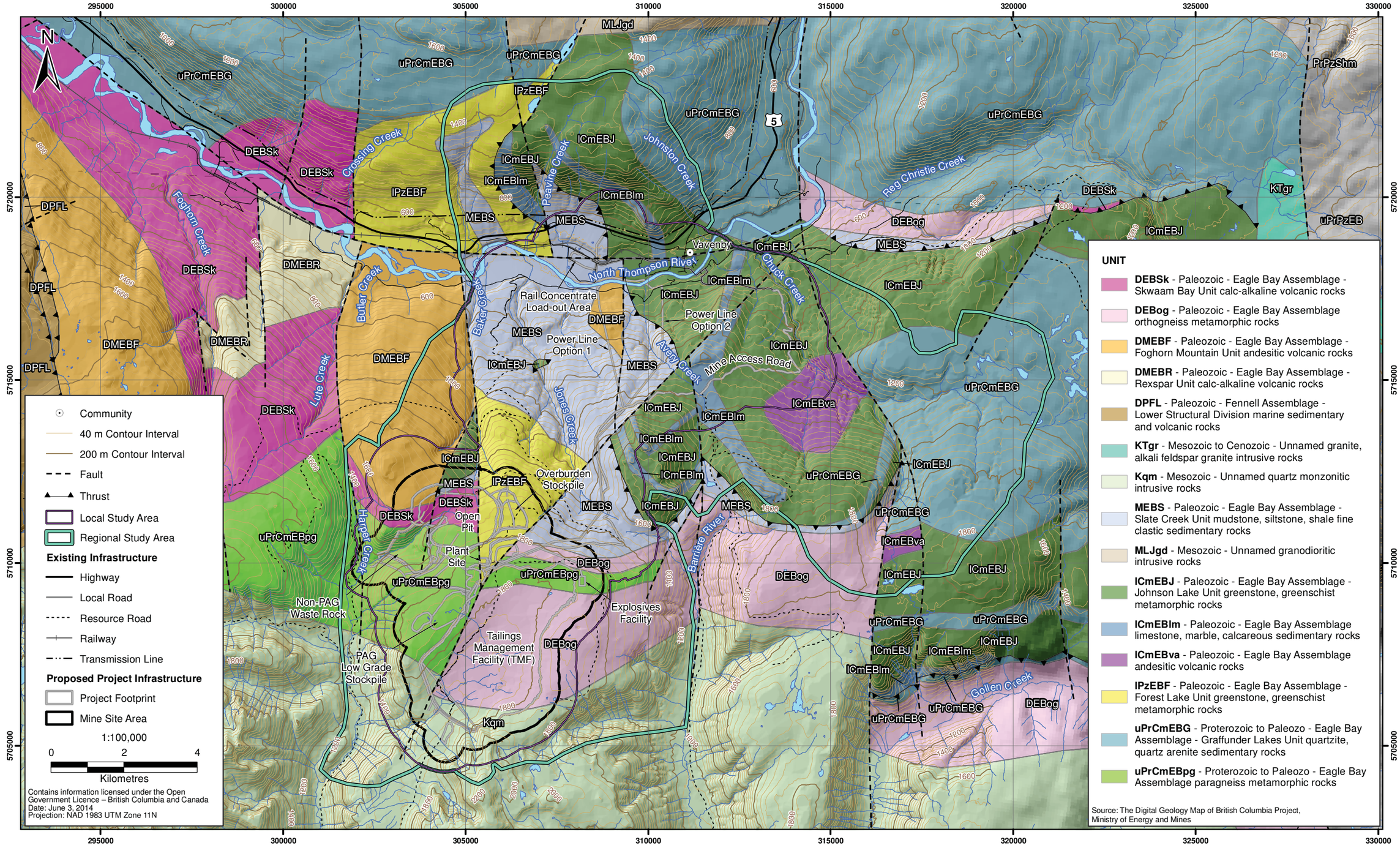

Figure 2.2 Soil pit showing dark grey weathered bedrock (below lower-most marker) underlying till.

Orthogneiss (metamorphosed igneous rock) covers much of the plateau on the southeast side of the Study Area. Paragneiss metamorphic rock (metamorphosed sedimentary rock) underlies the upper Chuck Creek watershed. Coarse-grained metamorphic rocks tend to break into large blocks and boulders, whereas foliated, finer-grained metamorphic rocks break into pebble-sized rubble and flaggy slabs.

The Cretaceous-aged intrusive bedrock (i.e., quartz monzonite), located at the southern edge of the Study Area, tends to break down into sand and coarse silt. Thus, till and colluvium derived from this type of bedrock typically has a predominantly sandy matrix with some silt. Well-jointed intrusive bedrock tends to break into large blocks and boulders. Within the Study Area, this rock type outcrops in the road cuts in the southwest corner of the Study Area and has weathered into coarse sand (Figure 2.3). There is a large bedrock slump with tension cracks in quartz monzonite in the southwest corner of the Study Area.

Figure 2.3 Weathered quartz monzonite in the southwest corner of the Study Area.

2.3 LANDSCAPE EVOLUTION

The physiography of the region dates back 200 million years ago (i.e., early Jurassic) when plate tectonics welded the former Pacific Ocean to the margin of the North American continent. This created ridges of metamorphic and plutonic bedrock orientated in a north-south direction. About 50 million years ago (i.e., early Tertiary), plate tectonics caused uplift of the area accompanied by extensive volcanism. A long period of relative stability followed, during which erosion and deposition formed a low-relief landscape with gentle slopes and low hills. During late Tertiary, the area was subject to uplift again, followed by a renewed period of down cutting, with the stream valleys deeply incising into the old erosion surface.

Both the plateau and the moderately steep-sided valleys were completely buried by ice during the Pleistocene glaciation; however, glaciers affected only relatively minor modifications to the older topography. Most of the surficial materials that are of significance with regards to resource development date from the last glaciation.

At the beginning of the last major glacial episode (i.e., Fraser Glaciation) ice accumulated in the high mountains and then gradually spread to valleys and lowlands. About 14,500 years ago, when the Cordilleran Ice Sheet was thickest and most extensive at the climax of Fraser Glaciation (Fulton, 1975), ice flowed generally from north to south across the Study Area (Ferbey et al., 2013). Within the Study Area, the rounded ridge tops suggest that the entire area was completely overridden by ice at this time, depositing till at the base of the ice sheet. The peaks of higher mountains, such as Dunn Peak (elevation 2,634 m) located west of Harper Creek, protruded through the ice cap. Till tends to be thickest on the lower slopes and tends to thin with elevation. On the plateau, till is generally thicker in the depressions and thin to patchy on the crests of the undulating terrain.

Deglaciation occurred between about 14,000 and 11,000 years ago. Deglaciation took place by downwasting (i.e., thinning of glacial ice due to melt) so that the uplands emerged from beneath the ice while tongues of ice remained in the valley bottoms (Fulton, 1969). Downwasting ice often forms characteristic subglacial and ice-marginal landforms on gentle surfaces, such as, eskers, kames, ice-dammed lakes and meltwater channels. Extensive glaciofluvial terraces formed along the

valley bottom (outwash terraces) and the lower valley sides (kame terraces). Meltwater channels and glaciofluvial terraces are present along the Harper Creek valley bottom. Small areas of glaciolacustrine sediments deposited by ice-dammed lakes are located near the mouth of Chuck Creek and in polygons 780 and 781 where Avery Creek meets the LSA boundary (Map 1). Knight Piesold identified glaciolacustrine sediments at site WP33 in a wetland on the plateau below the main embankment (Knight Piesold, 2012b).

During the post-glacial period, processes have re-worked some glacial sediments and weathered bedrock to redistribute them as colluvium and fluvial sediments. Some streams and rivers that have graded to the present day river level of the North Thompson have downcut into glacial deposits creating terraces, benches, and steep-sided scarps. A wide fluvial terrace is located in the North Thompson River valley bottom. Fluvial fans have formed at the mouths of many of the larger creeks including Baker Creek, Jones Creek, T Creek and Peavine Creek. Colluvium is present on many of the steep slopes in the Study Area and is usually mapped near bedrock outcrops (Section 2.2). A large bedrock slump located near P Creek in the southwest corner is mapped as colluvium. Colluvial fans are mapped at the mouths of the un-named gullies on the north side of the Study Area. Weathered bedrock is present on the gentle plateau and most commonly found in association with the sedimentary rocks of the Slate Creek Unit (Section 2.2).

3.0 METHODS

3.1 BIOTERRAIN MAPPING (2009 AND 2011)

Bioterrain mapping was completed for the Terrestrial Ecosystem Mapping (TEM) phase of the Environmental Assessment process. This mapping was used as a base for the Terrain and Geohazards assignment. Bioterrain mapping is a method of dividing the landscape into polygons based on surficial material type and soil drainage and forms the basis for the TEM. The bioterrain mapping that was used for the current project was completed at 1:20,000 scale in two stages. The mapping covers the LSA as follows:

1. West half: In 2008/2009, bioterrain mapping completed by Denny Maynard, M.Sc., P.Geo. for Clement Consulting used the bioterrain mapping to support the TEM (Clement Consulting, March 2009). Mapping was completed at 1:20,000 scale on hard copy air photos.
2. East half: In 2011, the LSA expanded eastward and northwards. Polly Uunila, P.Geo. of Polar Geoscience Ltd. was retained by Keystone Wildlife Research Ltd. to complete bioterrain mapping as a part of the TEM phase of the Environmental Assessment (Keystone Wildlife Research Ltd., 2014). Mapping was completed using digital 1:15,000 scale air photos dated 2000 in PurVIEW[2] and the bioterrain polygons were edge matched to the 2008/9 mapping to provide a seamless product.

Terrain mapping followed the standard British Columbia procedures for terrain classification (Howes and Kenk 1997), mapping methods (Resources Inventory Committee 1996), and bioterrain mapping methodology (Resources Inventory Committee 1998). The information added to each polygon included surficial material, surface expression, geomorphological process where visible, and soil drainage class. Polygon delineation was based on the following:

- terrain type;
- material depths;
- drainage;
- slope breaks;
- slope position;
- aspect: cool (from 285 to 135°) and warm (from135 to 285°);

[2] PurVIEW is computer software that allows air photo interpretation and mapping in 3-D on a desktop computer.

- geomorphological processes;
- surface expression and slope morphology (e.g., concave or convex);
- vegetation changes;
- riparian zones and corridors; and
- any other ecologically significant areas such as cliffs, talus slopes, and ponds.

TEM mappers further subdivided some bioterrain polygons based on plant communities.

Terrain and geohazards located outside of the LSA but within the RSA are described based on the following information:

- project air photos with exception of the upper Chuck Creek and Upper Barriere River;
- Clement Consulting (2009) mapping which covers the western side of the LSA south of the North Thompson River; and
- Knight Piesold (2012b) mapping which covers the RSA except for the upper Chuck Creek and Barriere watersheds to the east and slopes north of the North Thompson River.

