DETAILED TERRAIN STABILITY MAPPING (TSIL C) OF PISIMA FACE AREA WITHIN FOREST LICENSE A18693

Submitted to

International Forest Products
Adams Lake Division
Chase, B.C.

Terratech Consulting Ltd.
Salmon Arm, B.C.

Date: 26 March 1999
File: 496-14

F.R. Smith, G.I.T.
Project Geologist

C.D. VanBuskirk, P.Geo.
Review Engineer
1.0 INTRODUCTION

This report has been prepared as part of a terrain stability-mapping project of the Pisima Face, in the Clearwater Forest District. It is accompanied by a 1:20,000 scale map of the Pisima Face study area, which is located approximately 30 km north-northeast of Chase, B.C. (Figure 1). The study area as mapped is 5110 ha in size and spans portions of the TRIM sheets 82M013 82M023 and 82M024. The study area boundary was placed by aerial photographic interpretation of 1:15,000 scale photos with ground checks in critical areas. The study area is defined to the north by a large creek, to the east by the drainage divide, to the south by an operational chart boundary and to the west by Adams Lake.

This mapping has been done using standard methods of aerial photographic interpretation and field observations. The study area has been divided into a series of polygons with each depicting a relatively homogeneous area of terrain (surficial materials and geomorphological processes), slope (as classes), soil drainage and slope stability.

This report is intended to supplement the information presented on the terrain stability map. The report describes and reviews the geology and geomorphology of the study area; the characteristics of surficial materials and geomorphological processes that are present in the study area; the mapping methodology and map reliability; and the management implications.

1.1 Scope

This report and map have been produced as a portion of the Forest Renewal BC Project Contract # TOM98107-10491, entitled, Terrain Stability Mapping Momich, Spillman Creek Watersheds in the Kamloops Forest Region. This project was undertaken by Terratech Consulting Ltd. (TCL) for International Forest Products (Interfor), Adams Lake Division.

1.2 Report Limitations

The information presented in this report and on the accompanying map is intended for forest development applications only. The slope stability ratings are not considered appropriate for other land use applications. The identification and classification of terrain units and the assignment of ratings to derivative variables has been done using the standard methods employed by professional terrain mappers in British Columbia. The level of reliability associated with this mapping is consistent with other terrain survey intensity level (TSIL) C studies that rely on aerial photographic interpretation and field observations. The interpretations are largely judgmental and heavily based on aerial photographic interpretation. Accordingly, Terratech Consulting Ltd. cannot warrant or guarantee the exactness of the descriptions and/or boundaries of units shown on the accompanying map. Terratech Consulting Ltd. expects more detailed assessments will be undertaken for forest operational planning.

This report is submitted to Interfor and the B.C. Ministry of Forests as information to be used to assist development of forest resources within the defined study area. In order to protect the public, B.C. Ministry of Forests, Interfor and TCL from potential misuse of information.
2.0 PHYSICAL SETTING

2.1 Topography

The study area, known as the Pisima Face, is located north of the Spillman Creek and Bugcamp Creek watersheds along the east shore of Adams Lake, which is within the Shuswap Highland of the Interior Plateau physiographic region (Holland, 1976). In general, the Shuswap Highland consists of a series of gently to moderately sloping plateaus that in places are sharply dissected by river valleys. Summits rising above the plateau surfaces normally lack a ragged character, but there are limited areas of cirque topography in some regions. The study area lies immediately east of the Adams Lake between 410 m and 1900 m elevation and comprises several small unnamed watersheds. Lower and mid-elevations are within the Interior Cedar Hemlock biogeoclimatic zone while higher elevations are characterized by the Engelmann spruce subalpine fir biogeoclimatic zone. Gently sloping plateaus and subalpine areas characterize the terrain to the northeast and southeast.

The eastern portion of the study area consists of gently sloping open forest plateau areas between 1400 m and 1900 m elevation. The mid-elevations are characterized by moderately sloping, heavily glaciated drumlinized, ridged terrain. Surface waters flow west-northwest into Adams Lake and generally have small drainage basins. At 700 m elevation these streams are incised into hummocky rolling glaciofluvial and till deposits. Below the 550 m elevation these streams are deeply incised into rock. These streams flow into Adams Lake at the 407 m elevation and lack large delta features.

Adams Lake occupies a north/south trending deep trough in the middle of the Shuswap Highlands. Flow from Adams Lake flows are into Shuswap Lake (345 m elevation) via the lower Adams River.

2.2 Bedrock Geology

The bedrock geology of the Adams Lake region has been mapped by Campbell (1964) at the 1:250,000 scale (see Figure 2). The bedrock of the study area consists mostly of Shuswap Metamorphic Complex rocks of the Omineca Belt. Bedrock outcrops in the area are characterized by granitic gneiss (quartz-feldspar-biotite gneiss), quartz–mica schist, pegmatite and lesser amphibolite and biotite-granodiorite. Bedrock maps also list quartz-feldspar hornblende gneiss, quartzite, marble and muscovite granite as commonly found units within the Shuswap Metamorphic Complex. Although not indicated on Figure 2, the southern most portion of the study area comprises chlorite schist of the Eagle Bay Formation. Chlorite schist in the study areas is olive green, fine-grained and strongly foliated with layers of limestone. The contact between the two bedrock types was inferred to occur approximately 200 m north of the southern mapping boundary.
Bedrock structure within schist and gneiss units is variable but contains a strong north-south (004° to 012°) striking, steeply eastward dipping (40° to 80°) joint set. Strong foliation is evident in most exposures. Folding is sometimes observed. Foliation and folding is often cut by pegmatite dikes, which are in rare outcropping crosscut by basaltic dikes (Site 9). Eagle Bay Formation bedrock exposed at the southern mapping boundary (Site 1) shows strong foliation, carbonate veining and complex folding. Folding shows a general north-south trend with steeply dipping anticlinal limbs. Significant lineaments or faults are not found within the study and are not indicated on geology maps.

In the study area, some of the major gully systems expose steeply sloping bedrock. Areas of active rockfall were found at mid-elevations. On these steep bedrock slopes, jointing and foliation surfaces can function as slip planes due to the orientation of the strata (slides and topple). Weathering of the coarse-grained metamorphic and granitic rock units typically yields a rubbly soil with a sand matrix. Surficial materials overlying the finer-grained Eagle Bay Formation bedrock consists of sandy tills, likely derived from metamorphic rocks to the north, which is consistent with southerly ice flow. Colluvium derived from Eagle Bay Formation bedrock is typically platy and contains a sandy, silt matrix.

