

**MERRITT FOREST DISTRICT
WEYERHAEUSER CANADA LTD.
OPERATING AREA (WHIPSAW AND
PLACER CREEKS)
TERRAIN STABILITY MAPPING**

EBA Project No. 0806-98-87835

**DETAILED AND RECONNAISSANCE
TERRAIN STABILITY MAPPING
MERRITT FOREST DISTRICT**

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Terrain and Interpretive Maps, although not bound with this document, accompany this report.

1.0 INTRODUCTION

The objective of this project was to prepare detailed and reconnaissance terrain stability maps for mapsheets 92H.018, 92H.027, and 92H.037. This information is presented on 1:20,000 scale terrain stability maps. EBA Engineering Consultants Ltd. (EBA) completed the project for Weyerhaeuser Canada Ltd., and Forest Renewal British Columbia provided the funding for this project.

Terrain mapping and interpretations for terrain stability class were carried out according to the provincial standards (Section 2.0). Terrain mapping was done on approximately 1:17,000 scale, colour air photos by air photo interpretation, followed by field checking.

This report augments the information that is shown on the maps completed for this project. It explains the methodology used, guidelines for interpretations and mapping reliability (Section 2.0), and provides an overview of the physiography of the study areas (Section 3.0). Additional information about surficial materials and geomorphological processes (Sections 4.0 and 5.0) and a discussion of terrain stability (Section 6.0) are also included. Recommendations for forestry planning and management that arise out of this terrain analysis are discussed in Section 7.0.

2.0 METHODS

2.1 Terrain Mapping

The terrain mapping methods followed the guidelines and standards set by the Resources Inventory Committee (RIC, 1996) and the Forest Practices Code guidebook (FPC, 1995). Terrain classification followed the provincial system (Howes and Kenk, 1997).

The project area includes the entire BCGS mapsheets 92H.018, 92H.027, and 92H.37 excluding provincial parks, private land, operating areas belonging to other licencees, and previously mapped Small Business Forestry Enterprise Program areas (see Figures 1 and 2). On mapsheets 92H.027 and 92H.037, the areas with the greatest concentration of steeper slopes are mapped as detailed terrain stability mapping (TSIL C) and the areas with the greatest concentration of gentler terrain is mapped as reconnaissance terrain stability mapping (TSIL D). Areas mapped as detailed terrain stability mapping include the steep slopes adjacent to Frenchy and Granite Creeks on mapsheet 92H.037 and Friday and Sunday Creeks and the steeper tributaries of Copper Creek on mapsheet 92H.027. The remainder of mapsheets 92H.037 and 92H.027 (in the report this area is also referred to as Whipsaw Creek) and all of mapsheet 92H.018 (in the report this area is also referred to as Placer Creek) are mapped as reconnaissance terrain stability mapping (see Figures 1 and 2).

Existing terrain stability mapping, surficial and bedrock geology maps were reviewed to familiarize the mapper with the geomorphology and bedrock geology of the area. Preliminary terrain mapping was done by air photo interpretation of 1:17,000 scale, 1996 air photos (see Table 2.1 for a list of the air photos used). Pre-typing, completed by Sheldon Helbert, involved dividing the landscape into polygons and adding a terrain symbol and slope class to each polygon. The Regional Geomorphologist waived the stage 1 quality assurance review.

Table 2.1
Air Photograph List

MAPSHEET NUMBER	AIR PHOTO NUMBERS
92H.018	30BCC96022 #126-137 30BCC96022 #91-103 30BCC96022 #168-178 30BCC96021 #142-153 30BCC96021 #9-19
92H.027	30BCC96091 #37-44 30BCC96025 #74-78 30BCC96024 #122-133 30BCC96024 #77-88 30BCC96023 #112-124 30BCC96023 #76-82
92H.037	30BCC96043 #123-134 30BCC96043 #72-83 30BCC96026 #127-139 30BCC96026 #78-89 30BCC96025 #112-123

Field work was carried out from October 15-23, 1998 by field crew leaders Sheldon Helbert and Michael Hunter. Additional field work was carried out October 2-4, 1999 by Polly Uunila and Sheldon Helbert. In total, 17 crew days were spent in the field (9 days checking areas mapped as detailed terrain stability mapping and 8 days checking areas mapped as reconnaissance terrain stability mapping). Ground truthing was carried out by traverses on foot, from a vehicle and helicopter (see Figures 1 and 2 for traverse routes). Field work involved traversing representative polygons of different surficial materials and slopes, with attention focussed on slopes likely to be designated as terrain stability Classes **IV** or **V**, **P** or **U**. During the traverses, detailed observations of the terrain and surficial materials were made and field cards were filled out; these are shown as ground observation sites on the maps. Reconnaissance field checks were carried out in a few polygons where brief notes were made of the polygon; these are shown as reconnaissance sites on the maps. Less commonly, visual field checks were made during the traverses where terrain types could be reliably confirmed by viewing from a distance; these are shown as visual sites on the maps.

After the field work was completed, the mapping was completed by Polly Uunila, P.Geo. based on field observations and air photo interpretation. The guidelines for interpretation of terrain stability were refined and terrain stability classes were added to each polygon. Betsy Waddington, P.Geo., of B. Waddington Geoscience, completed the senior review of the mapping. TerraPro GPS Surveys Ltd. transferred the polygon boundaries from the air photos to the digital trim base by mono-restitution, and labelled the polygons with the attributes from digital files compiled by EBA.

2.2 Mapping Reliability

The accuracy of terrain mapping, and hence the reliability of terrain interpretations, depends on numerous factors, such as, the skill and experience of the mapper, the scale and quality of air photos used, type and density of vegetation, field access and length of time spent in the field, quality of base maps, and type and complexity of terrain and surficial materials. For this project the reliability of the mapping is considered to be relatively high because it was carried out by an experienced mapper and reviewed by an experienced mapper. The air photo scale for the photos are larger than the scale of presentation, which is ideal.

The greater the road network, the greater the reliability of the mapping, because the roads provide access and good exposures of surficial materials. For areas mapped as reconnaissance, road access is sufficient to achieve 21% field checking. The southern portion of the Placer Creek mapsheet has limited access and was viewed from the helicopter. For areas mapped as detailed, access to Frenchy and Granite Creeks is limited and access to the headwaters of Sunday and Friday Creeks is limited.