3.2 TERRAIN STABILITY AND SOIL EROSION POTENTIAL CLASSIFICATION

In May 2014, ERM Rescan retained Polly Uunila, P.Geo. of Polar Geoscience Ltd. to add Terrain Stability Class (TS), Soil Erosion Potential Class (SEP), and slope steepness range (in percent) to each of the TEM polygons located within the LSA. Information used to support this work included:

- field data collected by Denny Maynard in 2008 while working on the TEM phase (Clement Consulting, 2009; this work is integrated into Keystone Wildlife Research Ltd., 2014);
- field data collected by Polly Uunila in 2011 while working on the TEM phase (Keystone Wildlife Research Ltd., 2014);
- field data collected by Polly Uunila in 2012 while working on the baseline soils study (Knight Piesold, 2012a);
- field data collected by Knight Piesold in 2012 as a part of Reconnaissance Terrain Mapping (Knight Piesold Consulting, 2012b);
- digital stereo models (i.e. digital air photos viewed in PurView) available for the northern and eastern portions of the LSA;
- a series of historical air photos for the Project Site Area (air photos reviewed included 1952 (1:40,000 scale), 1965 (1:15,000 scale), 1990 (1:15,000 scale)); and

- computer-generated slope steepness maps based on a 5 m contour interval digital elevation model (DEM) of the Project Site area of the LSA and a 20 m contour interval DEM of the northern half.

During the course of adding the TS and SEP classes to each polygon, Polly Uunila viewed the dgital air photos stereoscopically in PurVIEW where it was available (northern and eastern portions of the LSA). Hard copy air photos and slope maps were utilized in the southern portion of the LSA (i.e., Project Site Area). While adding TS and SEP classes to the polygons, some polygon boundaries were refined based on attributes that influence terrain stability (e.g., slope breaks). In other cases, polygons were merged where the terrain attributes of adjacent polygons were the same but had been divided during the TEM mapping based on vegetation cover (e.g., where bioterrain polygons were subdivided along forestry cutblock boundaries).

Once the polygon boundaries were refined and TS classes, SEP classes and slope range were added to each polygon, two maps were produced. Map 1, Terrain and Geohazards Map includes:

- surficial material;
- geomorphological processes where present;
- soil drainage class;
- slope steepness range (in percent);
- on-site symbols showing location of geohazards; and
- colour themed polygons based on presence of mass movement processes (e.g., landslides and slumps) and snow avalanches.

Map 2, Terrain Stability and Soil Erosion Potential Map includes:

- TS class;
- SEP Class;
- on-site symbols showing location of geohazards; and
- colour themed polygons based on TS class.

3.2.1 Terrain Stability Classification

Terrain stability relates to gravitationally-induced mass movements (i.e., landslides). Slumps, slides, debris flows and earthflows are some examples of landslides. The method for assigning terrain stability classes followed the provincial standard used in the forest industry (B.C. Ministry of Forests, 1999) for detailed terrain stability mapping. Each polygon was assigned one of five classes, Class I to

Class III (stable), Class IV (potentially unstable) and Class V (unstable). The classes indicate the likelihood of instability resulting from mine development activities that occur in the upper few metres of the land surface within in-situ surficial materials and bedrock (e.g., these rating do not apply to future development-related deposits such as stockpiles, tailings and waste rock, and they do not apply to deep excavations such as open pits). Class IV polygons are expected to contain areas with a moderate likelihood of landslide initiation following mine development activities. Class V polygons are expected to contain areas with a high likelihood of landslide initiation following mine development activities.

The general guidelines developed for rating the area with detailed terrain stability mapping are shown in Table 3.1. These guidelines are based primarily on slope gradient, surficial material type and texture, and the presence of geomorphological processes. However, professional judgment is used in applying the criteria on a polygon by polygon basis. For example, the mapper may adjust ratings according to site-specific factors such as slope morphology and soil drainage. A slope morphology that includes irregular, near-surface bedrock would be rated as more stable than a similar slope with a smooth profile, because bedrock irregularities are more likely to hold surficial materials in place. Relatively poorly drained, wet slopes may be prone to slope failures through a reduction in normal stress due to high pore water pressure in the soil. Where wetter areas are mapped on slopes with gradients that occur within the upper end of a slope steepness class range, the polygon may be rated one terrain stability class higher.

Table 3.1 Guidelines for the assessment of detailed terrain stability classes.

Dominant texture	Typical surficial material	TERRAIN STABILITY CLASS					
		I	II	III	IV		V
					Dissected slopes (-V)	Uniform slopes	
fine s, z, c, m	LG, E	< 10%	10 – 25%	25 – 40%	>35%	>40%	all materials and landforms that are unstable
s, sdm, sdz	LG, M	< 15%	15 – 30%	30 – 55%	>45%	>55%	
dzs, zds, g, sd, sr, sx	M, F, FG, C	< 20%	20 – 40%	40 – 60%	>50%	>60%	
Fissile sedimentary bedrock and highly foliated metamorphic rock		< 20%	20 – 40%	40 – 60%	>50%	>60%	
a, b, resistant bedrock	C, R	< 25%	25 – 50%	50 – 70%	-	>70%	

Note: Numerical ranges in the table refer to the dominant range of slopes in percent. See Appendix A for definitions of texture and surficial material type. The classes indicate the likelihood of instability resulting from mine development activities that occur in the upper few metres of the land surface in *in situ* surficial materials and bedrock

3.2.2 Soil Erosion Potential

Soil erosion potential refers to the removal of material, particle by particle, by rain splash and the tractive force of surface runoff (soil erosion by wind is not considered in this assignment). Conditions that influence surface runoff, such as slope steepness, slope morphology, and material type and texture, form the criteria used to assess soil erosion potential. The method for assigning surface erosion potential followed the provincial standard used in the forest industry (B.C. Ministry of Forests, 1999). Soil erosion potential ratings range from VL (very low) to VH (very high), and refer to *in situ*, unvegetated surficial materials that are exposed as a result of development activities. The ratings do not apply to undisturbed, vegetated terrain, and they do not apply to future development-related deposits such as stockpiles, tailings and waste rock.

Sediments that are most susceptible to erosion consist of silt and fine sand with few or no clasts. Surficial materials with these properties may include glaciolacustrine, glaciofluvial and fluvial

deposits, till, and eolian sediments. Materials that are least susceptible to soil erosion consist of mainly coarse fragments (>2 mm) with little or no matrix, peat, or bedrock. Coarse-grained materials that often contain little or no matrix include some types of colluvium, glaciofluvial and fluvial sediments, and ablation till.

The criteria used for rating soil erosion potential are shown in Table 3.2. These criteria serve as a guideline only and may be modified by the mapper due to other slope characteristics. For example, concave shaped slopes (either across or down slope) tend to concentrate moisture and will generally have higher soil erosion potential ratings than straight or convex slopes. Similarly, slopes with abundant seepage will be given higher soil erosion potential ratings.

Table 3.2 Guidelines for the assessment of soil erosion potential classes

SURFICIAL MATERIAL CHARACTERISTICS		DOMINANT GRADIENT RANGE (%)		
		0 – 40%	> 40%	>30 - 40%
Dominant texture (In approximate order of decreasing erodibility)	Typical surficial material	Gentle to moderate gradient slopes; irregular, benched, terraced	Moderately steep and steep slopes	Dissected slopes
matrix supported: fine s, z, m	LG, M, E, F, FG	H	VH	VH
matrix supported: coarse s, ds, gs, sdm, sdz, c (cohesive)	FG, C, M, F, LG	M	H, VH	VH
consolidated till	M	L	M	VH
clast supported: g, sd, sr, sx	F, FG, C, M	L	M	H
resistant bedrock, talus slopes	R, C	VL	VL	VL
organics (peat bogs)	O	VL	-	-

Note: See Appendix A for definitions of texture and surficial material type. The classes indicate the likelihood of soil erosion resulting from mine development activities that expose *situ* surficial materials.

3.2.3 Terrain Stability and Soil Erosion Potential - Management Implications

Terrain stability and the potential for soil erosion should be considered as a part of the planning for construction activities related to mine development. Where construction activities are planned in areas in and near polygons rated as TS Class IV and V and SEP classes H and VH, it is recommended that detailed, site-specific assessments are conducted in order to implement construction techniques that minimize the risk of landslides and/or soil erosion.

Persons using terrain stability and soil erosion potential ratings should bear in mind that conditions are locally variable. Ratings indicate the mapper's judgment regarding the typical conditions for each terrain polygon, but locally steeper slopes, wetter slopes, emergence of water from seepage zones, and fine-grained materials give rise to areas that are potentially more unstable and/or subject to erosion than their surroundings. Consequently, persons planning, field marking, and constructing roads and other excavations should recognize and take into account the local conditions. The run-out and deposition zone of potential slides in terrain below potentially unstable and unstable terrain should be carefully assessed, especially where there is a risk to human life, infrastructure or resource values. General implications for detailed terrain stability classes are shown in Table 3.3 and those for soil erosion potential classes are provided in Table 3.4.

Table 3.3 Management implications of detailed terrain stability classes

Class	Rating	Implication
I	Negligible	No significant stability problems exist.
II	Very Low	There is a very low likelihood of landslides following mining-related construction. Minor slumping is expected along cut slopes, especially for one or two years following construction.
III	Low	Minor stability problems can develop. Minor slumping is expected along cutslopes, especially for one or two years following construction. There is a low likelihood of landslide initiation following mining-related construction.
IV	Moderate	Expected to contain areas with a moderate likelihood of landslide initiation following mining-related construction.
V	High	Expected to contain areas with a high likelihood of landslide initiation following mining-related construction.

Source: B.C. Ministry of Forests, 1999.

Table 3.4 Management implications of soil erosion potential classes

Class	Rating	Implications
VL	very low	Negligible or very minor soil erosion.
L	low	Expect minor erosion of fines bare soils.
M	moderate	Expect moderate erosion when water is channeled onto bare surfaces.
H	high	Significant erosion problems can be created when water is channeled onto or over exposed soil on these sites.
VH	very high	Severe surface and gully erosion problems can be created when water is channeled onto or over these sites.

Source: B.C. Ministry of Forests, 1999.

3.2.4 Reliability

The terrain stability mapping is based exclusively on air photo interpretation and relied on field data collected by a third party. The current assignment did not include any ground-based field verification. While the mapping was conducted by an experienced terrain mapping specialist, bioterrain, terrain stability and soil erosion potential mapping does not replace the need for on-site assessments for areas of proposed development. Uncertainty is inherent in this type of analysis, which is affected by air photo quality, photo scale, and especially the presence of shadows in forested and high relief terrain. The accuracy of polygon boundaries is limited by the scale and dates of the air photos upon which the mapping was based. The information and analyses contained in this report are based on observations of land-surface conditions and the current understanding of terrain stability and soil erosion potential. The following factors have not been taken into account by this study: subsurface conditions (e.g. groundwater conditions) not detectable by air photo interpretation or surface observations, events whose time of occurrence and severity cannot be predicted (e.g. storm events), management practices, and land-use. Maps 1 and 2 were created at 1:20,000 scale and are intended to be used at this or smaller scale.

4.0 TERRAIN AND LANDFORMS FOR THE RSA AND LSA

4.1 TILL (M) (M1)

Till is deposited directly by glaciers and usually exists as a veneer (Mv), blanket (Mb), or mantle of variable thickness (Mw) over the underlying bedrock surface. It typically consists of a fine-grained matrix (particles <2 mm) that surrounds and supports clasts (particles >2 mm) of a variety of sizes, shapes and rock types. Till characteristics, such as texture (particle sizes) and consolidation (or bulk density), vary according to specific processes of deposition by glacier ice (e.g., subglacial vs. supraglacial tills). These deposits can be highly variable and gradations in texture and consolidation can vary over short distances. Over the last 12,000 years, the upper half metre to one metre of these deposits have been weathered by pedogenic processes creating loose, permeable soils. The lower slopes are typically Brunisols and the upper slopes are generally Podzols.

