MURRAY CREEK AREA

DETAILED TERRAIN MAPPING WITH EVALUATIONS FOR SLOPE STABILITY AND EROSION POTENTIAL

Prepared by

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For

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CONTENTS

(1) INTRODUCTION

The objective of this project was to prepare terrain, slope stability and erosion potential maps as a basis for long term environmental planning, including forest harvesting, in the following three areas: Yalakom River (Retaskit-Peridotite Creeks), Murray Creek, and Pasulko Lake. A brief report for each study area accompanies the terrain and interpretive maps. The Murray Creek area, which is the subject of this report, encompasses about 1960 ha (Figure 1).

Terrain mapping and interpretations for slope stability and erosion potential were carried out according to provincial standards (Section 3). Terrain mapping was done on 1:15 000 scale colour air photos by air photo interpretation, followed by field checking. This mapping supersedes air photo interpretation that accompanied a preliminary report on the terrain conditions for proposed cutblocks and road alignments prepared for Bruce Hupman (MoF) in Spring 1995. Terrain, slope stability and erosion potential information are presented on 1:5000 scale base maps.

This report augments the information that is shown on the maps. It provides a general overview of the physiography of the study area (Section 2), descriptions of terrain mapping methodology and mapping reliability (Section 3), additional information about surficial materials and processes (Sections 4 and 5), and criteria applied to slope stability and erosion potential interpretations (Section 6). Implications and recommendations for forest land management that arise out of this terrain work are discussed in Section 7.

(2) PHYSIOGRAPHY

The study area is located in the headwaters of Murray Creek, situated on the transition zone between the Clear Range and the Thompson Plateau, both of which lie within the Interior Plateau physiographic region (Holland, 1964). Murray Creek is small (less than 5 metres wide), drains the eastern slopes of the Clear Range and the dissected surface of the Interior Plateau, and flows south-southeast to where it joins the Thompson River at Spences Bridge. Local relief in the study area is about 680 metres, with elevations ranging from 1340 m a.s.l. at Murray Creek to 2020 m on top of Lookout Point.

The study area can be divided into three distinct zones: 1) Murray Creek valley, 2) uplands, and 3) transition zone. Murray Creek valley is located on the west side of the study area and is confined by steep slopes which rise eastward to 1370-1830 m a.s.l. (metres above sea level); and westward to 2140 m at Murray Peak. The uplands zone is a gently rolling area of low relief within the Thompson Plateau between 1500 to 1830 m a.s.l. The transition zone is a narrow region, up to 1.5 km wide, that parallels a northwest-southeast trending fault that separates the two other zones. The transition zone consists of the dissected slopes of the uplands.