A quantitative measure of map reliability, referred to as terrain survey intensity level (TSIL) (Forest Practices Code, 1995), is given by the proportion of polygons checked during field work. The requirements for detailed terrain stability mapping are TSIL C (25-50% of the polygons field checked; field checks per 100 ha should be 0.5 to ≥ 1.0). For these areas, 123 of the total 495 polygons were field checked so that 25% of the polygons were ground truthed and there were 1.8 checks per 100 hectares. The requirements for reconnaissance terrain stability mapping are TSIL D (1-25% of the polygons field checked; field checks per 100 ha should be 0 to 0.1). For these areas, 129 of the 613 polygons were field checked so that 21% of the polygons were ground truthed and there are 0.34 checks per 100 hectares.

Reliability of boundary line positions, as assessed by the mapper during air photo interpretation, are indicated on the map by the use of three line types:

1. Solid lines indicate boundaries that are located with the greatest precision, usually because changes in terrain conditions coincide with a well-defined break in slope.

2. Dashed lines indicate boundaries that are marked by surface features with an approximate location, usually a result of either dense forest cover or because the true boundary is gradational rather than sharp
3. Dotted lines indicate assumed boundaries, usually a boundary that is more a transition zone than a distinct line demarcating areas of complex terrain.

2.3 Terrain Stability Interpretations

Terrain stability refers to gravitationally-induced mass movements such as slumps, slides, debris flows and earthflows. Terrain stability ratings range from Class I (stable) to Class V (unstable) for detailed terrain stability mapping and Classes S (stable), P (potentially unstable, and U (unstable) for reconnaissance terrain stability mapping, and indicate the likelihood of instability resulting from conventional harvesting and road building practices.

The general guidelines used for rating terrain stability for detailed terrain stability mapping are shown in Table 2.2 and for reconnaissance terrain stability mapping in Table 2.3. These guidelines are based primarily on slope steepness, material type and texture, and presence of geomorphological processes. In addition, the mapper may adjust ratings according to site-specific factors such as slope morphology and soil drainage. For example, 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 tend 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 soil pore water pressure. Wet slopes commonly occur on concave slopes, the lower slopes of drainage basins, or the lowermost slopes of long hillsides. Where these slopes occur within 1° to 5° of an upper slope steepness class boundary, the polygon may be rated one terrain stability class higher.

**Table 2.2
Guidelines for Rating Detailed Terrain Stability Class**

		SLOPE CLASS						
		1	2	3	4		5	
		0-5% (0-3°)	6-27% (3-15°)	28-49% (15-26°)	50-70% (26-35°)		>70% (>35°)	
					50-60% (26-30°)	61-70% (31-35°)		
TERRAIN STABILITY CLASS	I	Mv, Mb; FGp, FGU; Fp; Dv; LGp, LGu; Rp, Ru						
	II		Rj, Ru					
			Mv, Mb; FGf, FGU, FGj; Ff, Fj; Cf; Dv; LGj, LGu					
	III			aCa; Ra				
				Ruh, Rum, Rur with Mw, Cv, and/or Dv				
IV			LGa					
			Mv, Mb; FGak, FGa; Cv, Cb					
V				LGa-V, LGk-V (-V refers to dissected slopes or single gully)				
					LGk, LGs			
					Mb-V; Cb-V; FGks; Uks-V (-V refers to dissected slopes)			
					Mv, Mb; FGk, FGs; Cv, Cb			
					Mks-V; FGks-V; Cvb-V; LGks-V, Uks-V (-V refers to single gully)			
	V	all materials and landforms that are unstable (i.e. include mass movement processes: -F", -R", and/or -R"b* * Slopes that contain ongoing, active rockfall are assigned a Class V rating.						

For a description of the symbols used in this table, refer to Appendix B.

**Table 2.3
Guidelines for Rating Reconnaissance Terrain Stability Class**

		SLOPE CLASS					
		1	2	3	4		5
		0-5% (0-3°)	6-27% (3-15°)	28-49% (15-26°)	50-70% (26-35°)		>70% (>35°)
					50-60% (26-30°)	61-70% (31-35°)	
TERRAIN STABILITY CLASS	S	Mv, Mb; Op; FGp, FGj, FGa, FGU; Fp; Dv; Lgp, LGU; Rj, Ra, Ru			aCk; Rk		
	P	LGA-V, LGk-V (-V refers to dissected slopes or single gully)					
					LGk, LGs		
					Mb-V; Cb-V; FGks; Uks-V (-V refers to dissected slopes)		
U				Mv, Mb; FGk, FGs; Cv, Cb			
				Mks-V; FGks-V; Cvb-V; LGks-V, Uks-V (-V refers to single gully)			
		all materials and landforms that are unstable (i.e. include mass movement processes: -F", -R", and/or -R"b* * Slopes that contain ongoing, active rockfall are assigned a Class V rating.					

For a description of the symbols used in this table, refer to Appendix B.

3.0 PHYSIOGRAPHY

3.1 Topography and Bedrock Geology

Whipsaw Creek lies in the southwest corner of the Thompson Plateau, a subdivision of the Interior Plateau Physiographic Region (Holland, 1976). Placer Creek lies within the Okanagan Range in the southeast corner of the Cascade Mountains, a subdivision of the Coast Mountains Physiographic Region (Holland, 1976). The Thompson Plateau consists of a gentle, undulating, upland surface, separated by large valleys. Elevations range from 825 m at the confluence of Lamont and Whipsaw Creek to 1830 m at the upland surfaces. Mapsheets 92H.027 and 92H.037 are drained primarily by Whipsaw Creek, but also Granite, Frenchy, Lamont, Copper, Friday and Sunday Creeks. These creeks eventually flow into the Similkameen River. The Okanagan Range consists of low relief mountains. Elevations range from 950 m at the mouth to Placer Creek to 2195 m at the top of Placer Mountain. Mapsheet 92H.018 is drained by Placer Creek and Pasayten River which flow into the Similkameen River.

