Terrain Interpretation of operating areas for Kaslo Community Forest Licence, Woodlot 494, and Goose Creek Timber Ltd.

Report with Maps
for the licencees and
Kootenay Lake Forest District

Terrain Classification with interpretations for:
- **Terrain Stability Hazard,**
- **Surface Erosion Hazard**
- **Road & Ditch Erosion Hazard**
- **Landslide Induced Stream Sedimentation Hazard**
- **Sediment Delivery Potential**
- **Sediment Yield Potential**

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Subcontract to Kaslo Community Forest Society

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1. Introduction

This is a report on the land and water resources in the Kaslo Community Forest Licence, Crown Woodlot 494 and a portion of Crown land licenced to Goose Greek Timber, Ltd. It accompanies maps of the study area depicting terrain units with interpretations for slope stability and waterborne erosion issues. In addition to the terrain and related interpretations, a reconnaissance assessment of selected water sources was done in order to make observations of stream characteristics and recommendations regarding flow regimes . The field work for this report was done in the summer and autumn of 1998. The information is to assist in forest management planning and land management.

Among the terms of references, the contract sets out objectives which include data collection relating to existing sediment sources, recommendations with respect to preventative or corrective measures that might be applied where sediment sources are identified, and to make observations of stream channel stability, and sensitivity for selected reaches of the major stream channels in the area.

This work is done in collaboration with the Ministry of Forests' advisor to the project, Alan Davidson, PAg, (Earth Science Specialist, Kootenay Lake Forest District).

The study area lies in the area around Kaslo, BC, in the Central Selkirk Range in the West Kootenay region of B.C. The location of the project area is shown in Figure 1. The area is located on portions of NTS map sheets 82K006, 82F096, 82F085, and 82F086. The area covers approximately 5172 hectares, including 598 ha WL494. Field samples were described in 102 of the 284 polygons, with varying survey intensity levels depending on the sensitivity and implications of development (see Table 1). In addition 13 channel descriptions were completed on stream channels considered to be indicative of watershed sensitivity in five selected drainages in the study area. Extensive foot traverses were completed which are depicted on Figure 3.3. Most passable roads were used as transects, by vehicle, and by foot. The road transects are valuable because of the extensive visibility of subsurface materials exposed in the road cut banks.

The report accompanies a set of three interpretive maps at 1:20 000 scale covering the study area. The maps depict terrain units with pertinent interpretations for forest development and understanding of water sources and waterborne sediment production: These include:

Figure 3.1

- terrain materials,
- slope gradient ranges, and
- soil drainage classifications,

Figure 3.2

- terrain stability;
- landslide induced stream sedimentation hazard classifications;
- surface soil erosion potential,
- road & ditch erosion potential sediment delivery potential,

- sediment yield potential classifications

Figure 3.3

- transects and
- sample sites).

The maps and report are the results of this study, and these materials should be used together.

Panorama of the southeast portion of the study area. Ridged and fluted surface shape reflects the underlying geology.

1.1. Terms of reference and survey intensity

The specifications for this contract indicate a variety of survey intensity levels are expected for this project. We have varied the field checking intensity accordingly. We focused on sites and areas where there are downslope implications of development on populated areas, domestic and community water resources, in areas where air photograph interpretation indicated instability, and where access is possible. Table 1 sets out the range and criteria of Terrain Survey Intensity Levels recognized in British Columbia terrain mapping practice. Table 2 indicates the survey intensity achieved in various portions of this mapping project.

Table 1. Terrain Survey Intensity Levels (TSIL) used in BC terrain mapping adapted from Mapping and Assessing Terrain Stability Guidebook, April 1995).

Terrain Survey Intensity Levels	**Scale**	**% of Polygons Field Checked**	**Field Checks per 100 ha**	**Method of Field Checking**		**Typical Objectives**
A	<1:20 000	75 - 100	> 1.5 - 2	Foot		Detailed terrain stability assessments for cutblock & road design, sensitive sites etc.
B	1:10 000 - 1:50 000	50 - 70	1.0 - 3	Foot & vehicle		Terrain analysis
C	1:20 000 - 1:100 000	25 - 50	0.5 - > 1.0	Vehicle & flying		Inventory/ biophysical mapping
D	1:20:000 - 1:250 000	0 - 25	none - 0.1	Vehicle & flying		Regional planning, reconnaissance terrain hazard mapping
E	Any scale	0	none	air photo interpretation only		Regional planning, reconnaissance hazard mapping

In the consumptive use watersheds in this study area, a relatively high density of field sites were sampled:

- South side of Mt. Buchanan within the study area (265 hectares): 29 field checks; 10.9 samples /100 ha.
- Kemp Creek, above the village intake (1190 ha): 9 field checks; 0.77 samples / 100 ha.
- Lofstedt Creek basin (subdrainage of Bjerkness Creek -570 ha. within the study area): 13 field checks; 2.3 samples /100 ha.

Table 2. Survey Intensity Levels for Subunits of the Kaslo Community Forest Licence and Woodlot 494 Terrain Interpretation.

Map Subunit (North to south)	TSIL	Field Checks	Notes	Subunit Total Polygons	Subunit polygons (qualified*)	*qualification	Stream descriptions	% of Polygons Field Checked	Method of Field Checking
Lake Shore Area	E	8	2	49	15	In Crown land; 2 are operable		53.33	Foot, boat, drive
Blue Ridge Area	E	1		40	20	In Crown land; ~ half are operable		5.00	Helicopter
Seven Mile Area	C	7	2	18	18	In Crown land, all are operable		39	Helicopter, drive, foot
Buchanan A&B& McDonald	B	29		51	51	All considered		56.86	Foot, helicopter
McDonald	B	2		5	5	All considered	1	40.00	Foot
Buchanan B	B	7	1	25	25	All considered	5	28.00	Foot
Buchanan A	B	20	1	21	21	All considered	3	95.24	Foot
Kemp Cr above Intake	C	9		66	34	Below alpine	2	26.47	Foot, helicopter
True Blue - Airport	B	25	1	30	30	All considered		83.33	Helicopter drive, foot
Lofstedt Subdrainage of Bjerkness Cr	B	13	1, 2	41	8	Stability Classes IV and V	2 channel descripts, 1 Field check	> 100	Foot, drive
Totals		90		295	176				

Notes:
1 - some polygons are included in more than one subunit
2 - Author completed TSIL A assessment

1.2. Previous work

A terrain classification and interpretations of Kaslo Village and nearby surrounding area was completed by Wells (1981), and by Talisman Land Resource Consultants (1982). Portions of the study area were mapped as part of the Nelson Forest Region's reconnaissance terrain stability mapping project of the Transportation Corridors in the Kootenay Lake Forest District by Jordan (1995).

Wells, et. al. (1995) reported on and mapped much of the Kaslo-Schroeder Creek area terrain with TSIL-B standard interpretations for terrain stability and waterborne erosion issues. The field work for that report was done in the summer of 1995. The current study borders the 1995 Kaslo-Schroeder Creek project on three sides.

Soils with generalized terrain and soils inventory mapping has been completed at a scale of 1:100,000 by Jungen (1980) for 82F, and by Wittneben (1980) in 82K.

Bedrock geology has been mapped by various parties, and the study area includes portions of geology mapping projects by several different authors. The most recent publication for 82F East Half is by Reesor (1996) at 1:100,000. Wheeler and Read (1976) mapped the area outside the extreme northwest of the study area (including 82K.005, adjacent to the west of 82K.006). Reesor (1973) is the reference for 82K.006.

2. Study area background and descriptions

2.1. Physiography

The study area is comprised of eight distinct landscapes. From the north they are:

Blue Ridge In this area, the west side of the Kootenay Lake valley rises almost 1400 meters from lake level (540m) to the top of Mount Buchanan. Mount Buchanan, at an elevation of 1912 meters, is at the south end of the Blue Ridge along the eastern edge of the Selkirk Mountains. The slope is drained by a number of east flowing streams. These streams have large steep catchments basins which drain into deeply incised steep-walled gullies above Shutty Bench, through to the Kootenay Lake shoreline. The area between Blue Ridge and the lake shore are mapped in the Kaslo - Schroeder Creek Report.

The lake shoreline (corridor of Highway 31 to the beach, including some private land above and below the highway in the Shutty Bench area), The slope from Blue Ridge (including the Shutty Bench map area) drains through this area. A significant amount of the land between the highway and the shore line is composed of slopes and escarpments of gravel, sand and silt glaciofluvial and glaciolacustrine deposits. Slope failures have occurred at some sites where roads have been constructed across them, or where water has been diverted onto them. Bedrock is also exposed in steep bluffs and cliffs, or near the surface on gentle slopes and covered by broken rock debris.

South side of Mt Buchanan The Kaslo River drainage cuts through ridged and fluted terrain that expresses the bedrock structure of the Selkirk Mountains. It cuts across the grain of the structure resulting in steep sloping relief from the ridge top down to the river in the valley bottom. This steep gradient area is experiencing active earth slides. McDonald Creek drainage, some of which is north of this study area, includes several avalanche chutes off the southeast side of Mt Buchanan.

Lower Kemp Creek, airport, and Kaslo River terraces Sandy, gravelly and silty fan, terraces and terrace scarps. Some instability initiated because of saturated conditions in these materials. Kemp Creek water pipeline is laid down through these to cross Kaslo River. Land below the dump is naturally failing in several sites. Presumably the movement of the materials damaged the pipeline, causing further instability.

Seven Mile Creek area Above the river terrace deposits, the landscape is the southwest slope of Blue Ridge and shoulder of Mt. Buchanan. This is moderate to moderately steep (27 - 70%) and relatively stable. Lower slopes are frequently steep near the valley bottom because of ancient undercutting by the river, and because of construction of the highway and various road ways since the late 19th Century. Relatively resistant rock ribs of the north-south trending geologic structure are exposed in road cuts.

Upper Kemp Creek A steep flowing alpine glacier-carved drainage with steep avalanching slopes, leading to a steep gradient, V shaped creek valley above the Village water intake. There is some soil creep and several debris slides in the lower section

True Blue face and lower slope This is one of the Kaslo area landmarks: the steep east aspect of the Selkirks including the prominent peak between Lofstedt and Kemp creeks, and the step-like benches leading down toward the airstrip. There are several debris flow channels down the slope. Lower slopes are forested, and at the foot of the steep face are benches of glacier scoured bedrock covered by glacial drift and outwash.