Basal till (subglacial till) is deposited at the base of a glacier creating highly consolidated material. As a result, basal till has a relatively low permeability and commonly acts like an impermeable layer. It tends to be the strongest of all surficial materials.

Within the Study Area, till is the most common surficial material. The tills are finer grained, (sandy silt with some clay), especially where they are underlain by rock types that weather to fine material such as most of the rock types of the Eagle Bay Assemblage. Tills mapped in the southwest corner of the Study Area that are underlain by plutonic bedrock are sandy with some silt. In general, till is thicker on the lower slopes and tends to thin with elevation on either side of the North Thompson River Valley. Till is thin and discontinuous on steep slopes. On the plateau, till is generally thicker in the depressions and thin to patchy on the crests of the undulating terrain.

4.2 COLLUVIUM (C)

Colluvium has accumulated during post-glacial times as a result of gravity-induced slope movement, for example, rock fall and soil creep. The physical characteristics of colluvium are closely related to its source and mode of accumulation. Four processes generally create colluvial deposits: (1) rockfall

from bedrock bluffs, (2) soil creep in weathered bedrock, (3) mass movement processes in surficial materials (debris flows and debris slides), and (4) rockslides and rock slumps.

Rockfall from bedrock bluffs typically forms talus slopes (Ck). Talus is loosely packed rubble or blocks with little interstitial silt and sand near the surface, and is rapidly drained. Within the study Study Area, talus slopes are mapped in polygons 354, 356, 411, 430, 658, 703, 704, 710, 712, 763, and 764 (Map 1).

Colluvial veneers (Cv) and blankets (Cb) develop where weathered bedrock or surficial materials has been loosened and moved downslope by gravitational processes such as soil creep. It is loosely packed and usually rapidly drained. Within the Study Area, colluvial veneers and very thin veneers are most common on upper, moderately steep and steep gradient slopes and as discontinuous, very thin veneers on bedrock-controlled terrain. This can be found on the steep slopes of the larger creeks, including Baker, Jones, Avery, Chuck and Harper Creeks and the lower slopes of Harp Mountain. The matrix texture of the colluvium reflects the bedrock or surficial materials it is derived from.

Colluvial fans (Cf) and cones (Cc) form at the base of steep gullies due to deposition by debris flows (-Rd). These deposits are generally compact, and sorting may range from poorly sorted to well sorted. The deposit may or may not be matrix supported, and the matrix is usually sand. In the Study Area, colluvial fans are mapped at the mouths of some of the steep creeks within the Study Area, including in the following polygons: 17, 22, 114, 394, 402, 477, 478, and 549 (Map 1).

Deep-seated slumps in bedrock and surficial materials result in hummocky, irregular colluvial deposits (Chu). Rock slumps contain blocks and rubble with little or no interstitial silt and sand. Within the Study Area, deep seated bedrock slumps are mapped in polygons 339, 341, 350, 354, 356, 361, 368, 370, and 371 (Map 1).

4.3 WEATHERED BEDROCK (D)

Weathered bedrock has been modified *in situ* by mechanical and chemical weathering. In the Study Area, weathered bedrock is found as a discontinuous very thin veneer (Dx) overlying gently sloping or undulating bedrock outcrops. It typically contains a high proportion of angular coarse fragments with varying amounts of interstitial silty sand. It is non-cohesive and rapidly to very rapidly drained. Within the Study Area, weathered bedrock is present on the gentle plateau and most commonly found in association with the sedimentary rocks of the Slate Creek Unit (Section 2.2).

4.4 GLACIOFLUVIAL MATERIALS (FG)

Glaciofluvial materials were deposited by glacial meltwater streams near the end of the most recent glaciation. Sands and gravels accumulated along ice margins and on top of melting ice (FGu) (ice contact deposits), and downstream of glaciers (FGp) (outwash plains). Where outwash streams flowed onto flat ground, fans (FGf) were formed. Where outwash streams drained into former lakes, deltas (FGf and FGp) were created. Postglacial streams have incised into some outwash plains and fans transforming them into terraces (FGt) and scarps (FGk).

Glaciofluvial materials consist of sand and gravel with small quantities of finer material and are potential sources of aggregate. Sorting and bedding characteristics are variable depending on the mode and site of deposition. Gravels range from unsorted to well-sorted and bedding can range from absent to well-defined. Glaciofluvial deposits are loose (uncompacted) and clasts tend to be more subrounded than subangular. Ice-contact deposits may have distorted bedding, slump structures and faults as a result of settling and collapse due to the melting of supporting ice. Ice contact deposits may also contain lenses of fine-textured glaciolacustrine sediments and coarse-textured ablation till. Beds in raised deltas are inclined up to 40%, and indicate the frontal slopes of depositional landforms.

Extensive glaciofluvial terraces formed along the valley bottom (outwash terraces) and the lower valley sides (kame terraces) of the North Thompson River. Remnants of raised glaciofluvial fans are located at the mouths of Baker, Jones, Avery and Chuck creeks. Meltwater channels and glaciofluvial terraces are present along the Harper Creek valley bottom. Small pockets of

glaciofluvial sediments are mapped on the wide basin on the plateau, for example in polygons 459 and 460 (Map 1).

4.5 FLUVIAL MATERIALS (F)

Fluvial materials include sands and gravels transported and deposited post-glacially by streams. These sediments are loose, non-cohesive and highly porous and permeable. Associated landforms, such as floodplains (Fp, FAp) and parts of fans that are close to stream-level, have high water tables and are moderately to imperfectly drained. Floodplains are subject to periodic inundation during high flows. Fluvial terraces (Ft) stand above present day creek-levels, are relatively well drained and dry.

Within the Study Area, the North Thompson River flows through and has formed a wide fluvial terrace along the valley bottom. Fluvial fans have formed at the mouths of many of the larger creeks including Baker Creek, Jones Creek, T Creek and Peavine Creek. The wetlands located in the wide narrow basin at the location of the tailings management facility (TMF) consist of alternating layers of fine-grained fluvial sediments with layers of organic material (Figure 4.1).

Figure 4.1 Alternating layers of fine-grained fluvial sediments and organic material located in the large wetland polygon (polygon 460) on the plateau.

4.6 GLACIOLACUSTRINE SEDIMENTS (LG)

Glaciolacustrine materials have been deposited in glacial or ice-dammed lakes that were present during and shortly after glaciation. Glaciolacustrine materials generally consist of well to moderately well stratified fine sand, silt and/or clay with occasional lenses of till or glaciofluvial material. Glaciolacustrine materials are generally only slowly permeable, and so the presence of even a thin layer of this material is sufficient to cause impeded drainage, perched water tables, and surface seepage. These conditions may promote instability in some situations. These fine-textured materials are also susceptible to surface erosion by running water.

Within the Study Area, small areas of glaciolacustrine sediments deposited by ice-dammed lakes are located near the mouth of Chuck Creek and in polygons 780 and 781 (Map 1) where Avery Creek meets the LSA boundary. Knight Piesold found glaciolacustrine sediments at site WP33 in the wetland on the plateau below the main embankment (Knight Piesold, 2012b).

4.7 ORGANICS (O)

Organic materials form where decaying plant material accumulates in poorly or very poorly drained areas, for example wetlands. Organic sediments are common in the wide gentle basin located on the plateau in the area to be covered by the TMF. The organic materials occur as thin layers alternating with thin layers of fine-grained fluvial sediments (Figure 4.1).

4.8 ANTHROPOGENIC MATERIAL (A)

Anthropogenic materials are deposits that are sufficiently reworked or redistributed by human activities that their original character is lost. Examples include gravel pits and fill used for roads and other construction. This material is mapped in the vicinity of Vavenby and at the former Weyerhaeuser mill site (current location of the proposed rail concentrate load-out area) on the north side of the North Thompson River.

5.0 GEOHAZARDS AND GEOMORPHOLOGICAL PROCESSES IN THE RSA AND LSA

Geohazards within this report include mass movement geomorphological processes that may represent a hazard to life, property or the environment. This includes landslides, slumps, rockfall and snow avalanches (i.e., processes that can be reasonably inferred based on the air photos). Geohazards not considered during this project include seismicity (i.e., earthquakes) and flooding. For this project, geohazards visible on the air photos have been identified with on-site symbols on both the Terrain and Geohazard Map (Map 1) and the Terrain Stability and Soil Erosion Potential Map (Map 2). Polygons that contain geohazards include geomorphological labels in the terrain label on Map 1. These labels describe the geohazard type and whether the polygon contains the initiation zone or deposition zone of the mass movement process. Polygons have been colour-themed based on geohazard type (Map 1).

This report provides an inventory of geohazards, specifically mass movement processes. The scope of this assignment did not include determination of magnitude, frequency, and/or consequence of the geohazards, and thus it is not considered a geohazard risk assessment. The geohazards mapping indicates the current distribution of mass movements based on the visual evidence identified during the air photo review. Knowledge of where existing geohazards (Map 1) and potential geohazards (TS class IV and V polygons on Map 2) are located provides direction to focus future detailed geohazard and slope stability studies.

Rapid mass movement refers to downslope movement by falling, rolling or sliding of debris derived from surficial material and/or bedrock. Where a double prime symbol (”) is used with a mass movement process (e.g., -R”s), slope failure has initiated within the polygon. Mass movement symbols without the double prime symbol (e.g., -Rb) indicate a polygon that contains the transport or deposition zone of rapid mass movement. Transportation zones are generally not recognized as areas where landslides initiate; they may contribute additional volume of transported material to a failure. Transport and deposition zones represent hazardous areas downslope of slides or rockfalls.

The geohazards and other geomorphological processes mapped in the Study Area are included next. Section 6.0 describes the location and types of geohazards with respect to the proposed and existing infrastructure.

5.1 DEBRIS SLIDES (-R"S) AND DEBRIS FLOWS (-R"D)

Debris flows (-Rd) generally initiate in steep gullies and debris slides (-Rs) initiate on steep hillsides. They occur when a mass of surficial material slides rapidly downslope often as a result of the loss of soil strength due to high pore water pressure. Debris slides (non-channelized movement of debris) and debris flows (channelized movement of debris) are initiated on steep slopes where material slides along a shear plane. The shear plane often coincides with the boundary between more permeable and less permeable material (e.g. between weathered and unweathered material or between surficial material and bedrock). Debris flows and debris slides are triggered by heavy rain, water from snow melt, and/or rain on snow events, and result from loss of soil strength due to high pore water pressure. During wet conditions, slides are also triggered by wind stress on trees, tree throw, impact of falling rocks from up slope, and vibrations due to earthquakes or human activity. In logged areas, debris slides that occur several years after logging can be due to the loss of soil strength that results from root decay. Diverted drainage from roads commonly triggers failure of sidecast material and may initiate landslides some distance downslope. A debris flow may move downslope for several hundred metres or more before it is arrested by gentler terrain or by de-watering, or it may enter a trunk stream. Debris flows are effective agents of erosion, commonly increasing the volume of material as it progresses downslope. Debris slides and debris flows are significant potential sources of stream sediment and are a hazard to activities or structures (roads, culverts) located in runout zones.

Within the Study Area, debris slides and flows are mapped in many of the larger creeks, including Baker, Jones, Avery, Chuck, P and T creeks.

5.2 DEBRIS SLUMP (-R"U, F"U, R"X, -F"X)

Slumps in surficial materials consist of deep-seated, rotational failures along a zone of weakness within thick deposits. Small debris slumps are mapped in many of the steep gully walls of the larger creeks in the Study Area and the steep banks undercut by North Thompson River.