2.3 Quaternary Geology

The distribution of surficial materials and the small scale landforms that presently characterize the study area have largely been produced through bedrock weathering and the actions of glacial, fluvial and slope processes operating in the Quaternary Period. The large-scale features of the region are, in part, related to tectonic activity in the Tertiary Period when a pre-glacial landscape of low hills and plains was elevated. Stream incision into this surface over a long interval produced the major valley and plateau features of the Shuswap Highland. In the Quaternary Period, the landscape was modified by repeated glaciations. While there may have been as many as 20 glacial cycles in the Quaternary, there is direct stratigraphic evidence of only four major glaciations in southern British Columbia (Fulton et al, 1992).

The pattern of glacial expansion and contraction and the dynamics of glacial ice strongly influence the distribution of surficial materials and landforms. During the last major glaciation in this region, ice initially accumulated in the high elevation cirques and icefields of the southern Cariboo Mountains and the Monashee and Selkirk Mountains. Ice spread southward and westward from these areas into the valleys of the Shuswap Highland and Thompson Plateau. Pre-glacial sediments in the major river valleys were eroded and the valleys locally scoured. Gradually, the thickening valley glaciers covered the Highland. At the glacial maximum, an ice sheet that moved to the south and southeast in this region covered the whole of the Interior Plateau. On the upland and in the valleys, local sub-glacial conditions determined if materials were eroded by, or deposited from, the ice mass during this active phase. Glacial contraction across the plateau occurred by down-wasting rather than frontal retreat. The uplands were deglaciated first as the ice persisted longest where it was thickest, in the valley bottoms (Clague, 1989). In a few high elevation areas of the Shuswap Highland, glacial ice lingered in cirques while the adjacent plateaus were deglaciated. The sequence from expansion to decay and contraction is thought to have occurred between 25,000 and 10,000 years before the present (Alley et al, 1986; Fulton and Smith, 1978).
In the active phase, sub-glacial tills (moraine) are deposited locally and smattered into pre-glacial gullies while most the plateau and mid-elevation surfaces are scoured and streamlined. Rock drumlins on the plateau above the 1200 m elevation show southeast glacial direction, while closer to Adams Lake drumlins show a southward ice flow, suggesting topographic features may have controlled ice flow directions at some stage of the last glacial advance in this area. During the down-wasting phase, melt-out and supra-glacial tills (ablation till or moraine) accumulate across much of the surface and overlie denser sub-glacial tills. Glaciofluvial sediments deposited at this time accumulate along the ice margin as kame terraces and kame deltas. In the study area, ice persisted longest in the Adams Lake trough, damming south-flowing drainage. Where drainage was impounded, glaciolacustrine sediments accumulated in small embayments against ice.

Kame deposits forming along the ice margins accumulated to great thickness and are quite complex deposits with flow-tills and finer-grained deposits exposed at the same elevation. With further down-wasting following kame deposition a lower base level was established and subsequent erosion and redistribution of kame materials occurred. A sequence of coalescing fans developed in front of the till/kame deposits against the ice. Further lowering of base levels resulted in streams eroding their fans, incising deep ‘V’ shaped ravines into bedrock (Sites 5, 17 and downslope of Site 7). Below the 550 m elevation, most streams are incised into and flow over bedrock.

Fluvial and mass-wasting processes have governed post-glacial landscape modification with the redistribution of glacial sediments onto the drumlinized benches at lower elevations. The rate of sediment movement is highest immediately following deglaciation before surfaces are stabilized by vegetation. In addition, bedrock failures from steep slopes have produced talus deposits at mid-elevations. Small fluvial fans (deltas) are located along the shore of Adams Lake. Most of these fan deposits were constructed subaqueously due to the absence of shoals along Adams Lake.

### 3.0 SURFICIAL MATERIALS

The surficial geology of the area is mapped at the 1:250,000 scale by Fulton, Alley and Achard (1986). Soil mapping is also available for the 1:50,000 scale NTS map sheets 82M4 and 82M6 (Kowall, 1975). In the following sections, the types of surficial materials that are present in the study are described. The definitions for each material type are based on Howes and Kenk, Terrain Classification for British Columbia (RIC, 1997). The reader should note that the western portion of the study area, along Adams Lake, there is a complex distribution of fluvial, glaciofluvial, glaciolacustrine and morainal materials. A full reconstruction of the deposition of those materials is beyond the scope of this report.

#### 3.1 Colluvium (C)

Colluvium is surficial material that has come to rest in its present position following gravity-induced mass-wasting. Colluvial materials are not transported directly by, or within, water or ice, but colluvium may contain these materials during movement.
Colluvium includes weathered rock debris that is subjected to creep and deposits from mass movements. In the study area, colluvial veneers and blankets (Cv, Cvfb) were mapped on moderately steep and steep slopes generally mixed with rock and/or moraine (e.g. Cv/Mv/Rks). Colluvial blankets (Cb) also occur where deposits from debris slides, distant rockfall, debris flows and other mass movements accumulate. These sites are typically on the side slopes and bases of gullies and on lower valley walls. Rockfall from steep bedrock exposures has produced talus slopes (Ck, Cs) in several areas; some of these slopes are partially vegetated. In some instances these deposits overlie till (M) and older slope wash deposits. In the larger bedrock-controlled gullies, at mid-elevations, bedrock structure is conducive to rockfall and in rare instances sliding type failures. In these areas the blocky colluvium has come to rest forming moderate slopes of 27% to 50% (aCa). Morainal materials that have been subjected to soil creep and soil development processes, but no other mass-wasting processes and still retains some of the properties of moraine, have been mapped as moraine in this project.

Frost shattered and weathered rock that has experienced soil creep has been mapped as special colluvium (C1) to distinguish the very different material type and properties these deposits exhibit. These materials often comprise intermixed slope wash deposits and weathered till in most areas. These areas are found on the gently to moderately sloping areas within the ESSF and park land areas at higher elevations near the height of land.

3.2 Fluvial Materials (F)

Fluvial materials have been transported and deposited by flowing water. They generally consist of stratified, moderately to well-sorted mixtures of sub-rounded gravel clasts with sand and lesser amounts of silt. These sediments have a high permeability and are generally well drained with the exception of areas that receive groundwater discharge such as floodplains and gently sloping fans formed via mass wasting or fluvial processes. In the study area, fluvial deposits are generally not large enough to permit separate polygon delineation and the fluvial materials are mapped as part of a composite unit or are excluded.

3.3 Glaciofluvial Materials (F^G)

Glaciofluvial materials are the deposits of glacial meltwater streams. These deposits may vary from unsorted, massive sands and gravels to well-sorted stratified sand or gravel. They are usually highly permeable, well drained and non-cohesive. Thick, unvegetated exposures of these sediments will ravel on steep slopes. Hummocky ice contact deposits may contain lenses of flow till while outwash plain, kame terrace or kame delta deposits may have silty interbeds. These finer textured layers can impede the movement of sub-surface water. Where they occur on escarpment slopes or cutslopes, seepage can contribute to stability problems.