Woodlot 494 and South Kaslo benches A continuation southward of the step-like benches and rock ridges with relatively low relief, shallow-to-rock ridges, flutes and flats filled with glacial outwash, or fluvial deposits. Some of the ridges have exposed bedrock on the flanks, and some rock benches have exposed bluffs. It is generally stable terrain, except on sites where there is steep bedrock from which material may be displaced.

2.2. Climate

The study areas lies within the Moist Climatic Zone of the Nelson Forest Region (Braumandl, 1992). The southern half of the map area, below about 1200 m, including all of Woodlot 494, is in the Dry Warm Interior Cedar-Hemlock Variant (ICHdw) which is mapped along the shores of Kootenay Lake, and into the Kaslo River Valley as far west as Seven Mile Creek . The subzone fades out on the west side of the lake approximately at Kaslo’s north village limits. The ICHdw continues north on the east side of Kootenay Lake. The Columbia-Shuswap Moist Warm Interior Cedar-Hemlock Variant (ICHmw2 - with 'moderate' precipitation recorded as 840 mm) extends from 1200 to about 1550 meters. The Selkirk Wet Cold Engelmann Spruce-Subalpine fir (ESSFwc4) occurs above 1650m. Precipitation increases significantly as elevation rises, and the ESSF Subzone variants in this area have 'high' precipitation factors, in excess of 1000 mm annually. The highest peaks and ridges in the area are in the Alpine Tundra or Wet Cold Parkland Engelmann Spruce-Subalpine fir (ESSFwcp) above 1950 m. Braumandl et al’s *Field guide for site identification and interpretation for the Nelson Forest Region* identifies the Columbia Wet Cold Englemann Spruce-Subalpine Fir Variant (ESSFwc1) as a transitional variant, occurring in the margin between the ICH and the ESSF (1550 - 1650 m). In this study we simply assumed transitional ecosystem characteristics rather than separate ESSFwc1 from the adjacent ICH and ESSF.

2.3. Bedrock geology

According to Reesor (1996), bedrock in the study area is predominantly Paleozoic metamorphics with lessor amounts of Triassic argillites and Jurassic Intrusives (See Figure 2). Bedrock units and fault planes trend north-south, and foliations generally dip toward the west. Less competent rocks (i.e. argillite, phyllite and schist) have been preferentially ground down by the overriding glacier, leaving the characteristic ridged and fluted topography along the mid and lower slopes along the main Kootenay Lake Valley. Some competent rock types (e.g. quartzite, and grit) in the study area are subject to failure such as rockfall due to steeply dipping fracture planes, especially near fault zones, and in exposures on steep slopes were support has been removed.

The units described in the map areas are as follows: Lower Cambrian rocks include the Hamill Group (CH), which is mainly quartzite, and the Badshot-Mohican Formation (CBM) which consists of marble and dolomite. Cambrian to Devonian aged rocks of the Lardeau Group are mapped in the area as the Index Formation (PI - undivided, micaceous schist), the Jowett Formation (PJ - basaltic greenstone), and the Broadview Formation (PB - mica schist, grit and quartzite). The Upper Mississippian to lower Permian Milford Group (MPM) is mapped as argillite and phyllite with minor limestone. Permian rocks include the Kaslo Group (PK) which consists of greenstone and amphibolite with lesser amounts of diorite and serpentinite, and the Marten Conglomerate (PM). The Triassic Slocan Group(TS) includes grey argillite and phyllite with lesser amounts of black limestone. Jurassic rocks of the Nelson Granitic Suite consists of the Procter Intrusions (JNP) (foliated hornblende leuco-granodiorite) and Biotite granodiorite (JNgd).

The locations of these bedrock formations are described in more detail within their distinct landscape units:

The **Blue Ridge and Seven Mile Creek** areas have similar geology. The Milford Group argillite and phyllite are dominant with lesser amounts of the Kaslo Group greenstone and amphibolite. There are several exposures of this rock in road cuts. Large areas of Quaternary glacial material cover the Blue Ridge and the Seven Mile Creek portion of the map area. A large extensive fault runs parallel and below Blue Ridge on the east aspect and continues through the south Mt. Buchanan area, then ends or disappears at the mouth of Kemp Creek. Other thrust faults are mapped along Blue Ridge oriented both east and west.

The steep bedrock outcrops along the **Kootenay Lake shoreline** area are mapped as the Hamill quartzite, the Badshot Mohican carbonate, and the Index Formation schist. A large Quaternary deposit is mapped in the Shutty Bench-Wing Creek areas.

The geology on the south side of Mount Buchanan is somewhat complex. Just above the Village limits are the Procter Intrusives with inclusions of slivers of the Index Formation. Westward, the Broadview formation is exposed and cut by a thrust fault placing the Index Formation and the Jowett Basaltic greenstone along the mid to upper slopes. The fractured and incompetent nature of bedrock within fault zones may have contributed to the unstable conditions in this area. The upper slopes of this area are mapped as the Milford Group with some Kaslo Group occurrences.

Most of the **Kemp Creek area** is underlain by the Triassic Slocan Group (TS) - argillite, phyllite and limestone). The upper end of the tributary, however, is mapped as Jurassic Nelson Suite of Intrusives (biotite granodiorite). A large north-south trending fault is mapped along the eastern tributary of Kemp Creek and is in contact with the Milford Group and the Kaslo Group.

Bedrock in **Woodlot 494** and the Lofstedt Creek area is mapped entirely as the Index Formation (predominantly mica schist). Two northwest trending faults are mapped below the steep slopes above the Woodlot and are likely to be associated with highly fractured and easily erodible bedrock. The ice moving southeastward from the Kaslo River valley found little resistance near these faults and the less competent rocks of the Index Formation. Fluted bedrock characteristics are typical in the Woodlot area.

2.4. Glacial history

Kootenay Lake occupies a portion of the Purcell Trench, a long north-south trending valley in the Columbia Mountains with the Purcell Range on the east and the Selkirk Range on the west. Kaslo is on the west side of Kootenay Lake, about mid way on the North Arm. The Kaslo River Valley enters the larger lake valley from the northwest at Kaslo. Glaciers eroded softer rock, rode over harder rock, and gouged out the structural weaknesses created by a faulted and weakened geologic structure. The river replaced the glaciers, in time, cutting through the deposits left by the melted ice.

A review of the presumed sequence of deglaciation in the map area illuminates why some of the landscapes have unstable attributes[1]. Our simplified analysis of the post glacial history of this map area is laid out in the following scenario:

1. There have been several episodes when glacier ice covered and flowed over this study area including, Blue Ridge, Mt Buchanan, and True Blue. The present day surface mainly includes remnants of the last ice advance. It ended about 10,000 years ago. The ice incorporated the material it had eroded from lands to the north and north west depositing portions of its load on the sides and floor of the two valleys at the confluence.
2. The glacier in the Kaslo River valley becomes obstructed by the Purcell Trench ice and is forced southward from Kemp Creek across the face of True Blue and the South Kaslo benches.
3. Trench ice down wastes slower than the Kaslo River glacier, resulting in a barrier to drainage from the melting Kaslo River ice.
4. Kaslo River ice down wastes creating lakes along the valley bottom further west than Keen Creek area, evident in the present by the terraces at about 800 m elevation, and also exposing over-steepened unconsolidated materials on the south end of Blue Ridge/Buchanan.
5. When Trench ice reduced sufficiently to remove the barrier to glacial Kaslo River[2], a catastrophic change in local sea-level occurred as the released water flowed down to the next impoundment. This type of event evidently repeated at several times over the period of deglaciation to present-day stream and lake levels.
6. Reductions in the elevations of the valley bottoms precipitated the loss of toe support for the unconsolidated (and sometime saturated) glacial deposits. This led to over-steepened slopes and failures which continue to the present (see polygon 170, and some units along the river). Moreover, glacial erosion cleaned out the broken bedrock that had been shattered in the course of faulting and mountain building. Upon exposure to the atmosphere after the release from the huge weight of the ice, some weakened

[1] Readers are referred to Clague's works for further explanation about the sequence and effects of deglaciation in this region.

[2] The term 'glacial' prior to a local lake or river name implies its status during the time of the Late Pleistocene epoch when deglaciation was occurring. For example, glacial Lake Kootenay referring to a time when remnant ice occupied Kootenay Lake Valley,