The bedrock geology for this study area is taken from Rice (1946). The headwaters of Granite, Whipsaw, and Copper Creeks are underlain by intrusive bedrock of the Coast Intrusions. The mid reaches of these creeks are underlain by volcanic bedrock, argillite, tuff, limestone and schist of the Nicola Group. The eastern half of these two mapsheets are underlain by andesite and basalt and shale, sandstone and conglomerate of the Princeton Group. The Placer Creek mapsheet is underlain by the Nicola Group and the Princeton Group.

Characteristics of bedrock, such as mineral composition and structure, determine the shape and texture of its weathered material. These characteristics influence the matrix texture of till and colluvium, and the shape and size of clasts found in colluvium and till. Intrusive bedrock commonly has a coarse crystalline texture and tend to break down into sand and coarse silt. Thus, till and colluvium derived from these types of bedrock typically have a silty sand matrix. Well-jointed intrusive bedrock breaks into large blocks and boulders. Finer metasediments, such as, shists and argillite weather to create silt matrices. This bedrock fractures along foliation planes to create pebble-sized rubble and slabs. The volcanic bedrock breaks down into rubble and blocks, which weather into silt and clay.

3.2 Landscape Evolution and Deposition of Surficial Materials

During the early Tertiary, the study area was characterized by a low-relief landscape with gentle slopes and low hills. During the late Tertiary, the entire study area was subject to uplift followed by a period of erosion and downcutting, with the stream valleys deeply incising into the old erosion surface.

Most of the landforms and surficial materials found in the study area were formed during or since the most recent glacial period, the Fraser Glaciation (Mathews, 1944; Holland, 1976).

The climax of the Fraser Glaciation occurred about 14,600 years ago. Ice moved southwards across the Thompson Plateau, covering the upland surface with an unbroken ice sheet to a thickness of 500 to 1000 metres (Mathews, 1944). Ice also moved northwards from local ice caps on the Cascade Mountains. Glacial erosion produced rounded peaks and an undulating upland surface, and carved U-shaped valleys. Blankets and veneers of basal till were deposited at the sole of the glacier. Deglaciation events later modified some of the valley surfaces found at elevations below 1150 metres (Petro, 1972).

Deglaciation occurred between about 14,000 and 11,000 years B.P. During this time, ice stagnated and thinned on the upland surface while tongues of ice remained in the lower valley bottoms. Downwasting ice often formed subglacial and ice-marginal landforms on the gentle surfaces, such as, eskers, kame terraces, and meltwater channels. Ice-tongues blocked drainage so that lakes could form, such as, in the Whipsaw Valley.

During post-glacial times, processes have re-worked some glacial sediments and weathered bedrock to redistribute them as colluvium and fluvial sediments. Creeks and rivers that have graded to present day levels have downcut into glacial deposits creating terraces, benches, and steep-sided scarps.

4.0 SURFICIAL MATERIALS AND ASSOCIATED LANDFORMS

4.1 Till (M)

Till is deposited directly by glacier ice 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 weathered by pedogenic processes creating loose, permeable soils.

Basal till (subglacial till) is deposited at the base of a glacier forming 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.

Ablation till (supraglacial till) (not differentiated on maps) consists of debris that melts out on top of a glacier during deglaciation. It is usually coarse textured and non-consolidated. As result, it is generally highly permeable. This deposit may also contain lenses of other types of glacial drift, including glaciofluvial sand and gravel and glaciolacustrine sands, silts and clays.

Till is the most widespread surficial material within the study area especially on flat to moderately steep slopes. However, till is less common on the steeper slopes, for example, in those areas mapped as reconnaissance. Where till is found on these slopes, it is usually a veneer and often complexed with colluvium. Ridge tops usually contain a discontinuous mantle of till which is generally well drained. Mid and lower slopes contain more continuous veneers to blankets of till and these slopes are generally well drained. Along the valley bottoms, creeks have incised through thick deposits of till in some places to create steep sided till scarps. These areas may be moderate to well drained.

Based on matrix texture there are 3 types of till, likely from different source areas within the study area. These 3 types of till can be found throughout the study area. The most common texture is a sandy silt (sz), also common is sandy silt with minor amount of clay (sm where $m = z+c$) and least common is silty sand (zs). The finest textured till (sm) seems to be mostly derived from volcanic bedrock as the clast lithology is all or mostly volcanic. The sandy silt (sz) till appears to be derived from a combination of volcanic and intrusive bedrock, based on clast lithology and the silty sand (zs) till is largely derived from intrusive bedrock based on the clast lithology. The "sm" till is typically slightly consolidated and slightly to moderately cohesive. Generally the volcanic clasts make up 5 to 20% of the volume and are angular to subround. The "sz" till is typically non- to slightly consolidated and slightly cohesive. Volcanic and intrusive clasts make up 5 to 20% of the volume and are subangular to subround. The "zs" till is typically non- to slightly consolidated and non- to slightly cohesive. Intusive and some volcanic clasts make up 15 to 45% of the volume and are subangular to subround (see Photo 1).

4.2 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 (FGd and FGp) were created. Postglacial streams have cut down through some outwash plains and fans transforming them into terraces (FGt and FGk). Glaciofluvial sediments commonly overlie till.

Glaciofluvial materials consist of sand and gravel with small quantities of finer material. 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. Clasts tend to be subangular to subround. Ice-contact deposits may have distorted bedding, slump structures and faults as a result of settling and collapse due to 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 22°, and indicate the frontal slopes of depositional landforms.

Glaciofluvial materials consist of sands and gravels that are highly porous and permeable, and thus they form relatively dry and well drained sites. The material is non-cohesive, and so tends to ravel when exposed in steep slopes (greater than 70%) and road cuts. Perched water tables can develop where glaciofluvial sediments overlie impermeable materials, such as basal till, bedrock, and glaciolacustrine sediments. Where impermeable materials underlie moderately steep and steep slopes overlain by

glaciofluvial sediments (e.g., terrace scarps), slopes may be unstable. Glaciofluvial sands and gravels are potential sources of aggregate.

Within the study area, glaciofluvial sediments are found along many valley bottoms. Present day creeks have incised these meltwater deposits leaving benches and steep-sided scarps. In some of the larger valley bottoms, glaciofluvial sediments are overlain by till. Glaciofluvial terraces are generally well drained, and the lower slopes of glaciofluvial scarps are typically well to moderately drained.

The texture of the glaciofluvial sediments range from a gravely sand to a sandy gravel and quite often contain a trace amount of silt. The deposits are usually nonconsolidated and are massive to moderately well bedded (see Photos 1 and 2).