5.3 DEBRIS FLOOD

A debris flood is a rapid surging flow of water containing debris that occurs generally in second or higher order channels (moderate to moderately steep channels). Debris floods commonly settle out at slopes less than 10 degrees (e.g. on gently sloping colluvial fans). This geohazard was not mapped in the LSA. However it is included because this is the only hazard that has the potential to reach the LSA from the Upper Chuck Creek watershed (RSA Unit 2). If a debris flood initiating in RSA Unit 2 reached the lower Chuck Creek located inside the LSA, there is no project infrastructure in the pathway of the flood. A large debris slide occurring in P or T creeks could potentially initiate a debris flood in the upper reaches of Harper Creek. A short segment of the mine access road enters the Barriere River watershed on the plateau. This section of road is located immediately upslope of a potential unstable polygon 746. If large slide were to occur from this polygon, this could potentially initiate a debris flood in the upper reaches of the Barriere River. However, there is no evidence on the air photos that such events have occurred in these watersheds.

5.4 ROCK FALL (-R"B),

Rockfall (-Rb, -R"b) occurs when either a single block or a mass of bedrock falls, bounces and rolls downslope. In the assessment area, rockfall from local outcrops creates talus slopes, colluvial veneers and blankets. Polygons with rockfall are scattered throughout the Study Area in association with local bedrock outcrops or cliffs.

5.5 ROCK SLUMP, TENSION CRACKS (-F"M, -R"M, -F"K)

A slump in bedrock refers to a rotational slump where portions of the slide mass remain internally cohesive. Rotational slumps develop due to failure along vertical joints and horizontal weak layers.

Tension cracks are open fissures and lateral spread in bedrock that appear as structural lineations (trough oriented roughly parallel to the contour). These deep-seated features are commonly located near ridge tops. They indicate slow slope spreading, and may be the precursor to potentially catastrophic slope failure.

Bedrock slumping and tension cracks are mapped in the southwest corner of the Study Area in polygons 339, 341, 350, 354, 356, 361, 368, 370, and 371 (Map 1).

5.6 SNOW AVALANCHE (-A, -AF, AM)

Snow avalanches are rapid slides and flows of snow. Rocky and vegetative material is commonly transported by the snow. They present a hazard to winter and spring activities, and accumulated avalanche snow can delay the opening of roads in the spring. Removal of forest adjacent to the runout zone of an avalanche track may result in extension of the runout distance. A buffer of forest between the development area and the avalanche track can reduce the likelihood of this impact. Snow avalanches are mapped in P Creek. Snow avalanches are present in RSA 6 in the south portion of the Study Area.

5.7 ABUNDANT SEEPAGE (-L)

Seepage is mapped where relatively wet soils are widespread in a polygon. This commonly occurs where soils are on slowly permeable materials such as till, where thin surficial materials overlie bedrock, and on lower slopes where shallow subsurface water is received from a relatively large catchment area further upslope. They may also occur where groundwater is concentrated at the surface by a physical conduit such as a geological fault. Within the Study Area, this has been mapped in many depressions on the plateau.

5.8 GULLY EROSION (-V)

Gullies are small ravines typically with V-shaped cross sections that can form in either glacial material or bedrock. Gully erosion has been mapped in two kinds of terrain: (i) slopes with several

parallel shallow gullies in thick surficial materials (dissected slope) and (ii) single gullies where streams have exploited joints in bedrock or have cut down into thick surficial materials. Gullied terrain is an indicator of either former or active erosion, and the symbol serves to identify material that is potentially subject to erosion or mass movement (e.g., Uk-V). Gully sideslopes and steep headwalls are common sites of slope failures and are classed as potential unstable (Class IV) where there is no evidence of instability and unstable (Class V) where there is evidence of instability.

5.9 CHANNELED BY MELTWATER (-E, -EV)

Meltwater channels form alongside, beneath, or in front of a glacier or ice sheet. Glacial meltwater channels are typically sinuous in plan, flat-floored, and steep-sided in cross-section. The floors of the meltwater channel may contain glaciofluvial sediments, indicative of the water flow that once took place here. Meltwater channels are present near the valley bottom of Harper Creek.

5.10 GROUND DISTURBANCE (-G)

Ground disturbance refers to anthropogenic excavations where the remaining exposed surface has remained undisturbed and is *in-situ*; for example, the cutslopes in gravel pits, housing developments, and road cuts.

6.0 GEOHAZARDS AND TERRAIN STABILITY ASSESSMENT: RSA AND LSA

This section, identifies the proximity of existing and proposed infrastructure (file date May 12, 2014) to polygons mapped as TS Classes IV and V and polygons containing geohazards. This includes discussion of where existing and proposed infrastructure:

1. overlaps with polygons containing TS Classes IV and V and geohazards (project infrastructure is located on potentially unstable or unstable terrain);
2. is located immediately upslope of polygons containing TS Classes IV and V and geohazards (i.e. potential for downslope impact from the Project); and
3. is located immediately below polygons containing TS Classes IV and V and geohazards (i.e. potential for impact to the Project).

Table 6.1 summarizes this information for each of the proposed and existing infrastructure types.

This section also provides a discussion of the terrain and landforms in proximity to the existing and proposed infrastructure (i.e. AIR item 81). Also highlighted in this section are the potential impacts to existing and proposed infrastructure from upslope RSA 1, 2, 4, and 6. Locations where existing and proposed infrastructure could have an impact to downslope RSA 3 and 5 are also discussed.

Table 6.1 Summary of the proximity of existing and proposed infrastructure to geohazards and potentially unstable terrain.

Infrastructure Type	Geohazards with potential to affect project infrastructure		Potentially Unstable or Unstable Terrain[1]		
	Type	Polygon	Polygons containing project infrastructure	Polygons downslope of project infrastructure	Polygons upslope of project infrastructure
Rail Concentrate Loadout Area	-	-	-	-	-
Mine Access Road	Debris slide	535, 643	141, 686, 709	483, 647, 756	-
Non-PAG Waste Rock Water Management Pond and Non-PAG Waste Rock	Debris slide	208, 219, 229, 237, 244, 252, 267	208, 219, 229, 237, 240, 251, 252,254, 259, 287 288	267, 275, 291	236, 276, 281
	Snow Avalanche	251, 259			
	Rockfall and Snow Avalanche	240			
Open Pit	Debris slide	208, 219, 229	208, 219, 229	Polygons consisting of steep gully walls in Baker Creek and P Creek	-
Overburden Stockpile	-	-	-	-	-
West Topsoil Stockpile	-	-	-	-	-
PAG, Non-PAG, Processing Plant, East Topsoil Stockpile, North TMF Water Management Pond	-	-	-	-	-
Tailings Pipeline	Debris slide	208, 219, 252,	208, 219, 252, 288	Polygons consisting of steep gully walls in P Creek	-
Tailings Management Facility Pond and North TMF Water Management Pond	Rockfall	404, 409	404, 409, 476	-	412
Main Embankment and South TMF Water Management Pond	Rockfall	404, 409	404, 409, 476	339, 347, 341, 350, 354, 356, 357, 361, 368, 370, 371, 373, 375, 396, 403	-
South Topsoil Stockpile	-	-	-	-	-
Explosives Facility	-	-	-	-	-
Power Lines	Debris slide	Option 1: 519	141, 463, 519, 522, 555	-	709
	Debris slide	Option 2, Alt. 1: 602	141, 555, 602, 626, 627	-	709
		Option 2, Alt 2:	141, 555, 627, 638	-	709

Notes: 1. Terrain Stability Class IV and V. See Maps 1 and 2 for polygons referenced in this table.

6.1 RAIL CONCENTRATE LOADOUT AREA

This facility is located on a fluvial terrace of the North Thompson River. This facility is not likely to be affected by the geohazards reviewed in this assignment.

6.2 MINE ACCESS ROAD

The mine access road connects the rail concentrate loadout area in the North Thompson valley bottom with the processing plant on the plateau. The road follows existing public and forestry roads and crosses the North Thompson River, as well as many of the larger creeks or their tributaries, including Avery, Jones and Baker Creeks.

In the North Thompson valley bottom, the road is located on a fluvial terrace from the rail facility to the south side of the river. On the south side of the North Thompson River, the road climbs onto glaciofluvial terrace and follows this landform for about 3 km. Beyond this point, the road is built on till where thickness can range from very thin to several metres thick. In some areas, the road intersects bedrock.

The mine access road intersects two polygons within the LSA containing debris slides. Polygons 535 and 643 consist of the steep river banks of the North Thomson River in Vavenby where the road crosses the river. Due to the presence of landslides, these polygons are mapped as unstable. The road intersects the following three potentially unstable polygons: 141, 686 and 709. A section of the mine access road is located upslope from the Chuck Creek Canyon; the Chuck Creek canyon is mapped as potentially unstable (polygons 483 and 647). A short segment of the mine access road enters the Barriere River watershed on the plateau. **This section of road is located immediately upslope of a potentially unstable polygon 746. If large slide were to occur from this polygon, this could potentially initiate a debris flood in the upper reaches of the Barriere River (potential impact to RSA Unit 3).**

6.3 NON-PAG WASTE ROCK WATER MANAGEMENT POND AND NON-PAG WASTE ROCK

These facilities are located in P Creek; a tributary to Harper Creek. The gully walls consist of moderately steep to steep bedrock-controlled slopes partially covered by till and colluvium. Debris slides are present in several polygons (208, 219, 229, 237, 244, 252, and 267). Snow avalanche and rockfall is present at the western end of the facilities (240, 251, and 259). TS class IV and V terrain located upslope from the facilities includes polygons 236, 276, and 281 at the western end of the facilities. **TS class IV and V terrain located immediately downslope from the facilities include polygons 267, 275, 291 (where P Creek incises through thick glaciofluvial sediments). A large slide triggered from this area could impact the Upper Harper Creek (RSA Unit 5).**

6.4 OPEN PIT

The open pit is located largely on the plateau upslope from the non-PAG waste rock stockpile at the headwaters of P Creek and Baker Creek. This area consists of gentle bedrock–controlled plateau with discontinuous cover of thin till and weathered bedrock. The pit intersects three polygons (208, 219, and 229) which contain debris slides and are rated as TS Class V. TS Class IV and V polygons are mapped on the steep gully walls of P Creek and Baker Creek which are located downslope from the open pit. No potential upslope hazards to the open pit were identified.

6.5 OVERBURDEN STOCKPILE

The overburden stockpile is located on the plateau on gently undulating bedrock-controlled terrain that is partially covered by till and weathered bedrock. The stockpile does not intersect any polygons with geohazards, and it is located on and surrounded by stable terrain.

6.6 WEST TOPSOIL STOCKPILE

The west topsoil stockpile is located on the plateau on gently undulating bedrock-controlled terrain that is partially covered by till and weathered bedrock. The stockpile does not intersect any polygons with geohazards, and it is located on and surrounded by stable terrain.

6.7 PAG, NON-PAG, PROCESSING PLANT, EAST TOPSOIL STOCKPILE, NORTH TMF WATER MANAGEMENT POND

These facilities and stockpiles are located on the plateau characterized by gently undulating bedrock-controlled terrain that is partially covered by till and weathered bedrock. This facility is not likely to be affected by the geohazards reviewed in this assignment.