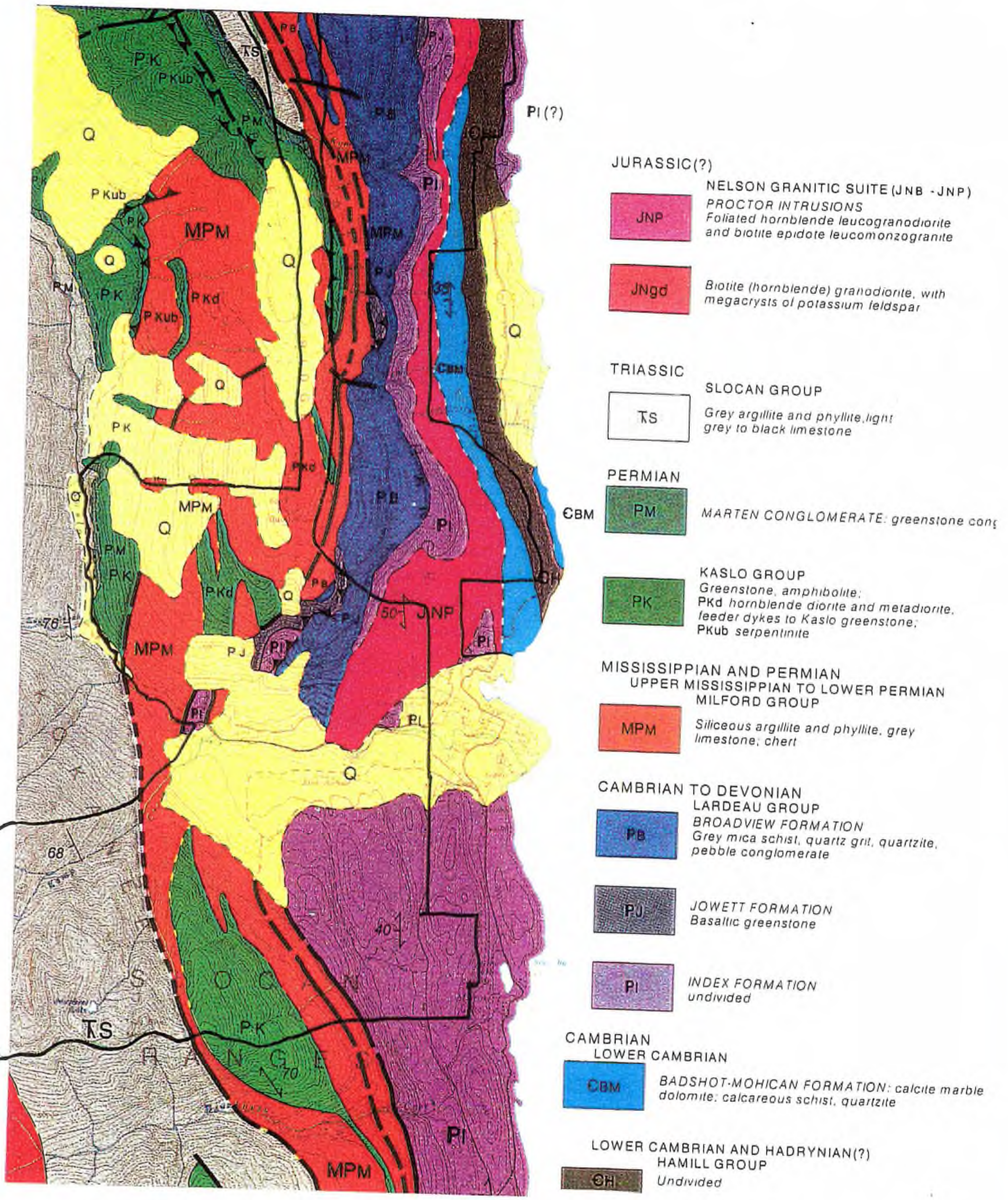

Figure 2. Schematic geology map of the study area from Reesor (1996). Scale: mapped at 1:100,000; enlarged to ~1:70,000.

rock rebounded and , commenced to ‘calve’ off blocks which have been slowly moving down slope into the present. (see polygons 158, 153,146,152, and 170).

2.5. Soils and parent materials

Soil features of permeability drainage, and surface erosion have been sampled and mapped. These are included in the terrain map (Figure 3.1), presenting the distribution and characteristics of the terrain in the study area. However, soil series identification was not mapped in this study because it is not necessary for the purposes of this report. Soils classification covering this study area can be found in Jungen (1980) and in Wittneben (1980) .

2.6. Hydrology and water courses

Major consumptive-use stream channels were visited and reaches considered to be representative of that stream’s stability characteristics were selected and described.

Following are the stream channel area descriptions:

Buchanan A (west drainage): (70 ha) This drainage is located in the South Buchanan area and flows southward into the Kaslo River. No water intakes are mapped on the development plan map on this stream. It is a *first order*[3] stream originating at approximately 1300 m (higher than shown on TRIM map). Three observation sites were made on this channel at varying elevations.

Buchanan B (east drainage): (160 ha) The channel parallels Buchanan (A) on the east side. The two tributaries of this first and second order stream starts at 1600 m and 1400m. An intake is mapped immediately below the junction of the two tributaries at 1090 m, where a diversion crosses the slope and carries water along a small hand dug ditch approximately 150m east transferring it into a previously dry gully. Five channel descriptions were made on this channel.

McDonald Creek: (35 ha within the study area) McDonald Creek is a first order stream on the southeast slope of Mount Buchanan and flows south until the town of Kaslo, where it changes direction and flows east into Kootenay Lake. One channel descripton site was established between 900 m and 700 m, at the community water intake.

Lofstedt Creek: (570 ha within study area) This Creek originates at 1800 m and flows into Bjerkness Creek at 640 m. It is unique as a drainage in this study because it has two major morphologies, and two points of interest: the shallow to bedrock step/ ridge-and-flute upper reaches above Lofstedt Farm in-take, and the gentle gradient lower reaches through the farm and marshy area before it joins Bjerkness Creek leading to Mirror Lake’s Community water system. Two channel descriptions were completed on the northeasterly flowing tributary in the upper reaches.

Kemp Creek: (1190 ha) Kemp Creek is a third order stream and flows north and north east into the Kaslo River. The stream consists of several steep tributaries flowing into two main branches. The west branch originates at 2150 m and the east at 2010 m. The lower portion of the channel consists of mostly very steep unstable terrain that is likely to

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[3] Stream orders are indicators of the number of tributary drainages contributing to a stream: first order streams have no tributaries, third order streams have two tributaries.

contribute to sedimentation. Two channel descriptions were completed for Kemp Creek, one on the eastern branch and the other, just above the intake.

3. Methods

3.1. Procedures and interpretations

Existing information reviewed included earlier terrain analyses of Kaslo Village and a reconnaissance map of slope stability hazards on transportation corridors, terrain and soils inventory studies, biogeoclimatic subzone maps, and geology maps.

After preliminary preparation and scanning of air photography of the study area preliminary polygons encompassing areas of similar terrain and slope were defined on the air photographs (nominal scale 1:20,000) by standard methods of airphoto interpretation.

Ground checks were made by means of foot traverses and road checks in the late summer and autumn of 1998. Road access is adequate in much of the map area, but access into the significant consumptive use watersheds is not. These required foot traverses along trails and 'cross-country.' Helicopter set-outs were used for a transect in Kemp Creek and across lower True Blue face, and for another transect from near the top of Mt Buchanan down through McDonald Creek. In addition to the ground checks (indicated on map Figure 3.3 by on-site symbols), observations were made while traversing between the sites. Where possible, road cuts and tree root churns were used for terrain cross section observations. Ground checks were concentrated on complex terrain and areas where developments may affect down slope areas and water resources. Intensive air photo interpretation was done concurrently with and after the field investigation.

Wallace and Deschênes were the primary mappers of the area and an overview by Wells was provided throughout the study. Each was subsequently the primary interpreter of the information developed in his/her respective areas. During the project, the mappers freely collaborated on the work in order to inform each other of discoveries about similarities and differences of significance.

Final polygon boundaries were transferred to 1:20,000 TRIM base maps by means of Mono Photo Restitution by Surewood Forestry Consultants Ltd., Kaslo, BC. Line work for the preliminary polygons depicted on the airphotos was plotted by Surewood's J. Reynolds, and these maps were used to further define the final polygons. The plotted polygon maps were overlaid on Triangle Network Slope maps (TIN) used to clarify slope breaks and gradients for the slope range data. The minimum polygon size is one square centimeter on a map or 4 hectares at this scale, and in general, 20 hectare areas are usually the smallest terrain units to be included in a polygon.

Stream and watershed evaluations are derived from on-site sample data, airphoto interpretation and mappers' experience. Streams and watersheds were selected for evaluation because of the significance of downstream values (i.e. civic infrastructure, fisheries, domestic use water).

The major stream channels in the area were reviewed in order to assess the characteristics of the channel in terms of its sensitivity and instability. Channel description cards were completed in conjunction with terrain mapping traverses on the following Creeks: Lofstedt, Kemp, McDonald, and two unnamed creeks designated as 'Buchanan A' and 'Buchanan B' for the purpose of this study. Data collected at channel observation sites are listed in Appendix 2. Reach breaks were not identified because that level of detail is not significantly more valuable for the purposes of this study. Hazard ratings defined in Table 17 were determined at each check point using a method described by Utzig and Carver (1999).

Table 3. Stream channel hazard class definitions (from Utzig and Carver, 1999)

Hazard Rating	Definition
High	1. Evidence of debris flow/flood activity, or
	2. Evidence of significant channel instability and of channel sensitivity to changes in flow and/or sediment regimes.
Moderate	1. No evidence of significant channel instability but channel stability sensitive to changes in flow and/or sediment regimes, or
	2. Evidence of channel instability but channel insensitive to changes in flow and/or sediment regimes.
Low	1. Channel generally insensitive to changes in flow and/or sediment regimes, and,
	2. Observed instability is not significant.

These ratings were determined using the following indicators of channel instability and sensitivity adapted from Utzig and Carver (1999), Carver and Putt (1999):

Channel Instability:

- debris flow activity
- side wall instability
- avulsions
- excessive scour or deposition
- step instability
- homogeneous bed composition
- low storage capacity (W_b/d_b)

Channel Sensitivity

- step instability
- high confinement (W_{1m}/W_b)
- low gradient
- erodible banks
- low storage capacity (W_b/d_b)

Where W_b = width at bank full: W_{1m} = width at 1 m depth; d_b = depth at bank full

Table 18 presents a summary of stream channel hazard ratings and primary observations of the channels.

Interpretations The following sections include a series of discussions about interpretations used in this report. They are associated with a number of tables presenting the procedures involved with developing the interpretations. In order to present some of the larger tables on one page some have been separated from their respective narratives. A guide to the various interpretation tables used in this study is available in Appendix 4

3.2. Terrain classification

Terrain units are defined according to *Terrain Classification System for British Columbia* (Howes and Kenk, 1997). Terrain and landform interpretation from field data and air photographs is based on observed attributes and features. Features which were determined to be significant to the study area are characterized in the size, configuration, apparent texture of landform materials, critical slopes, depths, and processes noted in the terrain units. Complex units (i.e. polygons depicting two or three units) are used where each component unit is significant but too limited in size for individual delineation. No texture modifiers are used if the area was not field checked and a reasonable inference cannot be made, or if the texture of the unit is the range implied by the generic material symbol.

3.3. Surficial materials

Following is a list of terrain materials and processes that were identified in the study area in terms used in Howes and Kenk (1997), and are indicated on the Terrain Maps (Figure 3.1):

Anthropogenic landforms(A): This designation is used where original genetic materials are so modified by human activity that their physical properties (structure, cohesion and compaction) have been drastically altered.

Bedrock derived landforms

Bedrock (R): Bedrock outcrops and rock covered by a thin mantle (≤ 10 cm thick) of unconsolidated or organic materials. The structure and composition of the rock leads to different terrain attributes and stability characteristics Fractures, chemical weathering and mechanical weakness are issues that are noted in this study.