Small remnants of glaciofluvial deposits, likely the result by ice marginal streams during the decay phase of the last glaciation, were found throughout lower slope. These deposits are very complex and given the time constraints on the field study were consequently not studied in detail. The southwestern portion of the study area comprises several kame deposits. Kame deltas consist of steeply dipping, loose, poorly sorted gravels and sands. Clast lithologies are diverse but comprise mostly metamorphic rock types within the pebble to cobble size range.
Meander scars can be seen on the kame terrace (skF^Geth) in the southwest corner of the study area near Adams Lake (Polygon 277). Smaller glaciofluvial (paraglacial) fans (skF^Gf) are found at lower elevations within the northwestern portion of the study area. These fans often coalesce to form aprons or blankets of glaciofluvial materials over bedrock.

Smaller glaciofluvial remnants (stratified deposits) are found within larger till deposits along Road 40, north of Taylor Creek Road.

3.4 Glaciolacustrine Materials (L^G)

Glaciolacustrine materials are sediments that are deposited on glacial (ice-dammed) lakebeds and shorelines. Lakebed sediments are predominantly stratified, moderate to well sorted, finely laminated, plane and ripple bedded, fine sands, silts and clays. These deposits may include clasts as dropstones (ice rafted) and lenses of till, glaciofluvial and colluvial materials. Glaciolacustrine terrain may be kettled and pitted or may show slump structures due to melting of underlying glacial ice during and following sediment deposition. Lakebed sediments are usually of low permeability, imperfectly drained and cohesive. When overlain by permeable materials, a perched water table may form on the lakebed deposits and seepage can occur on cut slopes exposing that contact. Rotational slumps and debris slides may occur on moderate to steep slopes when these materials are of high moisture content. Lake shoreline sediments are moderately well to well sorted, stratified to massive, sands and gravels. Their physical properties are similar to those for fluvial materials.

Glaciolacustrine sediments were found in two exposures within the northwestern corner of the study area (Site 7). At Site 7, glaciolacustrine sediments comprise mottled, thinly bedded, hard sands and silts with a trace of subrounded pebbles. Sieve analysis from a bulk sample of both sand and silt seams show the deposit to consist of silt (61%), fine sand (22%), sand (12%) and pebbles (5%). The sand and silt seams are plane bedded and lack any structure or signs of deformation. The deposit is generally very poorly drained but some of the larger sand seams show evidence of seepage. The deposit coarsens upward, is greater than 4 m thick and at this location is capped by a gravelly sandy deposit of dense, poorly sorted, non-stratified material, which was interpreted as till. Seepage is observed at the contact between the two units. Exposures of this type are rare and were only found in road cuts. The gully type within Polygon 228 was interpreted to reflect underlying fine-grained soils possibly of glaciolacustrine origin.

Site 6 is just north of the study area. The surficial materials exposed in this area comprise very poorly drained, mottled, silty sand that lacks obvious stratification. Site 6 is located 180 m upslope of the “Rock Island Slide” which occurred on 6 June 1996 (Photo 1). Similar deposits as that found in the area of Site 6 and Rock Island Slide may comprise the slopes below Road 40 in the northwestern corner of the study area.

3.5 Morainal (Till) Materials (M)

Morainal materials or tills are sediments that are deposited directly from glacial ice. The physical properties of tills and the surface expression of morainal terrain are highly variable
and are influenced by source material characteristics (bedrock type or other older surficial deposits) and the glacial depositional environment. In general, tills are massive (non-stratified), unsorted to very poorly sorted mixtures of angular to sub-rounded clasts supported by matrices of sand, silt and clay (diamicton). Sub-glacial (basal) tills include those deposited by the processes of lodgement and basal melt-out and are typically dense, cohesive, of low permeability and fine grained. Terrain associated with sub-glacial tills includes streamlined landforms (e.g. drumlins, flutes). Tills of the supra-glacial environment include ablation and flow tills, which are often coarser in texture, less compacted and cohesive, but more permeable than sub-glacial tills. Terrain characteristics include hummocky ground moraine. Where tills have been weathered and altered by soil forming processes, their cohesion and permeability may be greatly altered (decrease cohesion and increase permeability).

Moraine is the most extensively distributed sediment in the study area. In some polygons, till is mapped as a single unit (Mb, Mw). More commonly, moraine is mapped as a composite with either bedrock or colluvium (e.g. Mvb/Cv). Most moderate and gently sloping planar surfaces are covered by a veneer or blanket of till (Mv, Mb, Mbv). Where the underlying bedrock is streamlined or ridged till blankets comprise the hollows between rock ridges, while a discontinuous veneer of moraine and locally derived colluvium comprise surficial materials on the ridges (Mb over Rr, /Mv/Cv over Rr). Where the terrain is steep, the till cover is thin and discontinuous often with considerable amounts of colluvium and bedrock (e.g. Mw/Cv-Rr). The gullies within the study area are oriented east-west (perpendicular to ice flow) and subsequently infilled with till. Consequently the reforming of these pre-glacial gullies at mid-elevations has resulted in erosional slopes in thick sequences of till (Mk, Ms). In most of the larger gullies, the sidewalls near the crest of the gullies are very steep and bedrock-defended, however the mid-slope of the sidewalls of the gullies, may comprise partial veneers or blankets of till. At lower elevations till masks the underlying topography forming gentle slopes (Mj) often found in conjunction with ice contact materials (Mu/FG'h).

In the study area, the tills consist of gravelly sand (gs) with silt comprising a portion of the matrix. Clasts are sub-angular to sub-rounded and generally comprise 35% to 40% of the deposits by volume. The clast sizes range from pebbles to small boulders (blocks). Clast lithologies include mostly quartz-mica schist with lesser quartz-feldspar-biotite gneiss and pegmatite (Shuswap Metamorphic Complex). The tills are generally dense and moderately well drained within the upper surface. Where the fines (silt and clay) content was higher or the slope gradients low, imperfectly drained sites were observed.

Sieve analysis performed to ASTM\(^1\) standards on samples from Sites 1, 6 and 13 show: 25%, 23% and 26% fines (silt>clay) with fine sand comprising 20%, 31% and 26% and coarse to medium grained sand comprising 21%, 16% and 26% and gravels comprising 35%, 30% and 25%, respectively. What is apparent from the sieve sampling is that the fine sand component and silt component are not adequately described using the classification system outlined in RIC, 1997. These same samples have been described by others and by the mapper as sandy tills, which does not convey the manner in which these materials will behave from an engineering

perspective. The sieve analysis suggests the tills within the mapped area will behave like silt when conventional engineering principles are applied.