6.8 TAILINGS PIPELINE

The tailings pipeline connects the lower end of the TMF pond to the open pit. The pipe crosses the plateau from the TMF pond and crosses the upper slopes of the south gully wall of P Creek. Both the gully wall and plateau are bedrock-controlled slopes that are partially covered by thin deposits of till and weathered bedrock. Within the P Creek gully, the pipeline intersects polygons 208, 252, and 219 which contain debris slides and are rated as TS Class V. At the upper edge of the P Creek gully, the pipeline crosses a TS Class IV polygon (288). **Along this section of the pipeline, the downslope TS Class IV and V terrain contains the steep-sided gully walls of P Creek. There are no TS Class IV and V polygons located upslope from the pipeline. If a large slide were triggered from this area, Upper Harper Creek (RSA Unit 5) could potentially be impacted.**

6.9 TAILINGS MANAGEMENT FACILITY POND AND NORTH TMF WATER MANAGEMENT POND

This facility is located on a wide gentle basin on the plateau. The sides of the basin are underlain by thick till deposits. The low point along the centre of the basin consists of a large wetland with soils consisting of alternating layers of organic and fine-grained fluvial sediments (Figure 4.1). Pockets of glaciofluvial sediments are located in this area. Rockfall is mapped in polygons 404 and 409 at the southern edge of the pond. These two polygons area also rated with TS Class V. The southern edge of the pond intersects a polygon rated with TS Class IV. **There are no additional potential geohazards located upslope in RSA Unit 6 which could affect the facilities.** The rest of this facility does not overlap any polygons with identified geohazards, and it is located on and surrounded by stable terrain.

6.10 MAIN EMBANKMENT AND SOUTH TMF WATER MANAGEMENT POND

These facilities are located at the lower end of the wide, gentle basin mentioned in Section 4.3.9. Rockfall is mapped in polygons 404 and 409 at the southern edge of the main embankment. These two polygons area also rated with TS Class V. The southern edge of the main embankment intersects a polygon rated with TS Class IV. **There are no additional potential geohazards located upslope in RSA Unit 6 that could affect the facilities.** Within the LSA, the rest of this facility does not intersect any polygons with geohazards. Starting 400 m to the west of the main embankment, there is a large area of slumping and tensions cracks. This area is divided into several polygons, including 339, 341, 347, 350, 354, 356, 357, 361, 368, 370, 371, 373, and 375. TS Class IV terrain is located downstream along T Creek. **Any mass movements triggered in the vicinity of the bedrock slump and tension cracks noted above and in T Creek could potentially impact the Upper Harper Creek (RSA Unit 5).**

6.11 SOUTH TOPSOIL STOCKPILE

This stockpile is located on gently-sloping plateau terrain underlain by till of variable thickness. No geohazards were identified within the polygons where the south topsoil stockpile is located.

6.12 EXPLOSIVES FACILITY

This facility is located on gently-sloping plateau terrain underlain by till of variable thickness. No geohazards were identified within the polygons where the explosive facility is located.

6.13 POWER LINES

The proposed power line routes extend from Highway 5 on the north side of the North Thompson River (glaciofluvial terrace), across the river (fluvial terrace), and up the valley side (with optional routes on either side of Avery Creek) (glaciofluvial sediments on lower slopes and till on mid and upper slopes) to the plant site on the plateau. The power lines intersect two polygons (containing debris slides (rated as TS Class V) and consist of the steep-sided river banks of the North Thompson River. Option 1 route intersects TS Class IV polygon numbers 141, 463, 519, 522, and 555. Option 2, Alternative 1 intersects TS Class IV polygon numbers 141, 555, 602, 626, and 627. Option 2, Alternative 2 intersects TS Class IV polygon numbers 141, 555, 627, and 638. Polygon 709 is a TS

Class IV polygon located immediately upslope from all proposed route alignments. **It is unlikely that any potential slides initiating from the slopes of RSA will impact the northern edge of the Power Line where it meets Highway 5.** For many of these polygons, tower placement can likely be planned to span areas of existing instability or potentially unstable slopes.

7.0 SUMMARY AND RECOMMENDATIONS

7.1 TERRAIN, LANDFORMS AND SURFICIAL MATERIALS - SUMMARY

An overview of terrain, surficial materials and landforms for the entire Study Area is provided in Section 2.0. This report accompanies Map 1; a terrain map of the LSA providing a detailed distribution of surficial materials, geomorphological processes and soil drainage classes. In general, the North Thompson River consists of a wide floodplain with a series of fluvial terraces. The lower North Thompson valley slopes are flanked by glaciofluvial terraces and sediments. The mid and upper slopes are covered by varying thicknesses of till. Colluvium is present on the steepest slopes and weathered bedrock is present on many ridge crests of the bedrock-controlled, undulating terrain on the plateau. Organic material is present in a large wetland unit on the plateau, and there are small pockets of glaciolacustrine sediments in three locations. Detailed descriptions of terrain, landforms and surficial material are outlined in Section 4.0. A description of terrain, landforms and surficial materials in proximity to proposed and existing mine infrastructure is provided in Section 6.0.

7.2 GEOHAZARDS - SUMMARY

Geohazards and other geomorphological processes shown on Map 1 of the LSA are described in Section 5.0. Geohazards mapped within the Study Area include:

- debris slides;
- debris flows;
- debris slumps;
- rockfall;
- slumping in bedrock; and
- snow avalanche.

Section 6.0 provides a detailed description of the proximity of geohazards and potentially unstable terrain with respect to existing and proposed project infrastructure. This information is summarized in Table 6.1 and should be read in conjunction with Maps 1 and 2.

7.2.1 Debris Slides, Debris Flows and Debris Slumps

Steep-sided gully walls of all the larger creeks on the south side of the North Thompson River, including Baker, Jones, Avery, Chuck, P and T creeks, are the most common terrain types where debris slides, debris flows, and debris slumps occur. These landslides initiated in till, glaciofluvial sediments and weak rock types (fissile sedimentary bedrock and foliated metamorphic bedrock). Debris slides and slumps are present on the steep river banks of the North Thompson River, especially where these slopes are undercut by the river. Along the river banks, the landslides initiated in till and glaciofluvial sediments. Project infrastructure in close proximity to gullies on the north facing slopes of the North Thompson River banks and its valley to the south include the mine access road and the power lines. Mine infrastructure in P Creek may be affected by debris slides.

7.2.2 Rockfall

Rockfall occurs from isolated bedrock cliffs scattered throughout the Study Area. Mine infrastructure in P Creek could be affected by rock fall. A small area at the south edge of the main embankment and adjacent tailings beach overlap with polygons mapped with rockfall.

7.2.3 Slumping in Bedrock

A large bedrock slump is located below the main embankment and north of T Creek. Further detailed assessment of the identified bedrock slump is recommended as well as the potential impacts the main embankment could have on the slope.

7.2.4 Snow Avalanche

Snow avalanches are generally uncommon in the Study Area. However evidence of it is present where mine infrastructure is located in P Creek and near the southeast corner of the main embankment.

7.2.5 Potential Project-Related Impacts With Respect to the RSAs

Section 6.0 discusses locations where potential instability from the upslope RSAs (1, 2, 4, and 6) could impact project infrastructure and where downslope RSAs (3 and 5) could be impacted. In general, it is unlikely any potential geohazards initiating from the upslope RSA's (1, 2, 4, and 6) will reach existing and proposed mine infrastructure. Proposed mine infrastructure is located on and above potentially unstable and unstable terrain in P Creek. Geohazards initiating in P Creek could potentially impact RSA 5. The main embankment and the south TMF water management pond are located upslope from potentially unstable terrain and unstable terrain in T Creek and adjacent to the bedrock slump. Geohazards initiating from these areas could potentially impact RSA 5. It is unlikely that proposed and existing mine infrastructure will trigger a geohazard that will impact RSA 3.

7.3 RECOMMENDATIONS

It is recommended that more detailed, site-specific geohazard assessments be carried out by qualified registered professionals (QRP) for areas within the Project Site that can be impacted by upslope hazards, where Project Infrastructure is located on TSC Class IV and V terrain, and where the Project can potentially cause downslope impacts. The areas that require more detailed assessments include, but are not limited to, the polygons identified in Table 6.1. In summary those areas are:

1. the P Creek watershed (debris slide, debris flow, debris slump, snow avalanche and rockfall hazards);
2. the southeast corner of the main embankment (snow avalanche and rockfall hazard);
3. the bedrock slump on the Harper Creek valley located downslope of the main embankment;
4. the T Creek watershed (debris slide and debris flow hazards);
5. the mine access road where is it located upslope of steep gully walls, such as along Chuck Creek and above polygon 746 (tributary to the Barriere River) (debris slide and debris flow hazards),
6. the mine access road where it crosses creeks and their tributaries, such as Jones Creek (debris slide and debris flow hazards);
7. polygons with TS Class IV and V terrain crossed by the power line routes; and
8. any polygons with proposed or existing Project Infrastructure located on or near terrain that meets the criteria for potentially unstable (TS Class IV) and unstable (TS Class V) as outlined in Table 3.1.

8.0 REFERENCES

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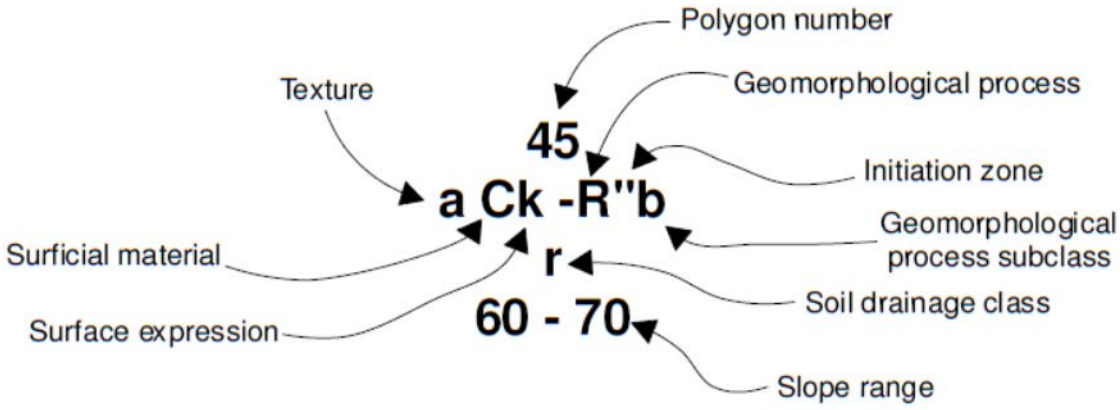
APPENDIX A: LEGEND FOR POLYGON LABELS

Map 1: Terrain and Geohazards Map Terrain Polygon Label:



A.1 TERRAIN SYMBOL

Composite Units: Two or three groups of letters are used to indicate that two or three kinds of terrain are present within a map unit.
Examples:

Mv.Rk indicates "Mv" and "Rk" are roughly equal in extent

Mv/Rk indicates "Mv" is more extensive than "Rk" (about 2/1 or 3/2)

Mv//Rk indicates "Mv" is much more extensive than "Rk" (about 3/1 or 4/1)

Mw/Rk indicates "Rk" is partially buried by "Mw"

Stratigraphic Units: Groups of letters are arranged one above the other where one or more kinds of surficial material overlie a different material or bedrock: e.g., Mv/Rr indicates that "Mv" overlies "Rr".

Note: one or more letters may be used to describe any characteristic other than surficial material, or letters may be omitted if information is lacking.