4.3 Colluvium (C)

Colluvial materials have accumulated during post-glacial time as a result of gravity-induced slope movement, such as soil creep and landslides. The physical characteristics of colluvium are closely related to its source and mode of accumulation.

Four processes generally create colluvial deposits. These are rockfall from bedrock bluffs, soil creep in weathered bedrock, mass movement processes in gullies (debris flows and debris slides), and rockslides and rock slumps.

Rockfall from bedrock bluffs typically forms talus slopes (Ck). Talus is typically loosely packed rubble or blocks with little interstitial silt and sand near the surface, and is rapidly or well drained (see Photo 3). Within the study area, talus slopes are most common in the Placer Creek area.

Colluvial veneers (Cv) and blankets (Cb) develop where weathered bedrock has been loosened and moved downslope by gravitational processes such as soil creep. The characteristics of this colluvium closely resemble those of the material it was derived from. It is loosely packed and usually well drained. This is the most common type of colluvium within the study area, and usually occurs on moderately steep and steep slopes.

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, where the matrix is usually sand. These landforms are generally stable so will not be indicated where they exist in areas mapped as reconnaissance. Debris flows that form colluvial fans and cones are uncommon in this region and none were found in the area mapped as detailed.

Rockslides and deep-seated slumps in bedrock result in hummocky, irregular colluvial deposits (**Chu**). Rockslide deposits consist of loosely packed rubble and blocks with little or no interstitial silt and sand and are well drained. Rock slump deposits contain blocks and rubble with little or no interstitial silt and sand. Bedrock slumps are mapped in polygons 185, 187, 233, 234, and 241 on mapsheet 92H.018. The largest slump initiated from polygons 233 and 234 (see Photo 4). The large landslide deposit has blocked a small valley and impounded a lake.

4.4 Fluvial Materials (F)

Streams have deposited fluvial gravels in post-glacial time. 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 and are relatively well drained and dry, and good locations for roads and landings. As fluvial landforms are stable, they exist only in the areas mapped as detailed. Discontinuous floodplains, are mapped along Granite and Copper Creeks and the gentle reaches of Copper Creeks tributaries. A fluvial fan is mapped in polygon 612 on mapsheet 92H.027.

4.5 Glaciolacustrine Materials (LG)

Glaciolacustrine materials consist of fine sediments that accumulated in ice-dammed lakes. Fine sand, silt, and clay ("rock flour"), initially produced by glacial abrasion, were transported to the lakes by meltwater streams. Finer sediments tend to remain suspended in the lake, and then slowly settle to the lake bottom. Glaciolacustrine sediments typically consist of interlayered silt, clay, and fine sand. Dropstones from floating melting ice, ranging up to boulder-size, may be embedded in the finer material. The sediments are usually slowly permeable to impermeable and are generally moderately to highly cohesive, depending on the percentage of clay. Beach sediments tend to be sands and gravels, and are loose and porous.

A glacial lake was formed along the mid and lower reaches of Whipsaw Creek. These sediments are found as far as about 1200 metres above sea level along the valley bottom (see Photos 5 and 6). For much of this valley bottom, the glaciolacustrine sediments are sandwiched between glaciofluvial sediments on the top and till underneath, occasionally, this deposit outcrops to the surface. Present day creeks have incised through the (glaciofluvial), glaciolacustrine, till sequence so that the layer cake outcrops in moderately steep and steep-sided scarps. Within the area mapped as detailed, glaciolacustrine sediments are in the lower Sunday Creek valley bottom and in the mid and lower valley bottoms of two tributaries to Copper Creek.

4.6 Weathered Bedrock (D)

Weathered bedrock has been modified *in situ* by mechanical and chemical weathering. It is usually developed on gentle slopes and has not been moved by gravitational processes. Mechanically weathered bedrock is typically rubbly, contains various percentages of interstitial silty sand, and is loose and well drained. This material is found in stable polygons, therefore is only shown in those areas mapped as detailed. Discontinuous veneers of weathered bedrock is commonly found on undulating, rocky ridge tops and is often found in association with partial mantles of till.

5.0 ACTIVE GEOMORPHOLOGICAL PROCESSES

5.1 Rapid Mass Movement (-R, -R'') and Slow Mass Movement (-F, -F'')

Where a double prime symbol (") is used with a mass movement process (e.g., -R''s, -F''m), slope failure has occurred within the polygon and the slope is classified as unstable (Class V and Class U). Landslide headscarps are located in these polygons.

Mass movement symbols without the double prime symbol (") (e.g., -Rb, -F) indicate a polygon that contains the transport and/or deposition zone of landslides and debris flows. Although transportation zones are hazardous areas, they are not unstable, therefore, these polygons will have a terrain stability class other than V or U.

5.1.1 Debris Slides (-Rs, -R''s) and Debris Flows (-Rd, -R''d)

Debris slides are a variety of landslide. They occur when a mass of glacial drift or colluvium becomes detached from a hillside and moves rapidly downslope by sliding along a shear plane. If the sliding debris is saturated, or if debris falls into a stream and becomes saturated, it is transformed into a debris flow. A debris flow is the rapid flow of a mass of viscous material, consisting of mud, sand, stones, and organic debris.

Debris slides are initiated on steep hillsides by the sliding of weathered till and/or colluvium along a shear plane that coincides with the contact between weathered till (i.e., pedogenic soil) and unweathered till, or between colluvium and till, or between any of these materials and bedrock. Slides are triggered by heavy rain, water from snow melt and 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 may be due to the loss of soil strength that results from root decay. Diverted drainage from roads commonly trigger failure of sidecast material and slides farther downslope.

A debris flow may move downslope for several hundred metres or more before it is arrested by gentler terrain or by draining, or it may enter a trunk stream. Debris flows are effective agents of erosion, and so the volume of material in a flow commonly increases downslope. Thus debris slides and debris flows are significant potential sources of stream sediment, and also a hazard to activities or structures (roads, culverts) located in runout zones.