3.6 Organic Materials

Organic materials are sediments that contain at least 30% organic carbon by weight. These materials are common in poorly and very poorly drained locations (wetlands) where peat accumulation results from the incomplete decomposition of the remains of hydrophytic vegetation such as sedges and sphagnum. Organic materials may also accumulate as a surface layer from deposition of leaf litter, twigs, branches and forest floor ground cover. Organic deposits typically have a low bulk density, are easily compressed and lack cohesion. The water content of wetland organics is high, but forest floor organics may be well drained in an undisturbed state.

In the study area, organic deposits occupy the hollows between rock drumlins where rainwater is trapped and very slow to drain or evaporate. These areas usually manifest as long narrow north/south oriented strips absent of timber. The orientations of these swamps allow for easy identification of bedrock drumlin areas on timbered slopes. Organic sediments in these areas are generally too small to map as separate map units and comprise smaller portions of composite units (e.g. Cv/Rr/Opv). Overall, the dominant textures of the peat are humic and mesic, but interbedded with these deposits may be layers of fine-grained silts and clay and occasionally fine sands resulting from slope wash soil erosion.

3.7 Bedrock

Bedrock is mapped where there are visible outcrops or where rock is covered by a thin veneer (up to 10 cm thick) of unconsolidated or organic materials. In the study area, extensive areas of outcrop occur in larger gullies at mid-elevation. Much of the lower to mid-elevations areas comprise drumlinized slopes of low elliptical hills comprising steep-sided bedrock ridges. These features are formed by moving ice that scour streamlined forms with elongate axes oriented parallel to the direction of glacial movement. In the study area, these features consist mostly of bedrock are therefore called rock drumlins.

Where possible, these bedrock units have been delineated as separate polygons, but they are often mixed with colluvium (e.g. Rs/Cvk) and sometimes moraine. There are some large bedrock-controlled gullies systems throughout the area where exposed bedrock is a dominant material. Within the drumlinized areas, in the southeast corner of the study area, discontinuous veneers of colluvium and/or moraine partially cover bedrock (/Cv).

Rr

Where morainal mantles are mapped alone, the reader should assume they overlie rock. Where rock has been mapped under a continuous forest cover, it is based on extrapolation from field traverses and on aerial observations of shallow rock structures from cleared ground on aerial photographs.
4.0 GEOMORPHOLOGICAL PROCESSES

Geomorphological process symbols are employed to indicate that either a large area of a given polygon has been modified by a particular process or that specific sites within a polygon have been affected by that process. The symbols used in this project that are relevant to slope stability are described below.

4.1 Rapid Mass Movement (-R)

Rapid mass movements are rapid downslope motions of debris derived from surficial materials and/or bedrock by falling, rolling, sliding or flowing. There are several types of rapid mass movements mapped in the Pisima Face study area. Where it has been possible, the mapping has separated initiation zones (-R") from runout areas (-R).

Rockfall (-R"b, -Rb)

Rockfall is a rapid descent of a small mass of bedrock by falling, bouncing and rolling. In the study area, rockfall is a common process from steep bedrock. Non-vegetated talus slopes in the runout zones denote the most active rockfall sites.

Rockslides (-R"r, -Rr)

A rockslide is a descent of a large mass of bedrock by sliding. During movement, the bedrock masses break apart and typically leave a hummocky deposit of blocky colluvium in the runout zone. Small rockslides (<100 m³) and topples are seen in the steep rock cliffs that forms the northern mapping boundary. Large rockslides were not found within the study area.

Debris Slides (-R"s, -Rs)

A debris slide is a rapid sliding movement of a disintegrating mass of surficial material. They are most commonly developed where elevated porewater pressures develop within till, glaciofluvial or colluvial materials located on steep and moderately steep slopes. Failure often occurs along a planar contact such as that between the failing material and an underlying smooth bedrock surface or an unweathered dense surficial material.

There are several areas in the study area where debris slides have occurred. Although natural failures are rare, they appear to occur where moisture contents are relatively high and slopes are steeper than about 55%. There are also failures that are related to road construction. These occur in similar terrain, particularly where road drainage is focused downslope and where steep road fills or cutslopes are present (partially in till).

Debris Flows (-R"d, -Rd)

A debris flow is a rapid flow of a saturated mass of sediment, rock and organic material. These failures are often initiated when a debris slide enters a stream channel and the resultant slurry scour and mobilizes materials in the streambed and banks. Alternatively, where debris
slides are large and of high moisture content, a debris flow may be generated without entering a stream channel. Debris flows have considerable destructive potential due to the length and possible location of the runout zone. Most of the larger landslides within the area are believed to have transported as flows rather than slides and are related to road drainage concentrations onto unconditioned slopes.

**Rock Island Slide:**

The Rock Island Slide occurred on 6 June 1996 and was investigated by TCL the following day. The Rock Island Slide initiated within an area identified as potentially unstable by TCL during TSIL Level D mapping of that year. The slide initiated within a thick sequence of glacial material on the east shore of Adams Lake approximately 2 km south of Rock Island following a major storm event. Anecdotal accounts of the event indicate that the storm created large waves on Adams Lake. The slide travelled one hundred metres depositing directly into Adams Lake. The slide was investigated from a helicopter and was estimated to have involved approximately 500,000 m$^3$ of material. As can be seen in Photo 2, some piping has occurred within the lateral scarp zone. Similar deposits as that found in the area of Site 6 and Rock Island Slide may comprise the slopes below Road 40 in the northwestern corner of the study area. The glacial materials in these areas are very thick and comprise several different surficial materials of different textural types. It can be postulated that the Rock Island Slide may have initiated as a piping failure within similar materials as that found at Sites 6 and 7. The deposits below and immediately above Road 40 in this area may also comprise similar materials.

**4.2 Slow Mass Movement (-F)**

Slow mass movements are the slow downslope motions of cohesive or non-cohesive masses of surficial materials and/or bedrock by creeping, flowing or sliding. The map symbol is applied to initiation, transit and depositional zones. The types of failures that are represented include slow earthflows, rotational slumps and lateral spreads. Terrain that is affected by slow mass-wasting typically shows a hummocky or undulating runout (deposition) zone with an arcuate shaped, steep headscarp in the initiation zone. No areas of slow mass-movement were found during field traverses, although some areas remain suspect and have been mapped as stability class IV.

**4.3 Gully Erosion (Gullying) (-V)**

Gullying refers to a series of processes (running water, mass movements and snow avalanches) that act to produce parallel narrow ravines or gullies in surficial sediments and/or bedrock. In practice, the gullying process symbol is applied by many mappers as a morphological descriptor. For this project, the gully erosion symbol was used to describe terrain where there are either a series of small gullies present in a polygon (e.g. Mb-V) or where the feature is a single large gully (e.g. Mk*Cv-V).
4.4 Seepage (-L)

Seepage zones are areas where there is groundwater discharge or shallow sub-surface flow (interflow) to the topographic surface either permanently or seasonally. This mapper has used the seepage process symbol to denote areas where considerable interflow was observed seeping from shallow road cuts or where vegetation communities (mostly horsetail and cattails) indicate there is considerable seepage.