Weathered Rock (D): Saprolites (bedrock decomposed *in situ* by processes of mechanical and/or chemical weathering) are described on a slope above the Allen Subdivision (Polygon 145) where bedrock is granodioritic (Procter Intrusions).

Caliche* or *tufa. Secondary carbonate deposits resulting from chemical weathering of carbonate rock or carbonate enriched unconsolidated materials, called lime, *Caliche* or *tufa,* occur in a number of places in the study area. These deposits are not mapped as a genetic material but are noted as a component in sample descriptions. These occurrences are prominent in the Shutty Bench area both above and below the highway on the bench in Lot 13A, in the fields of the Blue Ridge Farm (also neighbouring land in polygons 252, and 269), and in road cuts along to the shore line (Polygons 253, 254, 255, 272).

Ice-transported landforms:

Till (M): Till - or glacial moraine - is material deposited directly by glacial ice. Till characteristics vary according to the materials from which they were derived and their mode of deposition (ground moraine or basal till, lateral and terminal moraines). In general two types of till occur in this study area, basal till and ablation till. Basal till is the material which is gouged out of the land's surface and then redeposited under the pressure of the overriding ice (about 2000 meters deep here during Ice Age maximum).

Ablation till is the lateral or terminal moraine material that is deposited at the glacier margins amid the relatively complex processes occurring there--sometimes referred to as 'ice-contact' - materials.

Both types of till are wide spread in the study area but ablation till is more common at lower and middle elevations and may be among glaciofluvial deposits. Basal till appears to occur as thicker deposits where the mass of the ice passed over, such as on moderate gradient slopes, within depressions between bedrock ridges and as veneers on the higher elevation, steeper slopes, and as thick deposits underlying ablation till at lower elevations.

Till in the study area consists of a wide range of sizes of subrounded to subangular clasts of various lithology reflecting the area over which the ice has scoured. Basal till usually has a silty to fine sandy texture (with varying amounts of clay), is cohesive, poorly pervious, and derives its strength from its matrix. Ablation till in the area contains more coarse fragments in a sandier matrix and is generally less cohesive and consolidated. It is often clast-supported and is more pervious than basal till. Ablation till in the area is easily confused with some glaciofluvial deposits because some modification by flowing water may be expected in ice-contact environments. The criteria used in distinguishing between glaciofluvial and ablation till deposits is evidence of sorting, stratification and imbrication of coarse fragments, and deposits on planar surfaces which are more typical of glaciofluvial deposits. Ablation till may seem disorganized and poorly sorted, although composed of shapes and sizes that may appear waterborne.

The silt and clay components of till and some of the glaciofluvial and glaciolacustrine landforms lose strength under saturated conditions. There are numerous sites throughout the study area where landslides, earth flows and slope failures occurred as a result of saturation of the silt and clay fine fractions.

Gravity-transported landforms

Colluvial (C): Colluvium is material that has moved down slope to present locations as a result of gravity-induced movement. Throughout the area there are numerous cliffs and bluffs with talus slopes beneath them. Some of the more problematic areas are those with coarse material mixed with silty till-derived matrix.

Rocky colluvium resulting from fractured rock is a common feature along roads built through bedrock or under steep rocky slopes.

Some small gullies have disgorged colluvial cone deposits either of talus or as the result of debris flows: these are too small to be designated on the map as separate units.

Water-transported landforms

The chief characteristic of these landforms is particles with some degree of sorting by size, rounding, and imbrication. Roundness is a function of distance from source, and hardness and habit (crystal or fracture form) of the material, while sorting is a related to the speed of the water and particle size. Simply put, rounder particles have rolled farther, angular particles are closer to source; larger particles require faster water to move them than smaller particles.

Fluvial (F): Fluvial materials are those transported and deposited as a result of waterborne erosion by streams and rivers.

Glaciofluvial (F^G): Glaciofluvial materials exhibit evidence of having been deposited by glacial meltwater streams either directly in front of, or in contact with, glacier ice. Often glaciofluvial deposits have been eroded by more recent rivers or streams, leaving steep, unstable slopes above the creeks. The deposits are generally sandy gravel and gravelly sand with 45-75 % rounded to sub rounded coarse fragments.

Fresh water-deposited landforms

Lacustrine (L): These are sediments that have settled from suspension and underwater gravity flows in bodies of standing fresh water, or sediments that have accumulated as a result of wave action at margins of such bodies of water. These are generally fine textured materials with few coarse fragments (e.g. Along Kootenay Lake shore, Polygon 250), but may container coarser particles (observed in the area south of the air strip, Polygon 97).

Glaciolacustrine (L^G): Glaciolacustrine materials deposited in or along the margins of ice-dammed lakes, typically with fine textured material (sands, silts and clay), and may include coarse materials or other genetic materials that were rafted by floating ice, and left as relicts when the ice melted.

Organic (O): Organic sediments are composed largely of materials resulting from the accumulation of vegetative matter. Veneers and blankets of humic organic material is accumulating in some of the hollows (flutes) between rock ridges or on ponded areas at several sites in the study area (polygons 97 and 233). Some of the flutes contain small open pools of water and many are wet or swampy. Often thick moss mats or plant growth contribute to the organic soil build up. The organic material is usually underlain by mottled mineral material indicating poorly drained soils.

3.4. Geologic processes[4]

Natural processes affecting the terrain surficial materials (listed above), sometimes in response to human activities, are indicated on the Terrain Maps (Figure 3.1) in polygon labels by a suffix to the terrain genetic materials, separated by a hyphen.

Gullies: (-V) Many moderately steep to steep slopes mantled by glacial deposits exhibit some degree of gullying. Some gullies were formed by surface erosion and some by slope failures (i.e. debris slide-flow) or often a combination of the two. Gullying in the study area is a naturally occurring process. Most moderate to steep slopes mantled by a morainal blanket exhibit some degree of gullying. Only those polygons that contained fairly closely spaced significant gullies (≤ 50 m apart; > 2 m depth) were labeled as gullied on the map (e.g. Mb-V).

Rapid Mass Movements (-R): Rapid failing of debris derived from surficial materials or bedrock, such as debris and rock slides and flows (terrain unit label: -Rs, -Rr, -Rd, respectively).

Many of the cliffs exhibit rock fall (Rs -Rb), only those with active rock falls were designated in terrain map units. Most of the cliffs have formed along joint planes that coincide with slope. At a number of locations tension cracks and anti-slope scarps are present at the top of the cliffs.

Debris flows (-Rd) have occurred in all of the major drainages in the Shutty Bench map area (Wells et. al. 1995). Initiation zones of slides and head waters of most of these drainages are mapped in this project in the Blue Ridge area, and many of the deposits from these events appear in the Lake Shore area of this project. Some recent Debris flows have occurred in the area on the South side of Buchanan (polygons 165, 167).

Avalanches (-A): Rapid down slope movement of snow and ice, as well as incorporated rock, surficial material and vegetation debris by flowing and sliding. Avalanches often start at the head scarp of the stream catch basins and flow down the steep portions of the channels.

Slow Mass Movement (-F): Terrain units in which slow failures and instability are typical. Modifiers are added to the symbol where further classification of the type of slope movement is important, or apparent. These are slumps in bedrock (Fm), and in surficial material (Fu) and tension cracks (-Fk).

3.5. Terrain stability interpretations

Terrain stability hazard classifications were assigned to polygons based on information from field observations and airphoto interpretation using the following criteria. These are summarized in Table 4 on page 17.

[4] This section is adapted from Howes and Kenk (1997).

Attributes noted in assigning stability rankings to the polygons include:

- **Slope gradient and morphology:** Slope gradient is the principal factor in slope classification. Generally, polygons with slope gradients exceeding 65% are classified as high hazard. Some dry rocky slopes with gradients of greater than 65% may be categorized as a low hazard if the underlying bedrock is competent, ridged transverse to the slope and with colluvium which is blocky and free draining. Gullied slopes have an increased hazard.
- **Aspect:** South aspect slopes are generally drier than north facing slopes resulting from the effects of insolation, including higher evapotranspiration and reduced groundwater seepage. For similar materials on similar slope gradients, the hazard is higher on north aspect slopes.
- **Types and physical characteristics of surficial materials:** finer textured material with less coarse fragment contents are generally less stable than coarser textured material.
- **Moisture conditions and patterns:** Drainage and moisture regime is a function of slope position, aspect, material type and the degree of consolidation and cementation (which determines permeability and porosity). Generally the lower slopes and north aspect slopes tend to have poorer drainage and higher moisture content. The lower portions of long slopes are more likely to have high ground water levels and seepage zones as compared to short slopes.
- **Depths of surficial materials:** Depending on other factors, material depth can be add to or detract from slope stability. With sufficient density and diversity of particle size and shape, surface materials may be very stable. Or with a high degree of homogeneity and high moisture content deep materials may experience large scale failure. Sometimes shallow materials are likely to become saturated more readily than well drained, unconsolidated deeper material and therefore have a higher risk of instability. Deep materials may be layered; in these instances surface layers may slide over lower layers. When moisture concentrates along an impermeable layer, and slope gradient exceeds the friction strength between the materials, the surface layer will fail.
- **Underlying bedrock type and structure:** Soft and friable types of bedrock such as phyllite and argillites, which tend to weather rapidly, are more prone to instability than hard, competent types such as, quartzite, amphibolite, and granitic rock.
- **Active geomorphic processes and evidence of past failures**

Field sampling and observations led to the preliminary stability classification of the terrain units.

Table 4**.** Terrain stability classification (adapted from Mapping and Assessing Terrain Stability Guidebook FPC 4/95, and G. Utzig, Kutenai Nature Investigations Ltd. 1996).