A.1.1 TEXTURE

Specific Clastic Terms

c	clay	< 2 µm
z	silt	2 - 62.5 µm
s	sand	62.5 µm - 2 mm
p	pebbles	2 - 64 mm; rounded particles
k	cobbles	64 - 256 mm; rounded particles
b	boulders	> 256 mm; rounded particles
a	blocks	> 256 mm; angular particles

Common Clastic Terms

d	mixed fragments	subrounded and subangular particles of all sizes
x	angular fragments	mixture of rubble (r) and blocks (a)
g	gravel	mixture of pebbles (p), cobbles (k), boulders (b) and up to 20% sand
r	rubble	angular particles < 64 mm
m	mud	mixture of sand (s) and silt (z)

A.1.2 SURFICIAL MATERIAL

A	Anthropogenic materials	Artificial materials and materials modified by human actions such that their original physical appearance and properties have been drastically altered.
C	Colluvium	Products of gravitational slope movements; materials derived from local bedrock and major deposits derived from drift; includes talus and landslide deposits. Includes up to 20% bedrock.
C1	Slope wash	Slope wash is a result of rainfall events in which non-channelized overland flow carries surface material downslope. Typical texture is silty sand or sandy silt with generally less than 5% coarse fragments.
D	Weathered bedrock	Bedrock modified *in situ* by mechanical and chemical weathering.
E	Eolian sediments	Sand and silt transported and deposited by wind; includes loess.
F	Fluvial sediments	Sands and gravels transported and deposited by streams and rivers; floodplains, terraces and alluvial fans.
FA	"Active" fluvial sediments	Active deposition zone on modern floodplains and fans; active channel zone.
FG	Glaciofluvial sediments	Sands and gravels transported and deposited by meltwater streams; includes kames, eskers and outwash plains.
L	Lacustrine sediments	Fine sand, silt and clay deposited in lakes.
LG	Glaciolacustrine sediments	Fine sand, silt and clay deposited in ice-dammed lakes.
M	Till	Material deposited by glaciers without modification by flowing water. Typically consists of a mixture of pebbles, cobbles and boulders in a matrix of sand, silt and clay; diamicton. Includes up to 20% bedrock and/or colluvium.
M1	Fine-grained glacial materials	The deeply gullied terrain implies that the soils are fine-grained; the soils are likely of glacial origin (ie till).
N	Non-classified	Non-classified, for example, lake.
O	Organic materials	Material resulting from the accumulation of decaying vegetative matter; includes peat and organic soils.
R	Bedrock	Outcrops and bedrock within a few centimetres of the surface. Includes up to 20% colluvium.
U	Undifferentiated materials	Different surficial materials in such close proximity that they cannot be separated at the scale of the mapping.

A.1.3 SURFACE EXPRESSION

a	moderate slope(s)	predominantly planar slopes; 15-26º (28 - 49%)
b	blanket	material >1-2 m thick with topography derived from underlying bedrock (which may not be mapped) or surficial material
c	cone	a fan-shaped surface that is a sector of a cone; slopes 15º (27%) and steeper
d	depression	enclosed depressions
f	fan	a fan-shaped surface that is a sector of a cone; slopes 3-15º (5-27%)
h	hummocky	steep-sided hillocks and hollows; many slopes 15º (27%) and steeper
j	gentle slope(s)	predominantly planar slopes; 4-15º (6 - 27%)
k	moderately steep slope	predominantly planar slopes; 26-35º (50 - 70%)
m	rolling topography	linear rises and depressions; < 15º (27%)
p	plain	0-3º (0-5%)
r	ridges	linear rises and depressions with many slopes 15º and steeper
s	steep slope(s)	slopes steeper than 35º (> 70%)
t	terrace(s)	stepped topography and benchlands
u	undulating topography	hillocks and hollows; slopes predominantly <15º
v	veneer	material <1-2 m thick with topography derived from underlying bedrock (may not be mapped) or surficial materials; may include outcrops of underlying material
w	mantle	surficial material of variable thickness
x	thin veneer	a subset of v (veneer), where there is a dominance of surficial materials about 10-25 centimetres thick

A.1.4 GEOMORPHOLOGICAL PROCESSES

E	Glacial meltwater channels	Areas crossed by meltwater channels that are too small or too numerous to map individually.
F	Failing	Slope experiencing slow mass movement, such as sliding or slumping
G	Ground Disturbance	Anthropogenic excavations where the remaining exposed surface has remained undisturbed and is *in situ*.
L	Surface seepage	Zones of active seepage often found along the base of slope positions.
R	Rapid mass movement	Slope or parts of slope affected by processes such as debris flows, debris slides and avalanches, and rockfall
U	Inundation	Inundation refers to areas that are seasonally flooded, for example marshlands
V	Gullying	Slope affected by gully erosion.

A.1.5 GEOMORPHOLOGICAL PROCESS SUBCLASS

-F"	slow mass movement - initiation zone
-Fk	tension cracks
-Fm	slump in bedrock
-Fu	slump in surficial material
-R	rapid mass movement
-R"	rapid mass movement - initiation zone
-Rb	rock fall
-Rd	debris flow
-Rs	debris slide
-Rfl	debris flood

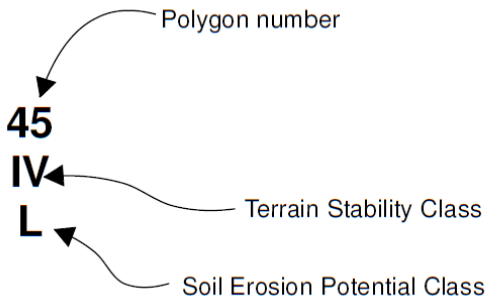
A.2 SOIL DRAINAGE CLASS

x	very rapidly drained	water is removed from the soil very rapidly in relation to supply
r	rapidly drained	water is removed from the soil rapidly in relation to supply
w	well drained	water is removed from the soil readily but not rapidly
m	moderately well drained	water is removed from the soil somewhat slowly in relation to supply
i	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
p	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
v	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
Where two drainage classes are shown: -if the symbols are separated by a comma, e.g., "w,i", then no intermediate classes are present; -if the symbols are separated by a dash, e.g., "w-i", then all intermediate classes are present		

A.3 SLOPE STEEPNESS RANGE

Slopes are given in percentages as a range. For example, '20-45' indicates that the majority of the slopes in the polygon are between 20% and 45%.

Map 2: Terrain Stability and Soil Erosion Potential Map Polygon Label:



A.4 TERRAIN STABILITY CLASS

Class	Rating	Implication
I	Negligible	No significant stability problems exist.
II	Very Low	There is a very low likelihood of landslides following mining-related construction Minor slumping is expected along cut slopes, especially for one or two years following construction.
III	Low	Minor stability problems can develop. Minor slumping is expected along cutslopes, especially for one or two years following construction. There is a low likelihood of landslide initiation following mining-related construction.
IV	Moderate	Expected to contain areas with a moderate likelihood of landslide initiation following mining-related construction.
V	High	Expected to contain areas with a high likelihood of landslide initiation following mining-related construction.

A.5 SOIL EROSION POTENTIAL CLASS

Class	Rating	Implications
VL	very low	Negligible or very minor soil erosion.
L	low	Expect minor erosion of fines bare soils.
M	moderate	Expect moderate erosion when water is channeled onto bare surfaces.
H	high	Significant erosion problems can be created when water is channeled onto or over exposed soil on these sites.
VH	very high	Severe surface and gully erosion problems can be created when water is channeled onto or over these sites.

APPENDIX B: GENERAL CONDITIONS

This report incorporates and is subject to these general conditions.

B.1 USE OF REPORT

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than to which it refers. Any variation from the site or development would necessitate a supplementary assessment.

This report and the recommendations contained herein are intended for the sole use of Polar's client. Polar does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any other party than Polar's client unless otherwise authorized in writing by Polar. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Polar. Additional copies of the report, if required, may be obtained upon request.

B.2 NATURE AND EXACTNESS OF SOIL, SURFICIAL MATERIAL AND/OR ROCK DESCRIPTIONS

Classification and identification of soils, surficial materials, and rocks are based upon commonly accepted methods employed in geoscience practice. This report contains descriptions of the methods used. Where deviations from these methods prevail, they are specifically mentioned.

Classification and identification of geological units or terrain polygons are judgmental in nature as to both type and condition. The information and interpretations presented in this report must be applied with due recognition of the inherent limitations associated with the use of remote sensing information, including aerial photos. Where such information is used, it should be recognized that while such information may reasonably represent the conditions on the ground at the same scale and date as that of the photos, any mapping or interpretations based on the information cannot be expected to reflect variations occurring on smaller spatial scales or changes that may occur after the date the information was collected. In addition, there is a limited level of accuracy associated with

the procedure. Field inspections are useful in confirming the spatial extent and likely depth of a given soil or surficial material, but they are by definition inspections of the ground surface; our judgment concerning the three dimensional extent of the material are the product of interpretation of information available at the surface. In addition, no areas in this assignment were field checked, which further limits the mapping accuracy.

The present report represents the current information available; it is valid for the condition of the study (assessment) area as of the date of the information, verified by observations on the date of the field review. If further information or observations become available, the interpretations and conclusions contained within this report may require updating.

Polar does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in geoscience practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified professional(s) should revisit the site and review recommendations in light of the actual conditions encountered.

B.3 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

Any stratigraphic and geological information indicated on drawings contained in this report are inferred from surface observations and/or shallow hand dug test pits and/or soil/rock exposures. Stratigraphy is known only at the locations of the test holes or exposures. Actual geology and stratigraphy may vary from that presented in this report. Natural variations in geological conditions are inherent and are a function of the historic environment. Polar does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

B.4 SURFACE WATER AND GROUNDWATER CONDITIONS

Any surface water and groundwater conditions that are mentioned in this report are those observed at the times recorded in the report. These conditions vary with location, time, development activity, and in response to special meteorological conditions. Interpretation of water conditions from

observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology, and development activity. Deviations from these observations may occur during the course of development activities. Where surface water or groundwater conditions encountered during development are different from those described in this report, qualified professional(s) should revisit the site and review recommendations in light of actual conditions encountered.