5.0 METHODS

The terrain stability mapping was done at Terrain Survey Intensity Level C (TSIL C). The methods followed were in accordance with provincial standards (Resources Inventory Committee, 1996, 1997, 1998; Ministry of Forests, 1995; and Luttmerding et al, 1990). The mapping procedure was divided into three phases:

i.) pre-typing phase;

ii.) fieldwork phase; and

iii.) edit phase.

In the following sections, each step of the mapping methodology is outlined and the criteria used to assign ratings to derivative variables are described.

5.1 Pre-Typing Phase: Terrain and Slope

Previous studies on the bedrock and surficial geology, landforms and soils were consulted prior to pre-typing. TSIL D terrain stability mapping of the region was reviewed (Terratech Consulting Ltd., report dated March 1998). In addition, reporting for two cutblock assessments conducted by Dr. Terence Lewis, P.Geo. was also reviewed prior to commencing fieldwork. Dr. R. Fulton, P. Geo. reviewed the pre-typing work prior to the commencing of fieldwork. Several suggestions and interpretations were made by Dr. Fulton as well as suggestions on areas to field check. Most of Dr. Fultons’ suggestions were incorporated into the terrain map. The findings of the field traverses were subsequently discussed with Dr. Fulton.

The terrain mapping was done by F.R. Smith, GIT on 1:15,000 scale aerial photographs that date from 1994 and 1995. The pre-typing phase involved the placement of polygon boundaries on the photos and, for each polygon, there was a preliminary interpretation of terrain type (surficial material, surface expression and geomorphological processes), slope range (as classes) and slope stability. Boundary placement was based, in large part, on the position of slope breaks and/or changes in surficial materials or geomorphological processes. On-site symbols were added where mass movements were observed. Where possible, initiation zones were separated from runout areas. Solid lines were used to denote definite boundaries such as those seen at very sharp slope breaks. Dashed lines were used to denote approximate boundaries that reflect changes in terrain (surficial material, surface expression or processes),
slope, drainage or stability that occur over distances of some tens of metres. Dotted lines denote assumed boundaries; these represent very gradual changes in variables or areas where the ground surface was obscured by shadow.

Boundary placement was assisted through the use of a slope map that was generated from digital elevation data. TRIM topographic data are available for the study area at a scale of 1:20,000 (20 m contour interval). The quality of the slope map was controlled by the TRIM topography. Small scarps and hummocks are not well captured by the digital data. The slope map was also used in conjunction with the aerial photographs to determine the range of slopes that were present in each polygon. Attempts were made to delineate polygons that had slopes from only one class, but in practice, most polygons contained slopes from at least two classes.

5.2 Fieldwork Phase

Fieldwork was carried out between 25-27 August 1998 while staying at Interfor’s Tracy Camp at Adams Lake. The Adams Lake East FSR (Road 40) provides access to the study area. This mainline enters from the north at the head of Adams Lake and runs due south along the east shore of Adams Lake and joins Spillman Creek FSR near 31 km. Spillman Creek FSR continues due south and climbs over the drainage divide into the Salmon Arm Forest District. Taylor Creek Road in the north and Scotch-Adams FSR in the south provide access to the upper elevation sites. These three road systems provide excellent access to the study area. Ground stations were established along these major roadways as well as along foot traverses. Approximately 42 km of roadway were checked by truck and 7.5 km was covered by foot traverse.

Ground stations were established where surficial materials were well exposed such as in road cuts, stream banks, slide tracks or in tree windthrow hollows. In some cases, shallow excavations were used to expose materials below the soil A horizon. Data collected at ground stations were either detailed or of a reconnaissance nature. At detailed sites, a standardized field form was completed and data were collected on:

i.) site location and applicable airphoto.
ii.) texture of surficial materials;
iii.) types and characteristics of surficial materials present;
iv.) surface expression;
v.) geomorphological processes;
vi.) soil drainage, hydrology and vegetation;
vii.) slope steepness and configuration;
viii.) aspect; and
ix.) slope stability (indicators).

In most cases, sketches were made of vertical sections, or the lateral relationships occurring between units were illustrated. At reconnaissance ground sites, a field form was not completed, but data were usually collected on terrain (surficial material, surface expression, processes), slope (steepness and configuration), slope stability and drainage and placed on
airphotos or field maps. Additional notes were recorded on the variance in surficial materials, slope stability and drainage that occurred between ground sites.

5.3 Edit Phase

The initial edits were done on the field-checked polygons. Where required changes were made to the preliminary polygon boundaries, terrain units, slopes and slope stability ratings. Soil drainage was added to these polygons, as was texture, where data were deemed of reliable quality. The criteria used to assess soil drainage are described in Section 5.4.

The GIS ARCView was used to generate two theme maps using digital elevation and soil parameter data as input. The first was a map of specific catchment. This theme illustrates how surface and shallow sub-surface waters may concentrate downslope. The second theme was a SINDEX map. This is a map of slope stability based on inputs of slope, soil moisture and soil strength (Terratech, 1997). The SINDEX map illustrated areas of potential instability and was generally in good agreement with the field observations where gully features and steep valley sides were well captured by the TRIM data.

Polygons not directly field checked were modified based on extrapolation of the relations observed in the field through recognition of similar terrain on the aerial photographs. The specific catchments and SINDEX maps were also used to highlight potentially poorly drained and potentially unstable areas. Thus, for the whole of the study area, polygon boundaries, terrain units (surficial material, surface expression and processes), slopes and slope stability were modified based on field relations, and soil drainage ratings were added. Edits were made following the FRBC review. Changes included line-type changes and lowering of stability class ratings in rockfall initiation areas from V to IV.

Polygon boundaries on the final typed aerial photographs were captured by mono-restitution and polygon labels entered into a terrain data form. A preliminary map was produced on a 1:20,000 scale TRIM base. A final round of edits to this map and some photos followed, mainly involving legend and label modification and splitting of existing polygons to reflect minor changes in derivative variables.