Within the study area, debris slides are commonly found along the steep gully walls where the slopes are undercut by Whipsaw, Frenchy, Granite, and Copper Creeks and the Similkameen and Pasayten Rivers. Generally these slides initiate in thick till, glaciofluvial or glaciolacustrine sediments. The steep hillslopes above the Pasayten River located north of the mouth of Calcite Creek (polygons 202 and 204, mapsheet 92H.018) contain several debris slides which initiated in veneers of till and colluvium.

Within the study area, debris flows are uncommon and only two are mapped. One is located adjacent to Frenchy Creek (polygon 53, mapsheet 92H.037) which failed in till and colluvium. The Sunday Summit Forest Service Road intersects the slide path of the other (polygon 633, mapsheet 92H.027).

5.1.2 Rockfall (-Rb, -R''b)

This process involves the release of relatively small masses of rock (e.g., a single block or a few cubic metres) and movement downslope by free fall, rolling and bouncing. Rockfall is common on steep alpine slopes also occurs on isolated rock bluffs.

Rockfall is the most common rapid mass movement process in the study area (see Photo 3). Rockfall is common from steep, bedrock outcrops throughout the study area.

5.1.3 Rock Creep (-Fg, -F''g)

This involves the slow movement of debris, usually under periglacial conditions (e.g. rock glaciers). Rock glaciers are an expression of mountain permafrost. They consist of rocks, sand, and silts cemented by ice. Rock glaciers creep due to internal deformation of interstitial ice at rates from several centimetres per year to one metre per year. The talus in polygons 139 and 193 on mapsheet 92H.018 located on the northwest and south flanks of Placer Mountain are currently creeping or has experienced past creeping.

5.1.4 Tension Cracks (-F^{''}k)

These are open fissures, which are commonly located near ridge tops. They indicate slow slope spreading, and may be a precursor to catastrophic slope failure. One tension crack is mapped in the volcanic bedrock of the Princeton Group north of Placer Mountain (polygon 137, mapsheet 92H.018), and it is oriented in a northeast/southwest direction.

5.1.5 Slump in Bedrock (-F^m, -F^{''}m)

This refers to sliding translational or rotational movement where the affected bedrock remains internally cohesive. Slumps tend to develop along weakness in bedrock, such as foliation or joint planes. There are four large bedrock slumps on mapsheet 92H.018 (located in polygons 185, 187, 233, 234, and 241). These slumps are oriented in a straight line running northeast/southwest, parallel to the tension crack in polygon 137 and perpendicular to the regional fault direction. Like the tension crack in polygon 137, the four bedrock slumps are located within volcanic bedrock of the Princeton Group. The deposit from the slump initiating from polygons 233 and 234 is large and has impounded a lake (see Photo 4).

5.1.6 Slump in Surficial Materials (-F^u, -F^{''}u)

A slump in surficial materials refers to the sliding of an internally cohesive mass of surficial material along a slip plane that is either concave upward or planar. Small slumps in fine grained till and glaciolacustrine sediments are common in the cutslope of roads throughout the study area and region (see Photo 5). These slumps are typically too small to see on an air photo.

5.2 Gully Erosion (-V)

Gullies are small ravines with V-shaped cross sections that can form in either glacial drift or bedrock. Gully erosion has been mapped in two kinds of terrain: (i) slopes with several parallel shallow gullies in drift materials, (dissected slope), and (ii) single gullies where streams have exploited joints in bedrock or have cut down into thick drift.

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., Mb-V). Gully sideslopes and steep headwalls are commonly sites of slope failures and have been rated as unstable (Class V or U). Single gullies and dissected slopes are common throughout the study area.

5.3 Glacial Meltwater Channels (-E)

Glacial meltwater channels are typically sinuous in plan, flat-floored, and steep-sided in cross-section. The floors are usually poorly drained and covered by organic soils.

5.4 Abundant Seepage (-L)

The -L symbol was mapped where seepage is widespread in a polygon. This commonly occurs on consolidated till or bedrock that is slowly permeable or impermeable, and on lower slopes where shallow subsurface water is received from a relatively large catchment area further upslope. It may also occur where groundwater is concentrated at the surface by a physical conduit, such as a geological fault. Such moist sites appear to be indicated by gaps in the forest canopy and the presence of deciduous vegetation (i.e. willow, alder). This is mapped in polygon number 235, mapsheet 92H.027.

6.0 TERRAIN STABILITY

6.1 Terrain Stability

The portion of the study area that lies within the Thompson Plateau (Whipsaw Creek) is overall a gentle, undulating upland surface, separated by large valleys. For the most part the upland surface contains stable ground (terrain stability classes **I**, **II**, **III**, and **S**), with occasional potentially unstable terrain (terrain stability class **IV** and **P**). The valleys that dissect the upland surface contain the most potentially unstable and unstable terrain (terrain stability Class **V** and **U**).

The portion of the study area that lies within the Okanagan Range of the Cascade Mountains contains low relief mountains where the steepest slopes are adjacent to Placer Creek, Pasayten and Silmilkameen Rivers and the flanks of the largest peaks, such as, Placer Mountain.

The most common mass movement process in the study area is rockfall. This occurs from steep bedrock outcrops that are scattered throughout the study area. Slopes with large amounts of active rockfall have been rated as unstable, otherwise these polygons are rated as potentially unstable.

Debris slides and flows are common along steep-sided valleys dissecting the plateau, for example, Whipsaw, Frenchy, Granite, and Copper Creeks and the Similkameen and Pasayten Rivers. Generally these slides initiate in thick till, glaciofluvial or glaciolacustrine sediments, especially where the creeks undercut slopes containing these materials. Potential sites of failure may also exist where natural planes of weakness are present between two materials with different rates of permeability for

example along Whipsaw Creek where there are up to three surficial materials in the creek cutslope. These planes of weakness can develop within a single type of surficial material, such as example, between layers of glaciolacustrine sediments with different texture (e.g. silt and sand), but they are more commonly found between two types of surficial materials (e.g. glaciofluvial gravels overlying till). Stability problems are typically more acute during wet periods, such as during rain-on-snow events, seasonal storms, or cycles of increased annual precipitation. Small slumps are common in the cut slopes of roads where the roads intersect thick fine-grained till and glaciolacustrine materials on moderate to steep slopes (see Photo 5).

Deep-seated mass movement bedrock failures are common in volcanic bedrock near the headwaters of Placer Creek. The headscarps of these failures occur along a northeast - southwest trending line (roughly perpendicular to the direction of the regional faults) from Placer Mountain to the headwaters of Placer Creek (see Photo 4). It is unlikely that forestry development would increase the rate of movement in these areas.