Terrain Stability Hazard Class	Interpretation
I	no significant stability problems exist field inspection by a terrain specialist usually not required
II	low likelihood of landslides following timber harvesting or road construction minor slumping may occur along road cuts, especially during first or second year following

	construction field inspection by a terrain specialist usually not required
III	moderate likelihood that stability problems can develop timber harvesting should not significantly reduce terrain stability; low likelihood of landslides following timber harvesting; minor slumping may occur along road cuts, especially during first or second year following construction; low to moderate likelihood of landslides following road construction field inspection by a terrain specialist usually not required
IV	expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting expected to contain areas with a moderate to high likelihood of landslide initiation following road construction; sidecasting and/or wet season construction will significantly increase the potential for road-related slides; hoe construction, back-casting, end-hauling, adequate drainage control and other appropriate engineering measures may significantly reduce the potential for road-related slides a field inspection by a qualified terrain specialist, to assess the stability of the affected area, should occur prior to road or trail construction, or any development that may result in significant soil disturbance or drainage diversion
V	expected to contain recent slope failures expected to contain areas with a moderate to high likelihood of landslide initiation following timber harvesting expected to contain areas with a high to very high likelihood of landslide initiation following road construction; sidecasting and/or wet season construction will significantly increase the potential for road-related slides; hoe construction, back-casting, end-hauling, adequate drainage control and other appropriate engineering measures may significantly reduce the potential a field inspection by a qualified terrain specialist, to assess the stability of the affected area, should occur prior to any development within the polygon, or development that may result in drainage diversion

3.6. Slope interpretation

In this project, a 'representative' slope for each polygon is presented with the map unit's slope range. These are indicated by numeric values in percent (i.e. *n* *(n_1-n_2)*).

In *Terrain classification system for British Columbia*, slope categories are used in the terrain map unit labels to indicate steepness and are presented in Table 5. These slope categories are useful as definitive descriptive terms for the landforms in this study.

Table 5 Slope categories - used in terrain classification

Slope Category	Map symbol	Slope range (%)
plain	p	0 - 5
gentle	j	6 - 26
moderate	a	27 - 49
moderately steep	k	50 - 70
steep	s	>70

3.7. Slope drainage class interpretation

Soil drainage class rankings were assigned to polygons according to the classification definitions in Describing Ecosystems in the Field (Walmsley et. al.1980). These classes are presented in tabular form in Table 7.

In order to facilitate the use of Utzig's terrain data analysis system a conversion matrix was developed to relate drainage class data with Biogeoclimatic Ecosystem Classification system (BEC) and Soil Moisture Regimes occurring in the study area. Table 6 presents this matrix.

Table 6. Soil drainage classes in relationship with BEC Subzone Variants in Study Area).

	Drainage Classes (map unit symbol)					
	r	w	mw	i	p	vp
BEC subzone	**Approximate moisture regime equivalent**					
ICHdw	Xeric	Mesic	SubHyGric	SHG	HyGric	SubHyDric
ICHmw2	X	SubMesic	M	SHG	HG	SHD
ESSFwc4	X	SM	M	SHG	HG	SHD
ESSFwcp	X	SM	M	SHG	HG	SHD

Table 7. Soil drainage classes (from Walmsley et al. 1980).

Symbol	Class	Definition	Mottling/ gleying	Other
r	rapidly drained	moisture content seldom exceeds field capacity (f.c.) in any horizons (except shortly after wetting.	none	often coarse textured &/or shallow; frequently on steeper slopes
w	well drained	moisture does not normally exceed f.c. for a sig. part of the year.	Usually none to 100 cm.	Usually medium textured
mw	moderately well drained	moisture remains in excess of f.c. for a small but significant period of the year.	Often faintly mottled in lower B& in C horizons	Usually medium to fine textured
i	imperfectly drained	moisture remains in excess of f.c. in subsurface horizons for moderately long periods of the year.	Often faintly mottled in lower B & in C horizons	soils are generally gleyed subgroups of soil orders.
p	poorly drained	moisture remains in excess of f.c. in all horizons for a large part of the year.	Usually strongly gleyed.	Soils generally of Gleysolic or Organic orders.
vp	very poorly drained	free water remains at or within 30 cm of the surface most of the year	Usually strongly gleyed	Soils generally of Gleysolic or Organic orders

3.8. Landslide-induced stream sedimentation interpretation

Polygons are rated for landslide-induced stream sedimentation potential utilizing the system adapted from Utzig (1983) and the Mapping and Assessing Terrain Stability Guidebook (Forest Practice Code 1996). The designation of this hazard for terrain units was determined from field data and air photo interpretation and presented in the map unit labels on Figure 3.2. The criteria for this interpretation are presented in Table 8, on the following page.

The interpretation includes mainstem and tributary creeks as shown on the TRIM maps. Taken into account are the attributes of the polygon and any other polygons intervening between the polygon in question and a hydrologic feature of interest. All areas with creeks contributing to domestic water sources and in community watersheds were considered in making this interpretation. If there is further concern about risks of development in areas with landslide hazards for streams or other hydrologic features this interpretation should be reviewed.

Table 8. Landslide-induced stream sedimentation classification (adapted from Mapping and Assessing Terrain Stability Guidebook Forest Practice Code 4/95 and Utzig et al 1983).

HAZARD CLASS	CRITERIA
1	Low likelihood that a landslide originating from this polygon will deposit debris in a stream; post-event surface erosion of the landslide scar and deposition zone will result in minimal stream sedimentation Slopes within or below the polygon have gradients $\le$30% for a continuous slope distance of >150 m or >200 m if immediately adjacent to a stream edge; no gullies with gradients $\ge$25% originating in the polygon No airphoto or field evidence of landslides originating from this polygon entering the stream
2	Moderate likelihood that a landslide originating from this polygon will deposit debris in a stream; post-event surface erosion of the landslide scar and deposition zone will result in some additional stream sedimentation Slopes within or below the polygon have gradients 30 to 45% for a continuous slope distance of >150 m or >200 m if immediately adjacent to a stream edge; or slopes within or below the polygon have gradients $\le$30% for a continuous slope distance of 30 to 150 m Gully channels within and below the polygon remain confined, have gradients <25% and end on slopes <25% and >50 m from the stream edge; or gully channels within and below the polygon remain confined, have lower reach gradients >25% and end on slopes <25% and >200 m from the stream edge minimal airphoto or field evidence of landslides originating from this polygon entering the stream
3	High likelihood that a landslide originating from this polygon will deposit debris in a stream; post-event surface erosion of the landslide scar and deposition zone will result in additional stream sedimentation Where there are slopes within or below the polygon with gradients 30 to 45%, they have a continuous slope distance of $\le$150 m; where there are slopes within or below the polygon with gradients $\le$30%, they have a continuous slope distance within 30 m Gully channels within and below the polygon remain confined, have gradients <25% and end 10 to 50 m from the stream edge; or gully channels within and below the polygon remain confined, have lower reach gradients >25% and end on slopes <25% within 200 m from the stream edge Clear evidence is visible on airphotos or in the field that landslides originating from this polygon have or potentially may enter the stream
4	Very high likelihood that a landslide originating from this polygon will deposit debris in a stream; post-event surface erosion of the landslide scar and deposition zone will result in additional stream sedimentation Little or no occurrence of slopes within or below the polygon have gradients <45%, and those that occur have continuous slope distances of <30 m Gully channels within and below the polygon remain confined, have gradients <25% and end within 10 m of the stream edge; or gully channels within and below the polygon remain confined, have lower reach gradients >25% and end within 20 m of the stream edge clear evidence is visible on airphotos or in the field that landslides originating from the polygon have entered the stream

3.9. *Surface soil erosion interpretation*

Surface erosion hazards were determined for each terrain polygon based on the following factors:

- Biogeoclimatic subzone/variant
- Moisture regime and drainage class
- Slope gradient
- Depth to restricting layer
- Surface soil texture (0-15 cm)
- Surface soil coarse fragment content (0-15 cm)
- Subsoil texture (30-90 cm)
- Evidence of erosion

The criteria for surface soil erosion hazard classes are shown in Table 9, below.

In order to better reflect factors that influence soil erosion in the project area, we have used a modification of the surface soil erosion hazard key in the *Hazard Assessment Keys for Evaluating Site Sensitivity to Soil Degrading Processes Guidebook* based on an adaptation by Utzig (1996)[5]. Polygons are rated for surface erosion hazard utilizing the key for determination of surface erosion hazard in Table 9.

The modifications include relating Soil Moisture Regime to Soil Drainage Class, and a regionally calibrated point rating system for climate and slope gradient that better reflects the characteristics of the Kaslo and Woodlot 494 study area (Table 6, page 18 above). This key also defines the subsurface texture at depths of 30 cm - 90 cm because significant erosion may occur where the surface is disturbed on landslides, and logging roads and ditchlines (see section 3.10 Road and Ditchline Erosion Interpretation). Another modification in this study is weighting the coarse fragment content points to better reflect the stabilizing effect of this feature. The total points accumulated result in placement in one of Surface Erosion Hazard Classes. Utzig's MS Excel formatted calculations were applied to the data set from this study to obtain the results.

The surface soil erosion hazard ratings for each polygon are presented on the Terrain Stability Interpretations Map (Figure 3.2), and in the data tables in Appendix 1.

[5] A new edition of the *Hazard Assessment Keys for Evaluating Site Sensitivity to Soil Degrading Processes Guidebook* has been released (April 1999), but the analysis in this study was underway at the release date of the guidebook.

Table 9. Key for determination of surface erosion hazard localized for Kaslo Community Forest Licence & Woodlot 494 TSIL B study area (adapted from B.C. Forest Practice Code 1995 and Utzig 1996).

SITE FACTORS	LOW --------- MODERATE --------- HIGH --------- VERY HIGH					
CLIMATE	PP,IDF **1**	MS,ICHdw, ICHxw **2**	ESSFdc1,ESSFdk, ICHmk1,ICHmw1-3 **3**	ESSFwc1-2 **4**	ESSFwc4,wcp ESSFwm,ICHwk1 **5**	ESSFvc, ICHvk1 **6**
MOISTURE REGIME (drainage class)	X-SX (r) **1**	SM (w) **2**		M (w - mw) **3**	(mw - l)	SHG-SHD (i - vp) **6**
SLOPE GRADIENT (%)	0-10 **1**	11-20 3	21-30 **5**	31-45 **7**	46-59 **10**	≥60 **14**
SLOPE LENGTH/ UNIFORMITY	short broken **1**	long broken **2**		short uniform **3**	long uniform **4**	
DEPTH TO RESTRICTING (cm)	>90 **1**	61-90 **2**		30-60 **3**	<30 **4**	
SURFACE TEXTURE (0 - 15 cm)	SC,C,SiC, R **1**	SiCL,CL,SCL **2**		L **4**	SL **6**	Si,SiL,fSL,LS,S **9**
SURFACE (%)COARSE FRAGMENTS	>60 **-4**	31-60 **-0**		16-30 **3**	<16 **5**	
SUBSOIL TEXTURE (30 - 90 cm)	S,LS,SL,fSL, R **1**	SiL,Si, L **2**		CL,SCL,SiCL **3**	C,SC,SiC **4**	
TOTALS	**<------- Low -------- <21**	**------ Moderate ----- 21 - 25**		**----------- High ----------- 26 - 33**	**---------- Very High -------> > 33**	

Note: In accordance with the *Community Watershed Guidebook*, mappers may modify the rating system of *The Mapping and Assessing Terrain Stability (MATS)* Guidebook to suit local conditions. In this analysis we have adjusted the rating system to yield results consistent with field observations.