5.4 Soil Drainage

Soil drainage refers to the rapidity and extent of water removal from a soil relative to additions (Luttimberding et al, 1990). Soil permeability, groundwater level, seepage inputs and vegetation all influence soil drainage conditions. Assessment of soil drainage in the field was done through recognition of diagnostic soil horizons or profiles, vegetation communities and terrain associations. Table 1 presents the typical associations that formed the basis for the soil drainage assignments. These relations were used as a guide and some variance from these criteria occurred during mapping due to local groundwater and soil characteristics.
<table>
<thead>
<tr>
<th>Drainage Class</th>
<th>Definition</th>
<th>Typical Terrain Units and Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapidly</td>
<td>Water is removed rapidly from the soil relative to supply. Excess water normally flows downward. Soils are often coarse textured and shallow.</td>
<td>Steep and moderately steep slopes in rock and colluvium (Rs, Rk, Ck, Cv). Soils are mainly Regosols.</td>
</tr>
<tr>
<td>Well</td>
<td>Water is removed from the soil readily, but not rapidly. Excess water flows downward or laterally as sub-surface flow. Soils are often intermediate in texture and depth.</td>
<td>Steep to moderately steep slopes in moraine (Ms, Mk, Mv, Mb, Mw), steep to gentle slopes in glaciofluvial (FgS, FgK, FgA, Fg), fluvial (Fa, Ff, Fj) and colluvial materials (Cv, Ca, Ck). Soils are mainly Brunisols, Podzols and Regosols.</td>
</tr>
<tr>
<td>Moderately well</td>
<td>Water is removed from the soil somewhat slowly relative to supply. Excess water may be removed slowly due to low permeability, shallow groundwater table and gentle gradients. Soils are often fine to medium textured.</td>
<td>Moderate slopes in moraine (Ma, Mv, Mb), gentle slopes in glaciofluvial (FgJ), fluvial (Fj) and colluvial materials (Cv). Plain slopes in coarse textured materials if there is no groundwater seepage to the surface. Soils are typically Brunisols, Podzols and Luvisols.</td>
</tr>
<tr>
<td>Imperfectly</td>
<td>Water is removed from the soil sufficiently slowly relative to supply such that the soil is kept wet for a significant part of the growing season. Soils have variable properties, but usually show gleyed horizons.</td>
<td>Gentle slopes in moraine (Mj, Mv, Mb) and gentle and plain slopes in other materials. Some evidence of periodic standing water on the surface, but vegetation is continuous forest. Mottling may be present in the soil profile.</td>
</tr>
<tr>
<td>Poorly</td>
<td>Water is removed from the soil so slowly relative to supply that the soil remains wet for much of the time the soil is not frozen. Soils have variable properties, but usually show gleyed horizons or fall within the Gleysolic or Organic soil orders.</td>
<td>Gentle to plain slopes in all materials. Openings in the forest canopy indicate seepage and poorly drained areas, usually due to a shallow water table. Standing water may be present. Organic sediments are common.</td>
</tr>
<tr>
<td>Very Poorly</td>
<td>Water is removed from the soil so slowly that the water table remains at, or on, the surface for much of the time that the soil is not frozen. Soils have variable properties, but are either of the Gleysolic or Organic soil orders.</td>
<td>Plain slopes in organic materials (Op, Ow, Ob) or fine textured elasic sediments. Areas are typically wetlands with standing water visible.</td>
</tr>
</tbody>
</table>

1 These are abbreviated definitions; see Luttmere et al (1990) for a full description.
2 These are typical relations only, actual ratings assigned may vary due to groundwater seepage, material texture, local topography, etc.

5.5 Slope Stability (Terrain Stability)

Slope stability or terrain stability refers to the likelihood of a landslide initiating in a terrain polygon following timber harvesting or road building (Ministry of Forests, 1995). Slope steepness and morphology, moisture conditions and the physical properties of the surficial materials primarily influence slope stability. Ratings range from I to V; the former indicates a
negligible likelihood of landslide initiation while for the latter, the likelihood of instability is high (Table 2).

<table>
<thead>
<tr>
<th>Slope (Terrain) Stability Class</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>No significant stability problems are expected.</td>
</tr>
<tr>
<td>II</td>
<td>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.</td>
</tr>
<tr>
<td>III</td>
<td>Minor stability problems can develop. There is a low likelihood of landslide initiation following timber harvesting or road building. Timber harvesting should not significantly reduce terrain stability. Minor slumping is expected along road cuts, especially for one or two years following construction. A field inspection by a qualified registered professional is not usually required, but may be appropriate in wet areas or in gullied terrain.</td>
</tr>
<tr>
<td>IV</td>
<td>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. A field inspection by a qualified registered professional is required prior to road or access trail development to assess the stability of the affected area, particularly in gullied terrain. Conventional ground-based logging practices may not be appropriate in gullied terrain these areas.</td>
</tr>
<tr>
<td>V</td>
<td>Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction. There is evidence of active or recent landslides. 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 registered professional prior to any development, to assess the stability of the affected area. Cable and aerial harvesting techniques will likely be required in these areas.</td>
</tr>
</tbody>
</table>

The preliminary slope stability ratings were assigned on the basis of slope steepness and a series of modifying factors including material type, drainage, surface expression and the presence of gullies. The assignment was based on a classification arising from statistical analyses of landslide features in the Kamloops Forest Region (Table 3, Terratech, 1994). Slope stability was found to be inversely related to steepness. Failures were more common in glaciofluvial, fluvial and glaciolacustrine materials and in any material where drainage was very poor to imperfect.
Table 3: Suggested Stability Mapping Classification
Derived from Landslide Inventory Data (modified from Terratech, 1994)

<table>
<thead>
<tr>
<th>Dominant Slope Class</th>
<th>1 &amp; 2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Historic or Active Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Angle</td>
<td>0 - 15°</td>
<td>15° - 25°</td>
<td>25° - 35°</td>
<td>&gt;35°</td>
<td></td>
</tr>
<tr>
<td>Preliminary Stability Class</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>V</td>
</tr>
<tr>
<td>Modifying Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surficial Material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- glaciofluvial, fluvial</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- glaciolacustrine, lacustrine</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td>- very poor to imperfectly</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Surface Expression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- blanket</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>- benched or irregular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Process/Morphology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- gullied</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Range of Stability Classes following Modification</td>
<td>I – II</td>
<td>II – IV</td>
<td>III – V</td>
<td>III – V</td>
<td>V</td>
</tr>
</tbody>
</table>

+ assign to the next highest stability class
++ assign two stability classes higher
- reduce to the next lower class

Following fieldwork, a modified terrain stability classification was developed that incorporated the field observations with the classification developed by Terratech (1994). These criteria are presented in Table 4. A slope stability class was assigned on the basis of the dominant slope steepness class or classes, surficial material type, texture and processes. The presence of seepage on uniform till-covered slopes was used to raise the stability ratings for some polygons. While this classification (Table 5) was applied across the study area, the mapper did modify the ratings for a few polygons based on airphoto or field observations.
### Table 4: Final Terrain Stability Classification for the Pisima Face Area Study