Terrain that was interpreted as potentially unstable (classes IV and P) typically consists of:

1. slopes greater than 60% that are covered or partially covered with veneers and blankets of till and colluvium;
2. scarps greater than 60% in glaciofluvial, morainal and colluvial sediments, or any combination of these materials;
3. slopes greater than 30% with glaciolacustrine sediments;
4. moderately steep and steep slopes that are dissected;
5. steep bedrock slopes shedding minor amounts of rockfall;
6. slopes with slides resulting from logging practices that likely are now out of date.

Terrain that is interpreted as unstable (Classes V and U) consists of slopes where, in the mapper's opinion, there is a high likelihood that landslide will result from forest harvesting and road construction by conventional means. Most unstable polygons contain landslide initiation zones. All single gullies and some dissected slopes are mapped as unstable as well as bedrock slopes shedding abundant rockfall.

6.2 Management Implications for Terrain Stability Classes

The Forest Practices Code of British Columbia requires that terrain stability considerations form part of the planning for timber harvesting and construction of access roads. Typically in the interior of British Columbia, terrain stability field assessments are required if development is proposed within polygons rated as terrain stability Class V and U, and where road building and/or ground-based harvesting is planned in polygons rated terrain Class IV and P. These assessments provide a detailed, site-specific evaluation of terrain stability and can provide recommendations for harvesting and road building techniques that minimize the risk of landslides.

Persons using these ratings should bear in mind that conditions are locally variable. The ratings indicate the mapper's impression of typical conditions for each terrain polygon, but locally steeper slopes, wetter slopes, emergence of water from seepage zones, and clayey materials give rise to areas that are potentially more unstable than their surroundings. Consequently, persons marking road alignments and cutblock boundaries should recognize and take account of the local conditions.

General management implications of DTSM classes are shown in Table 6.2.1 and for RTSM in Table 6.2.2

TABLE 6.2.1
Management Implications of Detailed Terrain Stability Classes

Detailed Terrain Stability Class	Management Implications
I	<ul style="list-style-type: none"> No significant stability problems exist.
II	<ul style="list-style-type: none"> There is a very low likelihood of landslides following timber harvesting or road construction. Minor slumping is expected along road cuts, especially for one or two years following construction.
III	<ul style="list-style-type: none"> Minor stability problems can develop. Timber harvesting should not significantly reduce terrain stability. There is a low likelihood of landslide initiation following timber harvesting. Minor slumping is expected along road cuts, especially for one or two years following construction. There is a low likelihood of landslide initiation following road-building. A field inspection by a terrain specialist is usually not required.
IV	<ul style="list-style-type: none"> Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction. Wet season construction will significantly increase the potential for road-related landslides.

Detailed Terrain Stability Class	Management Implications
	<ul style="list-style-type: none"> A field inspection is to be made by a qualified terrain specialist if road building and ground-based harvesting is planned to assess the stability of the affected area.
V	<ul style="list-style-type: none"> Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction. Wet season construction will significantly increase the potential for road-related landslides. A field inspection of these areas is to be made by a qualified terrain specialist prior to any development, to assess the stability of the affected area.

Source: Forest Practices Code, Mapping and Assessing Terrain Stability Guidebook, 1995

Table 6.2.2
Management Implications of Reconnaissance Terrain Stability Classes

Reconnaissance Terrain Stability Class	Management Implications
S	Stable. There is a negligible to low likelihood of landslide initiation following timber harvesting or road-building.
P	Potentially unstable. Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction
U	Unstable. Natural landslide scars present. Expected to contain areas where there is high likelihood of landslide initiation following timber harvesting or road construction.

Source: Forest Practices Code, Mapping and Assessing Terrain Stability Guidebook, 1995

7.0 RECOMMENDATIONS

Terrain stability: In general, moderately steep to steep slopes covered by variable thicknesses of surficial materials and moderate to steep glaciolacustrine slopes are rated as potentially unstable (terrain stability class **IV** and **IVR**) or unstable (terrain stability class **V**). Forest Practice Code regulations require that areas with significant terrain stability or erosion concerns have a terrain stability field assessment completed prior to development. A qualified registered professional in assessing terrain stability should be retained to carry out on-site assessments and to provide recommendations to reduce the likelihood of landslides in terrain stability class **IVR** and **IV** areas where road building and ground-based harvesting is planned in terrain stability class **V** terrain, or in other areas identified by forestry personnel as having characteristics or conditions that may cause instability.

General Road Construction Practices

Conscientious drainage planning is essential during road construction. Within or directly upslope of polygons mapped as terrain stability class **IVR**, **IV** or **V**, natural drainage patterns should be maintained through installation of culverts for even the most minor ephemeral stream channels. Ensure that culverts and ditches are of adequate size, the discharge points are properly armoured, and the system is kept clean. In some areas of sensitive terrain, even minor concentrations of hillslope runoff into drainage structures may not be appropriate, and terrain stability professionals may recommend alternatives to standard construction techniques. Do not schedule activities in or directly upslope from potentially unstable areas for those periods of the year when moisture conditions are highest, such as during rates of snow melt, during rain on snow events or during extended periods of high rainfall.

Redirected Drainage

Redirected drainage is the most frequent cause of landslides in the interior of British Columbia. Natural drainage pathways that develop over centuries and millennia are in a sensitive equilibrium with the volume of water discharge. Road drainage ditch networks can artificially increase stream catchment areas or alter flow paths within a catchment, which may cause overloading of drainage capacities to increase the hazard of failures and accelerated soil erosion.

Stable areas located above terrain stability class IVR, IV and V polygons:

Increased runoff and redirection and concentration of flow from forest development on stable slopes may increase the likelihood of terrain stability problems on potentially unstable terrain situated downslope. It is recommended that where development is proposed upslope of terrain stability class **IVR**, **IV** and **V** polygons, a terrain stability professional be retained to assess the areas and to make recommendations to minimize disruption to the natural drainage regime.