Table 10. Surface Erosion Hazard Classification (adapted from B.C. Forest Practice Code 1995 and Utzig et al 1996).

HAZARD CLASS	CRITERIA
L	low hazard for surface erosion; minor erosion of fines from ditch lines and disturbed soils no special management requirements; avoid stream side disturbances and channeling water; exercise care not to direct water on to more sensitive sites.
M	moderate hazard for surface erosion; expect problems with channeled water in road ditches or across disturbed areas plan for complete road deactivation; revegetate disturbed areas; drainage management is critical
H	high hazard for surface erosion; expect major problems with channeled water in road ditches or across disturbed areas minimize soil disturbance; plan for complete road deactivation; immediately revegetate disturbed areas; drainage management is critical
VH	very high hazard for surface erosion; expect severe problems with channeled water in road ditches or across disturbed areas; gully erosion may occur with channeled water avoid soil disturbance; immediately revegetate disturbed areas; drainage management is critical; erosion concerns take precedence over timber harvesting.
Note: Table 6 in the MATS guidebook's Surface erosion potential classes table uses a five class system. The adaptation used in this project employs four hazard classes. We have utilized this adaptation because it is appropriate for the Kaslo and WL494 study area, and it simplifies use of the Key for determination of surface erosion hazard (Table 9, above) which leads to placement of a site in one of four hazard ratings.	

3.10. Road & ditchline erosion interpretation

Erosion hazards associated with road surfaces, cutbanks and ditchlines were determined for each terrain polygon based on the following factors:

- Biogeoclimatic subzone/variant
- Moisture regime
- Slope gradient
- Subsoil texture (60-90 cm)
- Subsoil coarse fragment content (60-90 cm)
- Evidence of past road surface or ditchline erosion

A description of each of the road and ditchline erosion classes is presented in Table 11 on the following page. The key to the determination factors for road and ditchline erosion classes is shown in Table 12, on page 25. The total points accumulated result in placement in one of the Road and Ditchline erosion hazard classes. Utzig's MS Excel formatted calculations were applied to the data set from this study to obtain these results. The road and ditchline erosion hazard ratings for each polygon are presented on the Terrain Stability Interpretations Map (Figure 3.2), and in the data tables in Appendix 1

Table 11. Road and Ditchline Erosion Hazard Classification (adapted from B.C. FPC 1995, Utzig 1983, Jordan 1997, Thompson 1997).

Class	Description
L	low hazard for waterborne erosion from road surface, cutbanks and ditchlines; minor erosion of fines from ditch lines and disturbed soils no special management requirements; avoid channeling water
M	moderate hazard for waterborne erosion from road surface, cutbanks and ditchlines; expect problems with channeled water in road ditches or across disturbed areas revegetate disturbed areas; drainage management is critical
H	high hazard for waterborne erosion from road surface, cutbanks and ditchlines; expect major problems with channeled water in road ditches or across disturbed areas minimize soil disturbance; immediately revegetate disturbed areas; install sediment traps where appropriate; drainage management is critical
VH	very high hazard for waterborne erosion from road surface, cutbanks and ditchlines; expect severe problems with channeled water in road ditches or across disturbed areas; gully erosion may occur with channeled water avoid soil disturbance; immediately revegetate disturbed areas; install sediment traps where appropriate; drainage management is critical

Note: Roads across shallow-to-rock map units would likely have little ditchline erosion, but may have road surface erosion problems depending on the characteristics of surfacing material used Maintenance should be organized to manage the most sensitive of the potential problems.

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Table 12. Key for determination of road and ditchline erosion potential (adapted from B.C. FPC 1995, Utzig 1983).

SITE FACTORS	LOW --------- MODERATE --------- HIGH --------- VERY HIGH						Comments
CLIMATE	PP,IDF **1**	MS,ICHdw, ICHxw **2**	ESSFdc1,ESSFdk, ICHmk1,ICHmw1-3 **3**	ESSFwc1-2 **4**	ESSFwc4,ESSF-p ESSFwm,ICHwk1 **5**	ESSFvc, ICHvk1 **6**	groupings of BEC subzone/variants, ideally based on: frequency and intensity of rainstorms and level of runoff generated by snowmelt
MOISTURE REGIME (drainage class)	VX-SX (r) **1**	SM (w) **2**		M (w - mw) **3**	(mw - i)	SHG-SHD (i - vp) **6**	an indicator of the relative frequency of saturation and the potential to generate surface runoff during high intensity events or snowmelt
SLOPE GRADIENT (%)	0-10 **1**	11-20 **3**	21-30 **5**	31-45 **7**	46-59 **10**	≥60 **14**	steeper slope angles usually result in deeper roadcuts and more exposed soil; sediment delivery below culvert cross-drains increases with slope angle
SUBSOIL TEXTURE (30-90 cm)	SC,C,SiC,R **1**	SiCL,CL,SCL **2**		L **4**	SL **6**	Si,SiL,fSL,LS,S **9**	factor accounts for differing erodibility of various soil textures; most limiting of 30-90 cm
(%) SUBSOIL COARSE FRAGMENTS	>75 or bedrock <90 cm **-6**	60-74 or bedrock 90-120 cm **-1**	45-59 **4**	30-44 **8**	15-29 **11**	<15 **14**	an indicator of the likelihood of surface armoring to inhibit deep rilling and gullying; mean of % coarse fragments from 30-90 cm
TOTALS	**<------- Low ------ --** **<21**	**------ Moderate ---- -** **21 - 25**		**------------ High --------- ---** **26 - 30**	**---------- Very High ------->** **> 30**		**Where road grade is known to exceed 8%, increase the rating by one class.**

3.11. Sediment delivery interpretation[6]

The classes for sediment delivery **potential** provide a relative rating for sediment delivery for the polygon as a whole, without taking into account distance to a particular stream or hydrologic feature. Sediment delivery potential class was determined for each terrain type based on the following factors:

- Slope configuration - continuity of slope and likelihood of sediment-laden waters moving from potential sediment sources in the polygon to a stream channel
- Slope gradient - increasing hydraulic gradient and sediment carrying capacity; decreasing likelihood of sediment settling out in depressions
- Moisture regime - increasing moisture availability and increased frequency of water volumes sufficient to transport sediment (especially in ditchlines intercepting seepage)

Sediment delivery **hazard** ratings are then derived from the potential classes, by adding the factor of distance to the nearest hydrologic feature located downslope.

Utzig's MS Excel formatted calculations were applied to the data set from this study to obtain the results. The total points accumulated result in placement in one of the sediment delivery potential classes. The sediment delivery potential class ratings for each polygon are presented on the Terrain Stability Interpretations Map (Figure 3.2), and in the data tables in Appendix 1.

The key for determining the sediment delivery potential classes and hazards is shown in Table 13, on page 27. A description of each sediment delivery potential class and hazard rating is provided in Table 14, page 28.

The sediment delivery potentials can be estimated for specific locations and hydrologic features of interest. Table 13 includes a matrix for slope and distance factors at 50, 100 and 200 m in relation to hydrologic features, such as creeks, ponds, and lakes. Planning for the risks to significant features can be analyzed by starting with a map units' sediment delivery potential class in the label, and then proceed to Table 13. This procedure assists when streams or other points of interest have been defined.

[6] Some of the sediment delivery interpretation section in this study has been adapted from Utzig and Carver 1999 with thanks.

Table 13. Key for determination of Sediment Delivery Potential Classes and Hazard Ratings.

Slope Configuration	Slope (%)	Moisture Regime (drainage)	Sediment Delivery Potential Class	Sediment Delivery Hazard Ratings — Distance to Hydrologic Feature (m)			
				<50	50-100	101-200	> 200
	0 - 30	VX-M (r-w)	**1**	M	VL	VL	VL
	0 - 30	SHG-SHD (mw-vp)	**3**	H	M	L	L
Benched or Broken	31 - 60	VX-M (r-w)	**2**	H	L	VL	VL
	31 - 60	SHG-SHD (mw-vp)	**4**	VH	H	M	L
	> 60	VX-M (r-w)	**3**	H	M	L	L
	> 60	SHG-SHD (mw-vp)	**4**	VH	H	M	L
	10 - 30	VX-M (r-w)	**2**	H	L	VL	VL
	10 - 30	SHG-SHD (mw-vp)	**4**	VH	H	M	L
Smooth Continuous	31 - 60	VX-M (r-w)	**3**	H	M	L	L
	31 - 60	SHG-SHD (mw-vp)	**4**	VH	H	M	L
	> 60	VX-M (r-w)	**4**	VH	H	M	L
	> 60	SHG-SHD (mw-vp)	**5**	VH	H	H	M
	10 - 30	VX-M (r-w)	**3**	H	M	L	L
	10 - 30	SHG-SHD (mw-vp)	**5**	VH	H	H	M
Gullied	31 - 60	VX-M (r-w)	**4**	VH	H	M	L
	31 - 60	SHG-SHD (mw-vp)	**5**	VH	H	H	M

Notes: Relationship of Soil Moisture Regime and Soil Drainage Class. See Table 9, page 23.

Slope Configuration: assigned to each map polygon; determined with regard to potential for sediment-laden surface waters reaching the nearest hydrologic feature: **Benched or broken:** sloping, benched, terraced, ridged, hummocky or rolling terrain which includes topographic high points or benches; and all terrain slopes ≤ 10% **. Smooth Continuous:** sloping terrain with no slope breaks or benches with slopes < 10% and >20 m wide (slopes of ≤ 10% are considered benched/broken). **Gullied:** presence of gullies which lead directly into a specified hydrologic feature, gullies with depths > 2m and channel gradients > 10% (slopes of ≤ 10% are considered benched/broken)

Slope: representative slope of map unit (generally equivalent to median slope, determined by clinometer, topographic map and/or air photographs). **Moisture Regime/Soil drainage class:** representative for the map unit (determined qualitatively)

Table 14. Sediment Delivery Potential and Hazard Classification (adapted from B.C. FPC 1995 and Utzig et al 1983).