B.5 OBSERVATIONS DURING DEVELOPMENT

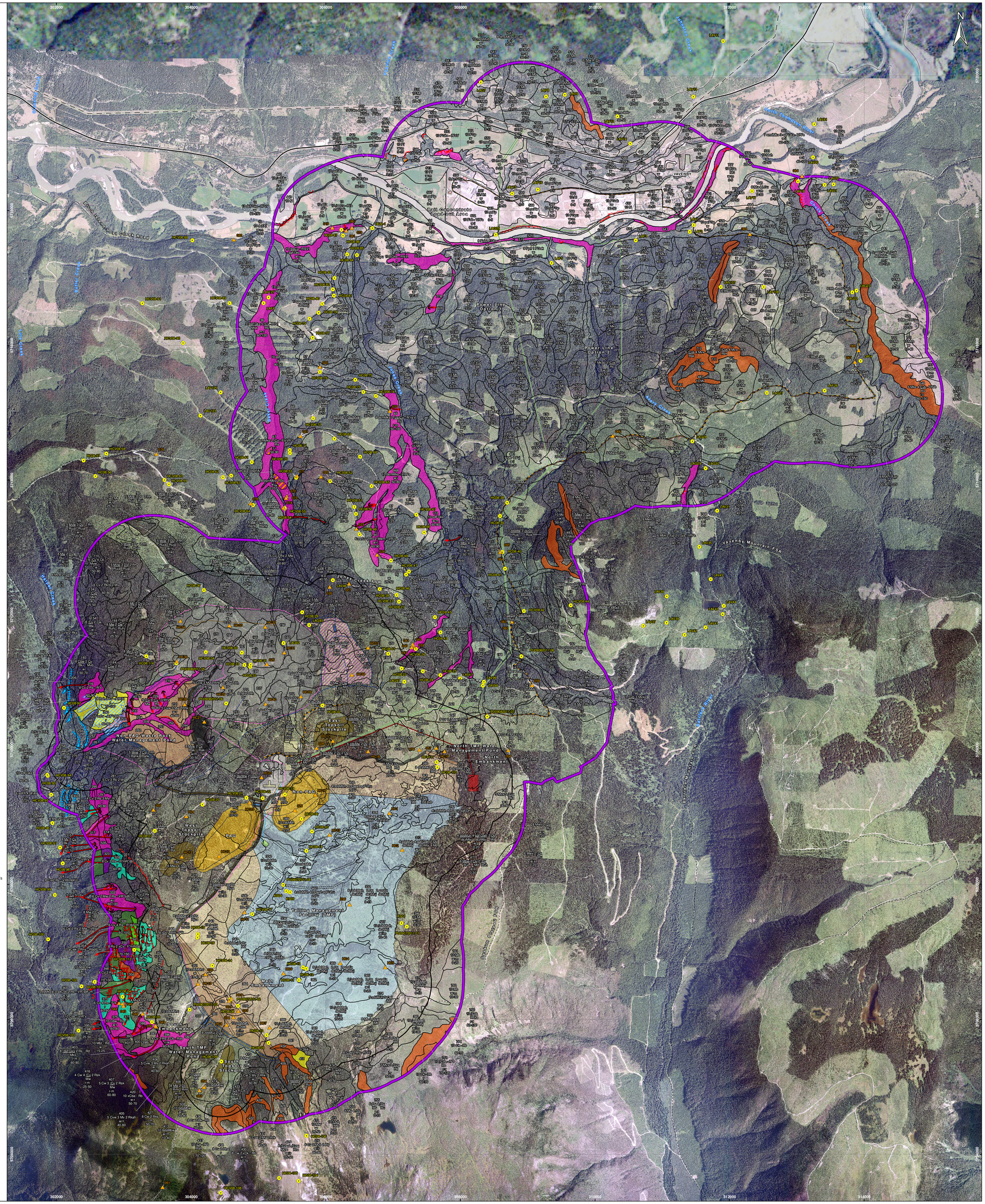
Because the nature of geological deposits, the judgmental nature of the assessment, as well as the potential adverse circumstances arising from development activity, observations during site preparation, excavation and construction should be carried out by a qualified professional, where specified in this report. These observations may then serve as the basis for confirmation and/or alteration of recommendations presented herein.

B.6 STANDARD OF CARE

Services performed by Polar for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the results, comments, recommendations, or any other portion of this report.

B.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Polar has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.



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9 10 FGk w 60-70	206 8 Cbw 2 Cv Rk Mvb w 50-70	323 8 Cv 2 Rs - VtRmbR'd w/i 60-90	523 10 FGj w 5-25
15 10 sgFGbs dsmMks w-i 60-90	207 10 Mb Rj i/m 0-20	325 6 Mwx 4 Dx Ruj m-x 50-70	524 10 Mvb w 10-25
16 10 sgFAp i-m 0-25	208 8 Msk 2 Cxx - R'sx Rs r-m 60-90	330 10 Cv Rks r 30-50	563 8 msdMAwa 2 FGks w 40-70
19 10 sgFGks dsmMks w-i 60-80	210 10 dmsMv zrsDv m/i 15-25	338 8 Cv 2 Rk r 50-70	564 10 Cak w 5-40
24 10 sFGv ksqvFGpu m-w 0-20	211 6 Cv 2 Mv 2 Rhk w-r 20-40	341 6 Rsr 4 xCvw - Ft'kmR'b r 70-150	569 10 gsFt w 0-40
25 10 sFGv ksqvFGk w 50-70	215 8 dsmMw 2 rzsDv Ruj Ruj w-m 0-20	347 8 Rhk 2 xCv - F'k r 40-70	570 10 msdMu w 0-10
35 5 Qv 3 Mvb 2 Rs Rsk Rsk r-i 60-100	219 6 Cv 2 Rs 2 Mv - R's r 60-90	356 8 aCwx 2 Rhs - Rb r 60-150	572 10 gCvs Mv w 60-75
41 7 jCvx 3 dFAj Ft w-i 0-25	233 8 Mv 2 Rh Ruhj w-r 0-20	359 10 Cvb w 40-60	573 10 Mbv w 20-40
43 10 Mw Ru w 0-20	236 6 Cvb 2 Mv 2 Rs - R's r/w 60-80	361 8 ItxCvDy 2 dsCvb - F'm zdsMb Rk w/r 50-80	574 10 Mka w 50-70
44 10 Mvb Ra w 40-50	239 8 Mv 2 Rh Ruhj w,r 10-40	362 4 jCv 4 zdFx 2 jCv zdsMd zdsMd zpsFAp w-p 0-10	580 10 gCv Mv w-r 50-70
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52 8 Mkaw 2 dFAj w-i 50-70	242 10 zsrDcx Ruj r-m 10-25	364 4 zdsMbh 4 NZw 2 sgFGhu zsFv w-p 0-20	589 10 FGka w 30-50
58 6 jCvx 4 dFAj Ft w-i 0-25	244 8 Mv 2 Rh Ruhj w-r 10-40	366 10 Mbw w-i 20-40	590 10 FGak w 40-60
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97 5 Mw 5 Cv Rks Rks r-m 50-90	251 10 Cb - AlRs w/i 40-60	371 8 srCv 2 Dv - F'kR's Rsh Rsh r 60-80	618 10 Mvb w 20-40
102 8 Mw 2 Rsr w 50-80	252 5 Cv 3 Mv 2 Rs - R's Rks Rks r 50-90	376 10 spFGuj w 0-20	624 9 FGuj 1 Fj i-w 5-40
114 8 sdCf 2 dFAj i-w 0-25	254 10 Cbw w 50-70	377 8 zdsMuj 2 Dv Md w/p 0-15	631 10 FGpt w 0-5
119 6 Dv 4 Mr Ruh Ruh r 0-50	257 8 Mw 2 Dv Rj Rj w/m 15-25	378 10 spFGuj w 0-20	632 10 Ft w-i 0-20
132 6 Cvw 2 Mx Rak Rak w,r 50-70	259 10 Msk - AlVl w 60-80	380 8 zdsMakw 2 sgFAj w-i 45-55, 0-25	633 10 FGak w 40-60
141 10 dCAv MaAv w-i 40-60	262 10 Mw Ra w/m 25-50	381 8 bsdMw 2 bsdMw dsmMww Rka w/m 40-60	635 10 dCv Mv w-i 30-50
142 10 dCAv MaAr w-i 25-40	263 10 sdMmw dszMb w/ti 20-50	383 8 Cv 2 spFAj zsFAp i-v 0-20	636 10 jFGla Mka i-m 20-50
143 10 dCAv MaAv w-i 40-60	264 8 dszMw 2 rzsDv Ruj Ruj w/m 10-30	388 8 Mwks 2 Cw - VR's r-m 60-80	643 10 FGks - R's w-i 60-120
146 4 MvwI 4 Dy 2 dFAv RaK Rak Rj r 40-60	267 6 jCw 4 dFAj - Aw Ft w-i 0-25	392 8 Mwks 2 Cw - VRad r-m 60-90	644 10 FGa w 30-50
152 10 Mvb Ra m/i 40-50	270 8 dzsMw 2 Qv Ma w-p 0-20	393 10 Cv Rsh r 60-80	657 10 Rs - R'b x-r 70-150
156 8 IMvw 2 Dv Ruj Ruj w/m 10-30	272 8 jCv 2 Cb Mbv w/m 40-50	394 8 zdCfv 2 dFAj Mb w/m 5-30	659 10 Mb w-m 25-40
162 8 Mv 2 Ruh Dv w/r 20-40	275 5 sdFGka 3 Qv 2 dFAj Rs r-m 60-80	397 8 dzsMw 2 Rr Rak w 50-60	683 10 Muh w 20-50
164 10 dzsMwh Ruj w 0-15	276 8 Cvb 2 Cv Rk Mv w 50-70	398 10 Cvb w 50-60	695 8 dmsMv 2 Cv w-r 30-50
166 8 dsmMkv 2 rzsrCv - R'vV Rk r-m 60-80	277 10 zsFv sdFGfu w/m 5-25	400 10 Cvb w 60-70	702 5 Cvv 5 Rs - R'b r-x 70-150
168 8 Mw 2 jDv Ru w-i 0-20	278 8 dszMw 2 rzsDv Ruj Ruj w/m 10-30	401 10 Mb w 40-60	703 10 jCbv - Rb Mv w-r 50-70
169 8 MaAv 2 dFAj w-i 40-60, 0-25	287 7 Mv 3 Cv Rak Rak w/ti 50-70	402 8 jCfv 2 dFAj Mb w/m 5-30	704 10 Cxv - Rb r 50-70
170 10 dzsMwh Ruj w 0-25	288 8 Mxw 2 Cv Rak Rak w/m 50-70	404 8 Cvb 2 Rk - Rb w/r 50-70	711 6 jCvk 4 Mvx - R'b Rsk r-x 60-100
176 8 IMv 2 Ruh Dv w/r 30-50	290 8 Mv 2 Dv Ra Ra w 0-20	409 8 Cv 2 Rsr - R'b r 70-100	717 7 zdsMw 3 zsrDv Ruyr Ruyr m/r 10-30
181 10 zdsMxw sdmMbw w/m 10-30	291 10 sdFGks r 60-80	410 8 Cv 2 Mv w 40-60	718 5 zdsMw 3 zsrDv 2 Rr Ruyr wRuyr w/r 0-30
182 10 jCv FAp i-v 0-5	293 8 dszMw 2 rzsDv Ruj Ruj w/m 10-30	411 10 xCak - RbAm w/ti 50-70	719 7 zdsMw 3 zsrCv Rua Rua w/r 40-50
185 5 Mx 3 Cv 2 Rk Rkah Rakh w/r 30-60	294 8 jCv 2 Cb Mbv w 25-50	412 8 Rs 2 Cv - R'b r 70-100	771 10 gsFau FGj i-m 0-20
189 10 zdsMxw sdmMbw w/m 0-20	295 8 Cvb 2 Cv - Rs Rk Mv w 50-70	418 5 Cv 3 Mv 2 Rr r-m 25-50	778 7 Mks 2 Cvk 1 Rs - VR's i-x 60-100
193 10 hCvb dszMw p,v 0-10	298 10 Mbv w 60-80	421 5 Cv 3 Rs 2 xCk - R'b r 60-100	779 10 FGj w 5-25
194 8 dszMw 2 rzsDv Ruj w/m 0-20	301 10 zsdMbh w/m 25-50	422 6 Mr 4 jCv Rua Rr w/r 0-40	
195 10 dmsMv zrsDv m/i 10-30	302 10 zsdMbh w/m 25-50	424 8 bsdMv 2 sdDcx Rur Rur r-m	
197 8 Mr 2 Dv Ruj Ruj w/r 5-25	306 5 Cv 3 Mv 2 Rhk w,r 25-50	426 8 jDcw 2 jDcw Mvw Rra w/r 25-50	
198 8 Mr 2 Cv Rak Rak w/r 40-60	308 8 Cv 2 Rks w/r 60-80!	428 10 jCv - R'b Rsh r 60-80	
199 8 dszMw 2 rzsDv Ruj Ruj w-m 0-20	314 6 Cv 2 Mw 2 Rs - VR'sdf'c w,r 60-90	432 6 Cv 4 Rsr - R'b r 60-100	
200 8 zrCv 2 Ms Rsk r/w 25-50	316 10 Mvb Ra w 25-50	434 5 Cv 5 Cv Mw Mw m-p 0-20	
201 10 Mb Rj m-i 0-20	317 6 Cv 2 Mw 2 Rs - VRsdf'c w,r 70-90	435 8 Cv 2 Rks - R'b r 60-80	
	319 5 Dv 3 Mv 2 Rh Ra Ruj w/i 10-30	503 8 dsmMak 2 zsrCv Rka r-m 40-55	
		505 6 Cv 2 Mw 2 Rs - VRsdf'c w,r 60-90	
		515 10 Mbv w 35-50	
		519 10 Fka - R's w-i 50-70	