Conventional road construction should be avoided if possible on steep gradient slopes mantled by surficial materials and on moderately steep and steep slopes with thick surficial materials. Wetter slopes with seepage or concentrated surface run-off (such as at the base of slopes) should be treated more conservatively and should be avoided if gradients are moderately steep to steep. If road construction is unavoidable through such areas, a terrain stability professional should be retained to assess the landslide potential and make specific recommendations to reduce the risk of landslides and erosion. Anticipate recommendations by a terrain stability professional for end-hauling of material where development is planned across steep slopes, particularly through areas of thick drift.

Road cutslope material must be assessed for terrain stability and soil erosion potential, as some material may slough or ravel and block ditches or culverts, creating drainage problems that could lead to slope failure. Steep cutslopes of gravelly sand glaciofluvial sediments and some types of colluvium are non-cohesive and tend to

ravel. Adjustment of cutslope ratios to less than 70 percent, minimizing cutslope heights, and/or armouring of the cutslope with coarse rock fragments may be necessary.

Cat tracks and skidder trails may increase erosion by creating channeled ruts that interrupt normal drainage patterns and concentrate run-off. Following harvesting, an assessment of cat tracks or skidder trails for evidence of interruption to natural drainage patterns should be completed. Scarification of compacted areas and breaching of berms that fill linear depressions may be required.

Yarding methods:

Yarding methods on moderately steep to steep terrain should ensure minimum soil disturbance, especially for slopes with a high or very high potential for soil erosion.

Steep slopes adjacent to the main creeks and stream scarps (Mks, FGks, LGks): Steep slopes adjacent to major streams and stream scarps are particularly sensitive with respect to terrain stability and soil erosion. There is a very high likelihood that landslide debris and sediment from soil erosion sources will reach the water courses. Where alternative road alignments across these slopes cannot be found, the importance of more cautious engineering and a well-designed drainage system cannot be over-emphasized.

Gullies:

Where timber harvesting is planned in or alongside gullies, the site should be investigated by a geotechnical engineer or geoscientist trained in forestry-related terrain assessment work to ensure that the landslide hazard is reduced to acceptable levels. Large debris flows are often triggered by relatively small gully wall debris slides into the main gully that become saturated and channelized, and increase volume downstream by entraining material from the channel bed and gully sideslopes. Gully wall failures or debris flows in tributary channels can block the main channel and create landslide dams. Catastrophic outbreaks of these landslide dams can have severe downstream consequences.

8.0 ACKNOWLEDGMENTS

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10.0 CLOSURE

The information and analyses contained in this report and on the air photos are based on observations of land-surface conditions and current understanding of slope processes. However, because slope stability is strongly influenced by subsurface conditions that are not apparent from surface observations or air photo interpretation (e.g., characteristics of subsurface materials, subsurface hydrologic conditions), by events whose time of occurrence cannot be predicted (e.g., extreme storms, earthquakes), and by land management practices, the results and recommendations provided in this report cannot guarantee that no landslides will occur in areas affected by forestry activities. Appropriate use of terrain information and implementation of recommendations will, however, reduce the risk of landslides and erosion.

Respectfully submitted,
EBA ENGINEERING CONSULTANTS LTD.

Prepared by:

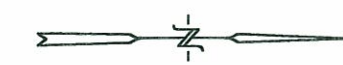
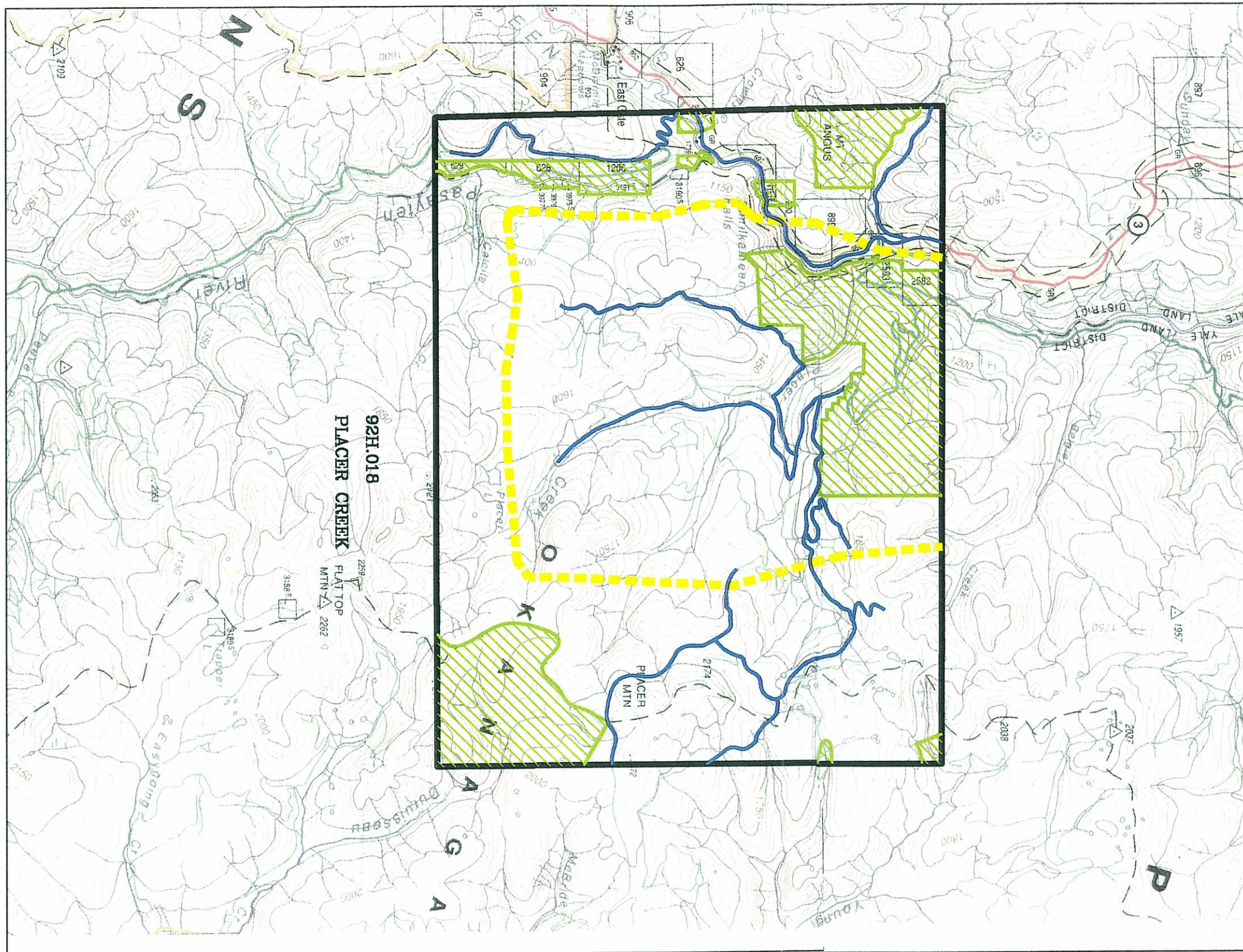