Potential Class	Description*
1	terrain units with a very low potential for sediment delivery except where <50 m from a stream, where the potential is moderate
2	terrain units with a very low potential for sediment delivery except where <50 m from a stream, where the potential is high, and 50 to 100 m from a stream where the potential is low
3	terrain units with a high potential for sediment delivery <50 m from a stream, moderate potential from 50 to 100 m from a stream, and low potential >100 m from a stream
4	terrain units with a very high potential for sediment delivery <50 m from a stream, high potential from 50 to 100 m from a stream, moderate potential 101 to 200 m, and low potential >200 m from a stream
5	terrain units with a very high potential for sediment delivery <50 m from a stream, high potential from 50 to 200 m from a stream, and moderate potential >200 m from a stream
Hazard Rating	**Description***
VL	very low sediment delivery hazard; this unit separated from any stream by >50 m on benched/ broken terrain, >100 m on gentle to moderately sloping smooth slopes and >200 m on gentle gullied slopes development on this unit is unlikely to provide an avenue for sediment input into a stream
L	low sediment delivery hazard; terrain unit separated from any stream by >50 m on moderately sloping benched/broken terrain, >100 m on steep benched and gentle to moderately sloping smooth slopes, and >100 m on gentle to moderately sloping gullied slopes roads, skid trails or ditch lines crossing this unit are unlikely to provide a direct avenue for sediment input into a stream
M	moderate sediment delivery hazard; terrain unit may be < 50 m from a stream on gentle benched/broken terrain, separated from any stream by >50 m on steep benched/broken slopes, moderate smooth slopes and on gentle gullied slopes benched/broken terrain, >100 m on steep smooth and moderate-steep gullied slopes roads, skid trails or ditch lines crossing this unit may provide a direct avenue for sediment input into a stream, but the normal drainage control measures should minimize sediment movement
H	high sediment delivery hazard; terrain unit may be < 50 m from a stream on moderately to steeply sloping benched/broken terrain, gentle to moderately sloping smooth slopes, or gentle gullied terrain; or separated by > 50 m on steep smooth slopes or moderate to steep gullied slopes roads, skid trails or ditch lines crossing this unit are likely to provide a direct avenue for sediment input into a stream; soil disturbance should be minimized, special measures may be required to control sediment
VH	very high sediment delivery hazard; terrain unit is < 50 m from a stream on steeply sloping smooth slopes or moderately to steeply sloping gullied slopes roads, skid trails or ditch lines crossing this unit will provide a direct avenue for sediment input into a stream; soil disturbance should be avoided, special measures will be required to control sediment

* all distances are overland flow distances

3.12. Waterborne erosion sediment yield Interpretation

The classes for waterborne erosion sediment yield potential provide a relative rating for sediment yield for the polygon as a whole, without taking into account distance to a particular stream or hydrologic feature. Sediment yield potential classes were determined for each terrain polygon based on a combined evaluation of the following factors:

- Surface soil erosion hazard (Section 3.9)
- Road and ditchline erosion hazard (Section 3.10)
- Sediment delivery potential (based on slope configuration, slope gradient and moisture regime/drainage class – Section 3.11)

Sediment yield hazard ratings are then derived from the potential classes, by adding the factor of distance to the nearest hydrologic feature located downslope. Increasing distance to a hydrologic feature is assumed to increase the likelihood that surface water may infiltrate or pool, allowing its sediment load to be deposited before reaching a stream.

A description of each sediment yield potential class and hazard rating is provided in Table 16, Page 31. The key to determination of sediment yield potential classes and hazards is shown in Table 15, Page 30. The sediment yield potential and hazard ratings for each polygon are presented on the Terrain Stability Interpretations map (Figure 3.2) and in Appendix 1.

Table 15. Key for determination of Waterborne Erosion Sediment Yield Potential Classes and Hazard Ratings.

Surface Erosion Hazard	**Road and Ditchline Erosion Hazard**	**Sediment Delivery Potential**	**Sediment Yield Potential Class**	**Sediment Yield Hazard Ratings – Distance to Hydrologic Feature (m): 0-50**	**50-100**	**101-200**	**> 200**
M,L	M,L	1,2	**1**	M	VL	VL	VL
All other combinations			**2**	H	L	VL	VL
M	H,VH	3					
H,VH	M	3					
L	H,VH	4,5	**3**	H	M	L	L
H,VH	L	4,5					
M	M	4,5					
H,VH	H,VH	3					
M	H,VH	4,5	**4**	VH	H	M	L
H,VH	M	4,5					
H,VH	H,VH	4,5	**5**	VH	H	H	M

Table 16. Sediment Yield Potential and Hazard Classification (adapted from BC FPC 1995 and Utzig et al 1983).

Potential Class	Description*
1	terrain units with a very low potential for sediment yield except where <50 m from a stream, where the potential is moderate
2	terrain units with a very low potential for sediment yield except where <50 m from a stream, where the potential is high, and 50 to 100 m from a stream where the potential is low
3	terrain units with a high potential for sediment yield <50 m from a stream, moderate potential from 50 to 100 m from a stream, and low potential >100 m from a stream
4	terrain units with a very high potential for sediment yield <50 m from a stream, high potential from 50 to 100 m from a stream, moderate potential 100 to 200 m, and low potential >200 m from a stream
5	terrain units with a very high potential for sediment yield <50 m from a stream, high potential from 50 to 200 m from a stream, and moderate potential >200 m from a stream
Hazard rating	**Description***
VL	very low sediment yield hazard; this unit separated from any stream by >50 m on benched/ broken terrain, >100 m on gentle to moderately sloping smooth slopes and >200 m on gentle gullied slopes development on this unit is unlikely to provide an avenue for sediment input into a stream
L	low sediment yield hazard; terrain unit separated from any stream by >50 m on moderately sloping benched/broken terrain, >100 m on steep benched and gentle to moderately sloping smooth slopes, and >100 m on gentle to moderately sloping gullied slopes roads, skid trails or ditch lines crossing this unit are unlikely to provide a direct avenue for sediment input into a stream
M	moderate sediment yield hazard; terrain unit may be < 50 m from a stream on gentle benched/broken terrain, separated from any stream by >50 m on steep benched/broken slopes, moderate smooth slopes and on gentle gullied slopes benched/broken terrain, >100 m on steep smooth and moderate-steep gullied slopes roads, skid trails or ditch lines crossing this unit may provide a direct avenue for sediment input into a stream, but the normal drainage control measures should minimize sediment movement
H	high sediment yield hazard; terrain unit may be < 50 m from a stream on moderately to steeply sloping benched/broken terrain, gentle to moderately sloping smooth slopes, or gentle gullied terrain; or separated by > 50 m on steep smooth slopes or moderate to steep gullied slopes roads, skid trails or ditch lines crossing this unit are likely to provide a direct avenue for sediment input into a stream; soil disturbance should be minimized, special measures may be required to control sediment
VH	very high sediment yield hazard; terrain unit is < 50 m from a stream on steeply sloping smooth slopes or moderately to steeply sloping gullied slopes roads, skid trails or ditch lines crossing this unit will provide a direct avenue for sediment input into a stream; soil disturbance should be avoided, special measures will be required to control sediment

* all distances are overland flow distances

3.13. Limitation and reliability

The surficial geology and landforms in the study area are complex. While the mappers have had an opportunity to sample extensively, there are many areas we did not visit. This study provides a snapshot of a moment in the area's long natural history where change is occurring constantly. Every effort has been made to provide accurate information. However, sources of possible inaccuracy are introduced to the final map products at several points in the mapping process:

- Precision of airphotograph interpretation is diminished where there is distortion, as at the edges and corners of air photographs.
- Vegetation and shadows obscure many of the smaller and some of the larger terrain features.
- Based on anecdotal reports from several GIS specialists, we assumed that the level of resolution with TRIM (and TIN) data presentations is about 70 meters. Field checks as well as air photo evidence confirmed some gullies and benches are not expressed by the TRIM contours. Mono photo restitution, however, is considered to have an accuracy of within 10 m (J. Reynolds, personal communication).
- Field work was concentrated in operable and accessible areas. Interpretation is more general in remote and alpine areas where only airphoto interpretation was applied.

The end overlap and side overlap of the air photos used is adequate to facilitate complete stereographic coverage of the study area.

The terrain stability classes provide a relative ranking of the likelihood of a landslide occurring after timber harvesting or road construction. They are not intended to indicate the expected magnitude of a landslide or potential down slope damage.

These interpretive maps provide basic information for planning purposes, and are useful in flagging potential problem areas. They are not a detailed planning tool for operational prescriptions. It is expected that planning for developments on Class IV and V landforms in this study area will include detailed terrain stability field assessments.

Because of the contemporary ease of copying and revision of the maps and digital information involved in this project the authors limit their responsibility for the accuracy and features of this report to the signed copies of the maps and report. If reproductions are to be used, it is important that the users assure themselves that all pertinent information (i.e. references, legends, definitions) is included.

It is expected that the authors will be consulted if any part of this report is not understood by contracted users, or conditions on the ground are found to be significantly different than the study indicates. Further, more detailed studies may be necessary in some areas for higher level planning if indicated by regulations in the Forest Practices Code (FPC).

4. Results of study

Tables of the data set used for interpretations, ratings of potential and hazard classes for each polygon are presented in Appendix 1.

Air photographs with terrain unit polygons and labels, are organized in lines. They are to be considered as a product of this study, and accordingly have been supplied to the Kaslo Community Forest Society, Lofstedt Forest Society (WL 494), and Goose Creek Timber for their reference.

4.1. Terrain Interpretation

Ice-transported parent materials (moraine or till) were deposited directly by glacial ice without modification by any intermediate agent. They include typical glacial till and the rubbly deposits associated with alpine glaciers. Till is related to the terrain over which the glacier ice passed (Wittneben 1980). Slopes of the Seven Mile area, parts of the settled areas around Kaslo, and much of the bench land in Shutty Bench and along the Back Road south of Kaslo have soils developed in these materials.