- Landslide Scar / Track
- Landslide Headscarp (Small)
- Landslide Headwall (large)
- Sackung
- Structural Lineation
- Tension Crack
- Meltwater Channel (unknown direction)
- Meltwater Channel (with flow direction)
- Snow Avalanche
- Landslide Area (large)
- Terrain Stability Polygon

Geohazard (based on Geomorphological Process)

- Bedrock Slump, Tension Crack
- Debris Slide, Debris Flow, Debris Slump
- Rockfall
- Snow Avalanche
- Bedrock Slump, Tension Crack & Debris Slide, Debris Flow, Debris Slump & Rockfall
- Bedrock Slump, Tension Crack & Debris Slide, Debris Flow, Debris Slump
- Rockfall & Snow Avalanche
- Bedrock Slump, Tension Crack & Rockfall
- Debris Slide, Debris Flow, Debris Slump & Snow Avalanche

- Community
- Keystone Field Site
- Knight Piesold Field Site
- Local Study Area - Terrestrial

Existing Infrastructure

- Resource Road
- Highway
- Local Road
- Railway

Proposed Project Infrastructure

- Site Road
- Site Distribution Power Line
- Power Line
- Mine Access Road
- Tailings Pipeline
- Water Pipeline
- Diversion Channel
- Mine Site Area

Tailings Management Facility

- Embankment
- Tailings Management Facility Pond
- Tailings Beach
- PAG Waste Rock Subaqueous Stockpile

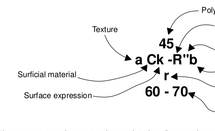
Stockpile

- Non-PAG Waste Rock
- Low Grade
- Topsoil
- Overburden

Other Project Infrastructure

- Open Pit
- Mine Site Road
- Mine Access Road
- Plant Site
- Mine Maintenance Building
- Explosives Facility
- Pond
- Rail Concentrate Loadout Area
- Reclaim Barge

Terrain Polygon Label



Note: one or more letters may be used to describe any characteristic other than surficial material, or letters may be omitted if information is lacking.

Composite Units: Two or three groups of letters are used to indicate that two or three kinds of terrain are present within a map unit.

e.g., 7Mv 3Rs indicates that the polygons contains approximately 70% "Mv" and 30%"Rs".
e.g., 6Mb 3Cv 1Rs indicates that the polygons contains approximately 60% "Mb" , 30% "Cv", and 10% "Rs".

Stratigraphic Units: Groups of letters are arranged one above the other where one or more kinds of surficial material overlie a different material or bedrock: e.g., Mv / Rr indicates that "Mv" overlies "Rr".

Texture	
Code	Name
c	clay
z	silt
s	sand
p	pebbles
k	cobbles
b	boulders
a	blocks
d	mixed fragments
g	gravel
r	rubble
x	angular fragments
m	mud

Surficial Materials	
Code	Name
A	Anthropogenic
C	Colluvium
D	Weathered bedrock
E	Eolian
F	Fluvial materials
FA	"Active" fluvial materials
FG	Glaciofluvial materials
L	Lacustrine sediments
LG	Glaciolacustrine sediments
M	Till
O	Organic materials
R	Bedrock
U	Undifferentiated materials

Surface Expression	
Code	Name
a	moderate slope(s) (27 – 49%)
b	blanket (>1m thick)
c	cone (>26%)
d	depression
f	fan (0 - 26%)
h	hummocky (>26%)
j	gentle slope(s) (6-26%)
k	moderately steep slope (50-70%)
m	rolling topography (0-26%)
p	plain (0-5%)
r	ridges (>26%)
s	steep slope(s) (>70%)
t	terrace(s)
u	undulating topography (0-26%)
v	veneer (<1m thick)
w	mantle of variable thickness
x	thin veneer (0-20 cm)

Geomorphological Processes	
Code	Name
A	Avalanches
Af	Major avalanches
Am	Minor avalanches
E	Glacial meltwater channels
F	Slow mass movement (tailing, slumps)
F"	Slow mass movement initiation zone
Fl	Inactive slow mass movement
Fx	Slump-earthflow
Fm	Slump in bedrock
Fu	Slump in surficial materials
Fk	Tension cracks
Fx	Soil creep
G	Ground disturbance
L	Surface seepage
R	Rapid mass movement (slides and falls)
R"	Rapid mass movement initiation zone
R1	Rapid mass movement initiated from a road
RI	Inactive rapid mass movement
Rb	Rockfall
Rs	Debris slide
Rd	Debris flow
Ru	Slump in surficial materials
Rx	Slump-earthflow
Rm	Slump in bedrock
V	Gully erosion

Geomorphological Processes	
Code	Name
x	very rapidly drained
r	rapidly drained
w	well drained
m	moderately well drained
i	imperfectly drained
p	poorly drained
v	very poorly drained

Where two drainage classes are shown:

- if the symbols are separated by a comma, e.g., "w,i", then no intermediate classes are present;
- if the symbols are separated by a dash, e.g., "w-r", then all intermediate classes are present.
- if the symbols are separated by a slash, e.g., "w/i", then the first drainage class is more extensive than the second drainage class
- if the symbols are separated by a double slash, e.g., "w//i", then the first drainage class is considerably more extensive than the second drainage class

Slope Range

Slopes are given in percentages as a range.
For example, '20-45' indicates that the majority of the slopes in the polygon are between 20% and 45%.

1:20,000
0 1 2
Kilometres

NOTE: This map accompanies the following report: Harper Creek Project: Terrain Mapping and Geohazards
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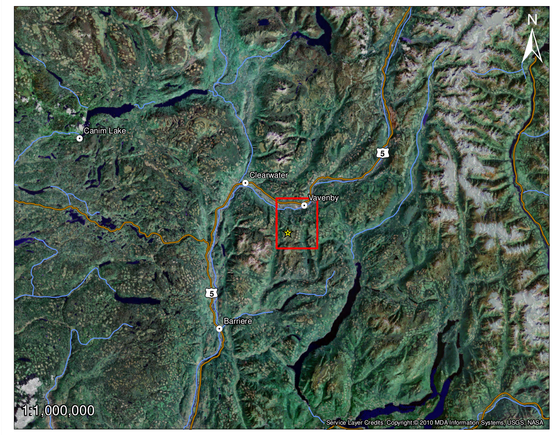
Date: June 3, 2014
Projection: NAD 1983 UTM Zone 11N



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GIS by: ERM Canada	Terrain and Geohazards Mapping by: POLAR GEOSCIENCE LTD.
Project: Harper Creek	Site: British Columbia
Figure: Map 1	Terrain and Geohazards Map
Scale: 1:20,000	Project Number: 0230881-0024
Revision: 00	Date: June 03, 2014
Size: 36x44in	Layout: T1.0
Checked by:	PM:
Client: YELLOWHEAD MINING INC	File: HCP-18-001

GIS projects\HarperCreek\Arcmxd\HCP-18-001.mxd
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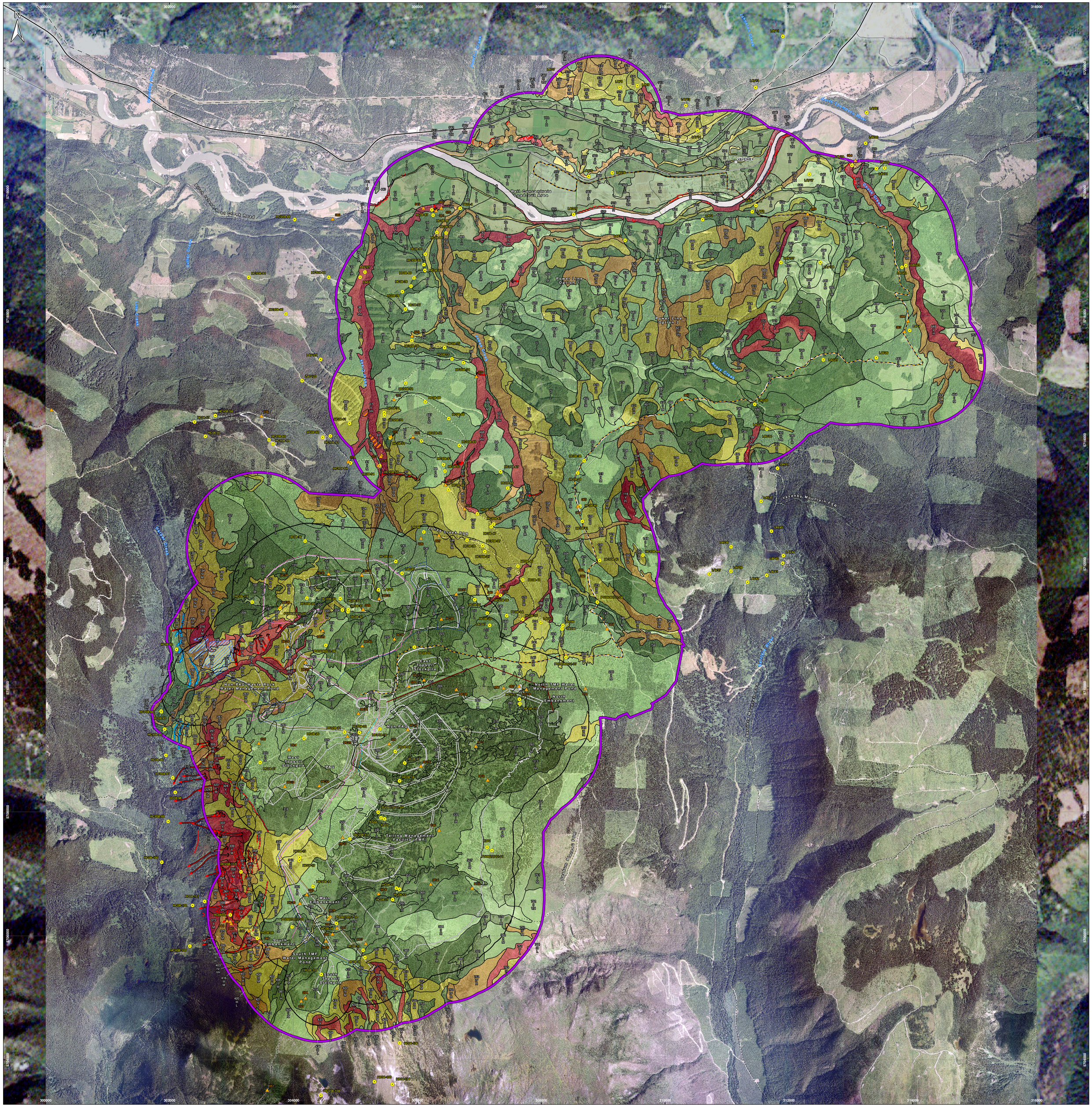
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Iskut River
Bowser River
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