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Geomorphologist

Reviewed by:

Chi Wall.

for
Sheldon Helbert, M.Sc.
Terrain Analyst

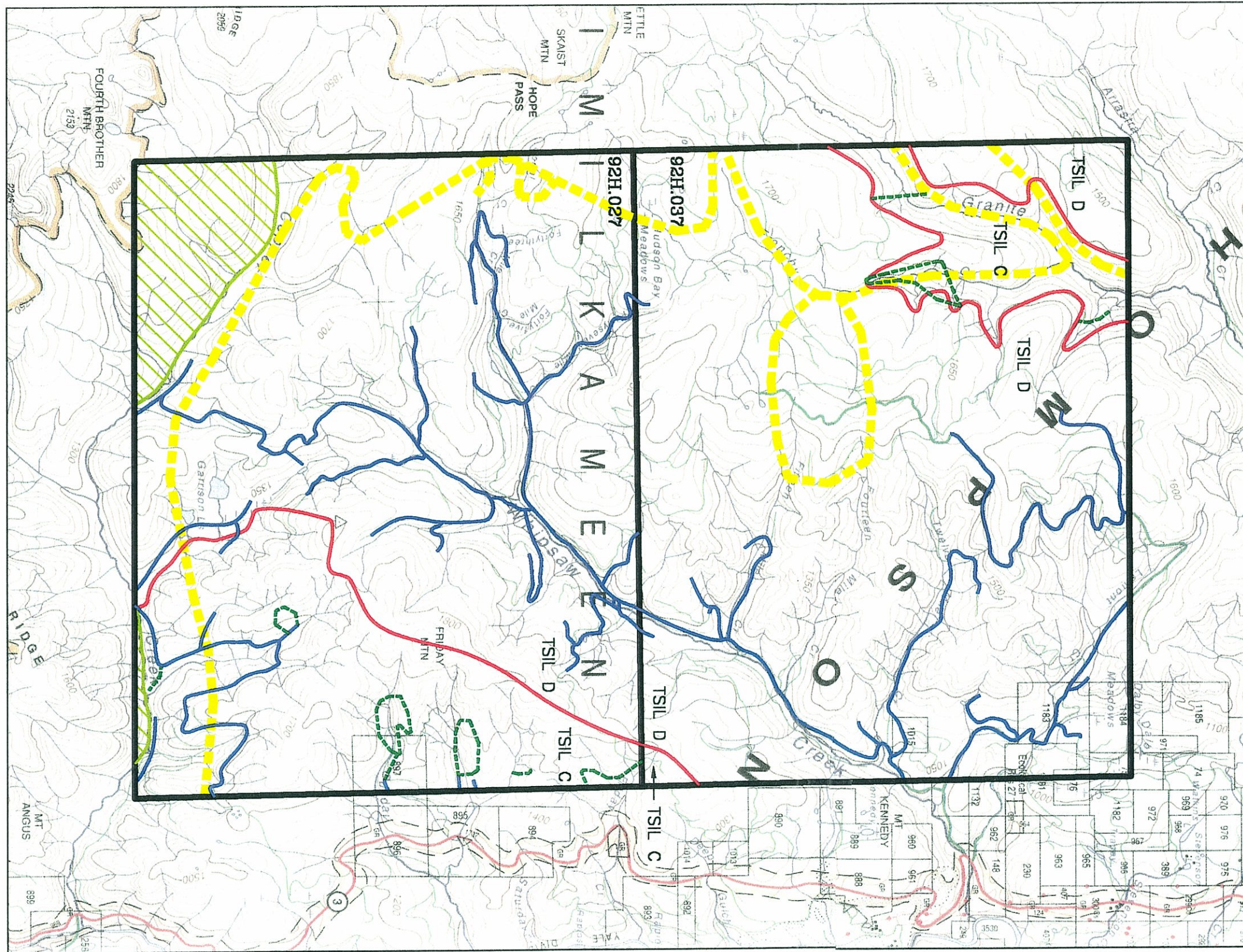


LEGEND







- PROJECT BOUNDARY
- VEHICLE TRAVERSE
- HELICOPTER TRAVERSE
- NOT MAPPED - OUTSIDE OF STUDY AREA

SOURCE: 92H/SE


CLIENT	WEYERHAEUSER CANADA LTD.	EBA Engineering Consultants Ltd.		
PROJECT	TERRAIN STABILITY MAPPING	TITLE TRAVERSE ROUTES & LOCATION MAP		
LOCATION	MAPSHEET 92H.018 PLACER CREEK	DATE	JUNE, 2000	DWN LM
		SCALE	1:100 000	CKD PU
		FILE No.	0806-98-87835	
		FIGURE No.	2	



LEGEND

-  PROJECT BOUNDARY
-  VEHICLE TRAVERSE
-  FOOT TRAVERSE
-  HELICOPTER
-  BORDER BETWEEN DETAILED TERRAIN STABILITY MAPPING (TSIL C) & RECONNAISSANCE TERRAIN STABILITY MAPPING (TSIL D)
-  NOT MAPPED – OUTSIDE OF STUDY AREA

SOURCE: 92H/SE

CLIENT	WEYERHAEUSER CANADA LTD.	 EBA Engineering Consultants Ltd.					
PROJECT	TERRAIN STABILITY MAPPING	TITLE TRVERSE ROUTES & LOCATION MAP					
LOCATION	MAPSHEETS 92H.027 & 92H.037 WHIPSAW CREEK	DATE	JUNE, 2000	DWN	LM	FILE No.	0806-98-87835
		SCALE	1:100 000	CKD	PU	FIGURE No.	1