Gravity transported parent materials (Colluvium) are associated with steep land over which terrain materials have moved from their site of original deposition as a result of mass wasting (may have been small or large scale). These materials are the dominant soil parent material in the study area.

Water transported parent materials (glaciofluvial, glaciolacustrine and fluvial) dominate lower slopes along the Kaslo River and eastward through Kaslo Village, some of the bench lands in Shutty Bench to the north, and southward from the air strip to Lofstedt Farm at the south boundary of the study area.

4.2. Terrain Stability

Stability concerns in the study area are associated with debris flows/slides and slow moving slumps. The south side of Mount Buchanan has experienced large slow mass movements since glaciation, some of which are still active in localized areas. Several slumps and tensions cracks in surficial material and bedrock were observed in the deposit area of these older events. The old scarp in polygon 158 is actively sliding in till material, exposing bedrock.

Development proposals for land under the forest licence involving access corridors across this area will require detailed terrain stability field assessment of road route possibilities by a qualified terrain specialist.

Debris flows are a concern along the steep gullied slopes in the Kemp Creek drainage basin and along the east facing steep slopes above Woodlot 494. Steep side slope failures in most of the channels in the area are likely to contribute to the initiation of debris flows.

Debris slides caused by development activities in the area were field checked. Polygon 128, at station C-15, a slide was caused by a burst water line, in pure sand and silt layers in glacial fluvial deposits. The slide appears to still be flowing and is located immediately above the Kaslo River. The recent debris slides caused by the drainage diversion along the sideslopes in the Buchanan B channel occurred in till material, and caused a debris flow within the channel. This event is discussed further in the watershed channel observations section.

4.3. *Waterborne erosion and sediment sources*

4.3.1. Sediment Sources

Road surfaces are potential sediment sources throughout the study area. A key recommendation is for appropriate ditching, erosion control, regular maintenance, and sediment traps designed into roads to deal with road and ditch erosion.

Ditches are not always appropriate, and where road cutbanks tend to slump or fail, keeping a ditch open may lead to loss of toe support. There may be situations when, particularly in saturated sites, where additional support is required, or the road surface must be in-sloped or raised in order to achieve suitable drainage while maintaining stability.

Sediment traps require monitoring and maintenance., They must be emptied when full in order for them to function. They are best installed in low gradient sites at the foot of grades, on the inside of switchbacks, and at the uphill side of creek crossings.

4.3.2. Study area watershed channel observations

Section 2.6, above (page 10) presents descriptions of the major watersheds in the study area. This section describes our assessment of the stability and the sensitivity of these channels. Table 17, page 36 below, summarizes channel observations and hazard ratings.

Buchanan A (west drainage): Some disturbances were noted along the channel at each description site, and a Moderate Hazard rating was assigned to the creek. The channel in the upper elevations is not well defined and some avulsion is expected during peak flows. Unstable side slopes are expected to contribute to sedimentation. Steps observed in the channel are made up of small woody debris and may be sensitive to an increase in peak flow. Increased bed deposition at lower elevations may be due to the road crossing at 920 m.

Buchanan B (east drainage): At the time of our field checks it was observed that a small log had created a dam across the hand dug, apparently licenced diversion, spilling water over the steep (Terrain Stability Class V) slope below. This initiated a debris slide/flow in the main channel. Two description sites were mapped as a moderate hazard and three as a high hazard. Evidently previous debris flow activity has occurred in this channel. At CK-5, above the junction, is an old debris flow deposit area. The channel suffers from significant aggradation in this area, There also is aggradation in the more recent deposition area at station CK-8. (See the series of photographs in Appendix 3.)

McDonald Creek: The hazard rating on this section of the channel in this study is high due to a highly mobile sediment lode and unstable steps composed of small woody debris (see photo in Appendix 3). There is limited development within the watershed, yet natural instability seems to be the cause of the unstable channel conditions. Steep side slopes are unstable and are likely to contribute sediment to the channel.

Lofstedt Creek: The northeasterly flowing tributary in the upper reaches crosses the prominent bedrock structure of the area, resulting in benched topography. These benched areas are expected to show some aggraded channel conditions, and also serve the purpose of limiting sediment delivery within the channel. The hazard rating in upper Lofstedt creek is Moderate, based on the log jam potential, and the unstable nature of the gully side slopes. The lower reaches are not considered to have sediment deposition problems unless serious flooding from snow melt or rain on snow events, or disturbance on the public road grade fill slopes cause sedimentation. However there is a potential for transporting farm waste residue or pollutants into the stream system. There are recommendations for measures to mitigate this problem in Section 4.3.3.

Kemp Creek: The lower portion of the channel consists of mostly very steep unstable terrain that is likely to contribute to sedimentation. The hazard rating for both descriptions is Moderate.

4.3.3. Channel and waterborne erosion management recommendations

Additional assessment is recommended in all channels if development is proposed within its drainage area. Most channels reviewed are confined by steep, potentially unstable gully side slopes that are likely to add sediment to streams by natural causes, such as slumps or churns from upset trees. It is essential to maintain the integrity of the riparian areas especially on these steep side slopes and surrounding areas to maintain wind firmness.

Plans for forest removal on slopes in these drainages must consider effects of opening size and cumulative cleared area (i.e. Equivalent Clear Cut Area -% ECA) on snow melt timing and drainage regimes.

The two channels of greatest concern are Buchanan B and McDonald Creek. McDonald Creek appears to be naturally unstable and should be granted additional assessment prior to development.

Natural instabilities in the Buchanan B channel were evident, however, the drainage diversion continues to pose a immediate stability concern for the channel. Older slides were observed below the diversion path and it is assumed they were also initiated from a blockage/overflow from the diversion. A water intake location is mapped at approximately 840 m within the gully receiving the diverted water. It would be best for the integrity of the channel to remove the diversion, however it would increase the flow and may create disturbances to the main Buchanan B channel.

Lower reaches of Lofstedt Creek may be buffered from farm pollutants by using bioremediation techniques such as plantings of Cat Tails (*Typha latifolia*) in hygric and hydric (perennially saturated) sites, and poplar (particularly Hybrid poplar - *Populus x*) on subhygric and drier sites. Both of these plants are able to metabolize large amounts of nitrates which result from eutrophication.

As reported by Wells, et al (1995), the Shutty Bench area is drained by easterly flowing streams (the main ones are Wing, Shutty, Kemball, and Milford creeks) cutting across the bedrock ridge structure. Along the middle reaches the streams have cut down through thick till deposits into rock.

The easterly flowing streams are characterized by large (relative to stream length), steep catch basins (1 to 2 km^2, average gradient of 70%) in the upper reaches; steep incised channels (~50% gradient) in the middle reaches; and more gentle (<20%) less confined lower reaches.

Subsurface water moves down the slope to the hollows where it is deflected by the rock ridges. There are numerous springs and seeps in lower reaches and at the base of the slopes which are in the study area of this study.

Table 17. Summary of Stream Channel Hazard Ratings and Primary Observations.

Channel	Station	Elev (m)	Slope (%)	Hazard	Observed instability	Observed sensitivity
Buchanan A	CK-3	1205	40	M	Steep, unstable side slopes. minor avulsion.	Unstable steps
	CK-6	1060	45	M (L)	Steep, unstable side slopes.	Unstable steps, composed of small branches.
	BK-1	830	40	M	Increased bed deposition.	
Buchanan B	CK-1	1360	65	M	Steep side slopes	Mostly fines in channel
	CK-4	1160	45	M	U-shaped gully, old debris flow gully, steep, unstable side slopes	
	CK-5	1160	15	H	Avulsions. some subsurface flow. homogeneous composition. mobile material	Low gradient, high confinement
	BK-2	875	30	H	Recent debris flow, unstable side slopes	
	CK-7	850	7	H	Recent debris flow deposit area. bank overflow. braided channel. mostly fines and sand.	Low gradient, high confinement.
McDonald	CK-2	820	18	H	Scoured banks. significant sediment wedges. high mobilized sediment load. failing steep side slopes. Tree Churns	Steps loose and composed of small branches.
Lofstedt	MK-2	1330	40	M (L)	Seepage in gully side slopes. steep unstable side slopes.	Log jam potential, mostly wood in bed material.
	MK-3	930	20	M (L)	Steep side slopes.	
Kemp	MK-1	1225	20	M (H)	unstable side slopes.	
	BK-3	955	23	M (H)	sediment wedges common. steep, unstable side slopes.	Side slopes map be undercut by increase in peak flow.

4.4. Transportation corridor issues

Rock falls, debris flows, surface materials sliding off steep rock on to slopes and infrastructure beneath them are issues in several locations in the study area. Highway 31 and 31A, and other roads, have required cutting across or under many slopes including moderately steep and steep ones with instability. Road cuts through rock and under unconsolidated surface materials especially where slope drainage create perennial or seasonal saturation are subject to rock fall and landslides. Much of this problem is unavoidable in mountainous terrain, but development and road construction activities may be planned so as to minimize these occurrences.

Several notable sites are:

- A slide just north of 'South Fork' junction (Keen Cr.) on Highway 31A where road and ditch maintenance continually undermines the slope causing slumping. This is down slope of Kaslo Community Forest Licence's CP. 2, Block 2. (Polygon 175)
- A perennial slide causes seasonal mud flows over Highway 31 in Polygon 275 at the south end of Shutty Bench.
- Ravelling of boulders and cobbles as in Polygon 135.

As previously noted, Jordan (1995) mapped transportation corridors in the many areas of the Nelson Forest Region for terrain stability hazards, including those in this study area.

5. Conclusion

The terrain and derivative interpretations maps of the Kaslo Community Forest Society, Woodlot 494, and Goose Creek Timber operating area are presented as adjuncts to this report and should be used with this report as a reference (see Figures 3.1, 3.2. and 3.3). It is expected that further detailed planning exercises will take place in areas mapped as having potential problems relating to terrain stability, landslide-induced or waterborne erosion-induced stream sedimentation.

6. References

Airphotos used for the Kaslo Community Forest Licence and Woodlot 494 Terrain Interpretation Study.

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line 3: 30BCB 97108 No. 210-212
line 4: 30BCB 97108 No. 116-120
line 5: 30BCB 97108 No. 77-82
line 6: 30BCB 97094 No. 217-220
line 7: 30BCB 97094 No. 199-204
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7. Appendices

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Appendix 4

Guide to Interpretations Tables and Figures

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