<table>
<thead>
<tr>
<th>Slope Stability Class</th>
<th>Dominant Slope Class(es)</th>
<th>Typical Surficial Materials And Surface Expressions</th>
<th>Typical Textures</th>
<th>Typical Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1 &amp; 2</td>
<td>F\textsuperscript{4}p, F\textsuperscript{4}j, F\textsuperscript{4}f; Mw, Mb, Mv; Cv, Cb, Cj; Cv, Op; Ru</td>
<td>s\textsubscript{z}, zs, gs, sg; s, ds, zxs; rs, sr</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>2 &amp; 3</td>
<td>Mw, Mb, Mv, Mu; Cv, Cb, Ca, Cf; Cx; Rh, Rr, Ru</td>
<td>s, ds, zxs; rs, sr</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>2 &amp; 3</td>
<td>Lb</td>
<td>sz, cz, csz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Mb, Mk</td>
<td>s, ds, zxs</td>
<td>-V</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>F\textsuperscript{4}a</td>
<td>gs, sg</td>
<td>(k &gt; p)</td>
</tr>
<tr>
<td></td>
<td>3 &amp; 4</td>
<td>Mw, Mb, Mv, Mak</td>
<td>s, ds, zxs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Cv, Cb, Ck; Rh, Rr, Rk</td>
<td>sr, rs, x, a</td>
<td>-Rb</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>Lb</td>
<td>sz, cz, csz</td>
<td>-V</td>
</tr>
<tr>
<td></td>
<td>4 &amp; 3</td>
<td>Mks, Mv, Mb</td>
<td>s, ds, zxs, cz</td>
<td>-V</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>F\textsuperscript{4}k</td>
<td>gs, sg, g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 &amp; 5</td>
<td>Csk, Ck</td>
<td>r, x, a (talus slopes)</td>
<td>-Rb</td>
</tr>
<tr>
<td></td>
<td>4 &amp; 5</td>
<td>U; Mks, Mv, Mb</td>
<td>gs, sg, ds; s, ds, zxs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Ms, Mv, Mb</td>
<td>s, ds, zxs</td>
<td>-Rs</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Cs, Cv; Rs</td>
<td>sr, rs</td>
<td>-R''b, -V</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>Any gradients and materials where initiation of</td>
<td></td>
<td>-F''R''s,</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>Active or recent mass movement have occurred</td>
<td></td>
<td>-R''d</td>
</tr>
</tbody>
</table>

1 The stability ratings were generally increased by one class if the polygon displayed a gullied morphology and/or seepage and the slope steepness was class 3 or greater (e.g. a Mb-L on slope class 3 was raised to stability class III).

### 5.6 Mapping Reliability

The information contained in this report and on the accompanying map is based on aerial photographic interpretation with limited field checking. The classifications and criteria employed are consistent with methods used by terrain mappers in British Columbia. Interpretations for slope stability are subjective by nature due to difficulties in assessing subsurface conditions, forecasting extreme events, and by changing land use practices. The data presented should not be used for detailed operational planning that requires on site assessment.

There are 79 polygons delineated in the 5110 ha study area yielding an average polygon size of 65 ha (note: the polygons on the plateau area are typically several hundred hectares in size). There were 106 ground stations established during the field phase with detailed observations made at 17 sites. At TSIL C, the forest practices code requires that there be 0.5 to 1 ground checks per 100 ha or ground checks for 25% to 50% of the polygons (Ministry of Forests, 1995). Using all ground sites, this study has 4.8 checks per 100 ha covering approximately 68% of the polygons. Using the detailed sites, this study has 0.33 checks per 100 ha covering approximately 20% of the polygons. Most of the field sites were located near or adjacent to roadways. Sites were located across the full range of elevations and terrain types that characterize the study area. While there was little ground checking of the steep bedrock and talus
slopes in the northeast corner and along the northern boundary of the study area these areas are visible from the road ways and easily defined on airphotos.

It is beyond the scope of terrain survey intensity level C (TSIL C) mapping to assess individual cutblocks and individual gullies. Dr. Terence Lewis, P.Geo. performed two “field assessments of terrain stability” within the study area. These cutblocks are located partially within areas mapped as Stability Class 4. Dr. Lewis has assessed these areas in detail and the reader is reminded that in no way should terrain mapping (TSIL C) supersed the results of a detailed terrain stability report(s).

6.0 RESULTS AND MANAGEMENT IMPLICATIONS

Much of the study area is characterized by gently and moderately sloping terrain, which has already seen extensive harvesting with only small instabilities. The main problem areas are the steep and moderately steep slopes at mid-elevations. The steep areas of exposed bedrock and active rockfall are located in areas that are not expected to be harvested by either ground or cable methods (likely helicopter harvesting).

The data presented on the terrain map are generalized and it should be expected that within a given polygon there would be variance in materials, stability, drainage or other variables. The stability ratings are often conservative. For example, there may be small stable areas within an unstable (Class V) polygon. Alternatively, there may be locally steep, wet or fine-grained soils in polygons that have an overall moderate stability (Class III). Such areas may be less stable and more erodible than the average conditions that are present in the polygon and field workers should be aware of this potential variability.

6.1 Slope Stability

Stability Class V polygons have been mapped where there is evidence of active or recent initiation of one or more of the following types of mass movements: debris slides, debris flows debris slumps and soil slumps. Debris slides typically occur on slopes steeper than 55% where there is seepage or imperfectly drained soils near slope breaks. Debris flows have occurred in areas were small debris slides have occurred on moderately steep slopes within shallow swales adjacent to larger creeks. Natural instabilities of these types were only found in one area (Site 8).

Slumps occur in thick sections of cohesive tills, glaciolacustrine or glaciofluvial sediments just north of the study area. Rockslides tend to develop in steep bedrock slopes where there is a joint set parallel to the cliff or bluff face, or where bedding or foliation planes dip out of the slope face. Rockslides in the area appear to be infrequent and small and located in areas that are either within inoperable terrain or in areas with low forest site indexes and consequently are not likely to be part of future development.

There is one polygon mapped as Stability Class V in the study area. This area comprises a steep northeast facing gully slope with small areas of seepage and small (50 m³) debris slides in till (Site 8, Polygon 236).
Slump activity is not extensive in the study area. The thick sequence of unconsolidated glacial deposits in the northwest corner (near Road 40) of the study area are similar to the deposits observed in the Rock Island Slide. Some areas of gullies and steeper Slope Class 4 areas were noted during field traverses. Further fieldwork is needed in these areas to confirm or deny the presence of silty morainal and glaciolacustrine deposits. Until the properties of the surficial deposits in these polygons can be investigated more thoroughly the presence of glaciolacustrine deposits is considered suspect. The conservative terrain stability class rating in the northwest corner area reflects the presence of glaciolacustrine deposits (for rational see Table 3).

Several of the polygons mapped as Stability Class IV contain large debris slides and flows. However, these failures are thought to be due to either drainage diversions caused by road or trail construction or are associated with fill slope failures. The slides located near Sites 4, 9, 12 and 14 were judged to have been caused by drainage diversions along logging roads and trails. Veneers, blankets and mantles of fine to medium-textured tills at mid elevations are particularly problematic with respect to drainage changes caused by logging activities. The slopes in these areas typically range from irregular to uniform and the tills are "unconditioned" (i.e. they respond poorly to changes in drainage as a result of road building. Debris slides and debris flows have occurred where water is concentrated along the margins of bedrock ridges (Site 9); downslope of culverts; or in areas of surface water diversion (Site 14). The reason for these larger events on what appears to be mostly sandy well drained soils can be partly explained by the high content of silt (~25%) and fine sand (20-31%). The high percentages of these two materials types and the grading (sorting) of the materials in these deposits suggests that these materials behave more like fine textures soils and subsequently have lower stability than would be expected from a well graded sandy till deposit. However, the hydrologic changes created by surface water diversions can trigger slides in coarse-grained deposits, as was observed at Site 9, were sieve analysis of a sample from the initiation zone showed the deposit to consist of: 72% angular gravel, 24% sand and 4% silt. Large landslides in these types of deposits and typically infrequent. The presence of this large landslide (Site 9) is a good example of the impact that drainage diversions can have on slope stability (regardless of soil type).

A variety of materials and steepness classes are present in the polygons mapped as Stability Class IV in undeveloped areas. Included are: (i) morainal materials on Slope Classes 4 and 5; (ii) gullied morainal materials on Slope Classes 4; (iii) morainal materials in mixtures of Slope Classes 4 and 5; (iv) colluvial and bedrock surfaces in mixtures of Slope Classes 5 and 4; and (v) composite units of the above materials. Talus slopes on Slope Classes 4 to 5 were generally mapped as Class IV terrain as these slopes have proven to be problematic and are in some areas overlying moraine or other finer-grained deposits. Several of the polygons mapped as Stability Class IV contain large debris slides and flows. However, these failures are thought to be due to either drainage diversions caused by road and trail building or associated with fill slope failures. Rockfall initiation zones are mapped as Class IV.

Stability Class III terrain includes runout areas for (1) rockfall on Slope Class 3 to 4 and (2) debris slides on 3 and 4. Slopes range from Class 3 in glaciofluvial or gullied morainal materials to Class 4 in blocky colluvium and bedrock. The management implications and the typical terrain response associated with each slope stability class are outlined in Table 5.
Table 5. Management Implications Associated with Slope Stability Classes
(modified after Ministry of Forests, 1995).

<table>
<thead>
<tr>
<th>Slope (Terrain) Stability Class</th>
<th>Management Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>None.</td>
</tr>
<tr>
<td>II</td>
<td>Minor slumping is expected along road cuts, especially for one or two years following construction.</td>
</tr>
<tr>
<td>III</td>
<td>Timber harvesting should not significantly reduce terrain stability. Minor slumping is expected along road cuts, especially for one or two years following road construction. A field inspection by a terrain specialist is not usually required, but may be appropriate in wet areas or at gully locations.</td>
</tr>
<tr>
<td>IV</td>
<td>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 road or access trail development, to assess the stability of the affected area, particularly in gullied terrain. Conventional ground based logging practices are may not be appropriate in these areas.</td>
</tr>
<tr>
<td>V</td>
<td>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. Cable or aerial harvesting techniques will likely be required in these areas. In some instances logging may have to be deferred.</td>
</tr>
</tbody>
</table>

7.0 SUGGESTIONS

The majority of the slope stability problems in the study area are confined to moderately steep and steep uniform terrain. Debris flows occur mainly in tills that are fine-textured, of veneer and blanket thickness, and imperfectly to moderately well drained. Slumps in glaciofluvial and glaciolacustrine sediments occur where toe support has been removed by stream undercutting (or wave erosion in the case of Rock Island Slide), road construction or where seepage has caused small piping failures.

Most of the larger debris flows in the study area are likely a result of drainage diversion and/or concentration. Some of these debris slides have initiated up to one hundred meters below built roads within forested areas on short pitches of moderately steep terrain. As it is drainage diversions/concentrations which have triggered many of these slides, it is judged that the slopes are of marginal stability (Class IV).

The following suggestions are made with an aim to reduce instability:

1. Limit road construction on steep slopes in colluvium and on moderately steep (>55%) and steep slopes in moraine and glaciofluvial materials. A qualified registered professional should assess polygons with Stability Class IV and V prior to road construction. Care should be taken to identify seepage zones and poorly drained areas, which can be unstable even on moderately sloping ground.
2. Roadside ditches and culverts should be inspected and maintained frequently. Ditch lines should be kept free of slumped or ravelled sediments from road cuts. Seed road cuts as soon as practicable after construction and limit the cutslopes height in areas where they are in unconsolidated sediments. Care should be taken not to divert drainage away from natural stream courses. Inspect slopes below culvert outflows on moderate to steeply sloping ground to determine if the materials present are likely prone to failure or erosion. Walking of the proposed alignments during times of the year when peak runoff conditions are expected may be beneficial in helping to establish surface water flow conditions and aid in the proper location of culverts.

3. Where conventional logging practices are followed, align skid trails such that drainage is not focused downslope along a small number of pathways. All fireguards should be rehabilitated prior to winter.

4. Some sites that appear favorable for conventional ground skidding may have to be harvested via cable yarding systems.

5. The areas below and immediately above Road 40 in the northwest corner of the study area contain areas that appear “similar” to the terrain within which the Rock Island Slide occurred. If harvesting is to occur in these areas a qualified registered professional should assess the terrain and soil types in these areas to determine if “similar” deposits exist and if the slopes are potentially unstable.
8.0 REFERENCES CITED


Rock Island Slide. View from helicopter. Note: Site #6 is located on Mainline, 180 m upslope of slide. Landslide occurred 6 June 1996, approx. 2 km south of Rock Island, on the eastern shore of Adams Lake. Site reported by TCL, estimated at 500,000 m³.
Rock Island Slide. View from helicopter. Note: Site #6 is located on Mainline, 180 m upslope of slide. Landslide occurred 6 June 1996, approx. 2 km south of Rock Island, on the eastern shore of Adams Lake. Site reported by TCL, estimated at 500,000 m^3.
Rock Island Slide. View from helicopter. Note: Site #6 is located on Mainline, 180 m upslope of slide. Landslide occurred 6 June 1996, approx. 2 km south of Rock Island, on the eastern shore of Adams Lake. Site reported by TCL, estimated at 500,000 m³
Rock Island Slide. View from helicopter. Note: Site #6 is located on Mainline, 180 m upslope of slide. Landslide occurred 6 June 1996, approx. 2 km south of Rock Island, on the eastern shore of Adams Lake. Site reported by TCL, estimated at 500,000 m³