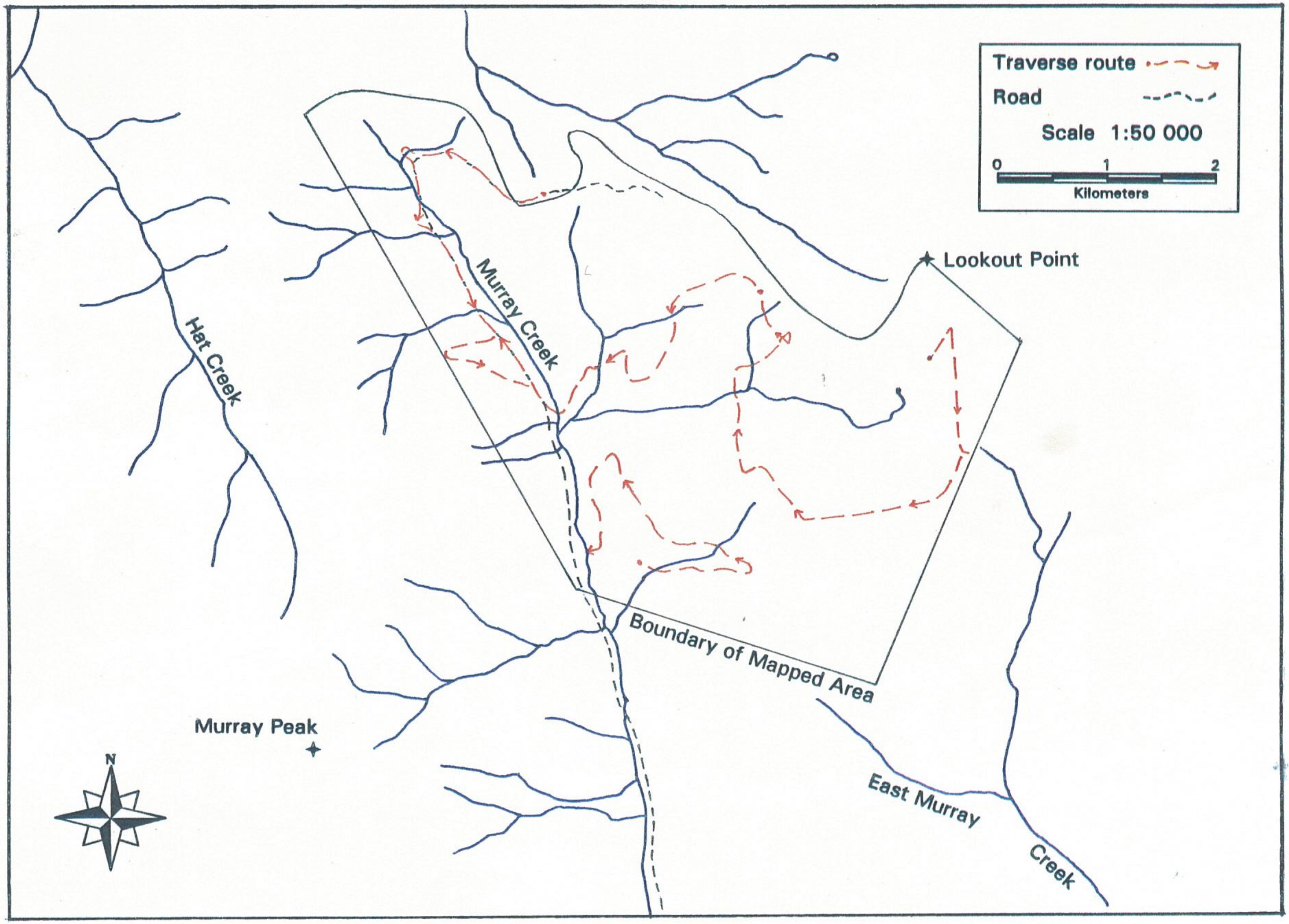

Figure 1. Location map for Murray Creek study area.

Bedrock geology of the study area has been mapped at a scale of 1:250 000 (Duffell and McTaggart, 1952; Monger and McMillan, 1989), and surficial geology 1:125 000 (Ryder, 1976). The study area is underlain by volcanic and sedimentary rocks of the Spences Bridge Group and younger (Eocene) volcanic rocks of the Kamloops Group (Figure 2). The presence of the major rock types and surficial materials was confirmed during field work. Columnar volcanic rock (basalts) identified at site B73 (Photo 1) probably belong to the Kamloops Group. Near site S75, soft shales or mudstones exposed along the bed and banks of Murray Creek may be overlain unconformably by vesicular lavas. The regional-scale surficial geology map of the study area identifies drift deposits (mostly till) and colluvium.

In the study area, bedrock is mostly buried by glacial drift that ranges in thickness from less than a metre to a few metres (see Section 4). The drift, which is chiefly basal till but includes small areas of glaciofluvial gravel and ablation till, was deposited during the last major glaciation (Fraser Glaciation). At first, ice flowed east from the Coast Mountains, but later it was deflected south and southeastward by ice from the Cariboo Mountains (Duffell and McTaggart, 1952; Tipper, 1971). At the glacial maximum about 15 000 years BP, all of the study area was buried by ice. To the northwest, the highest peaks, Blustry Mountain and Cairn Peak, may have protruded above the ice-sheet (nunataks). During deglaciation, about 12 000 to 11 000 years BP, ice thinned and stagnated over the study area. Till ridges (drumlins) deposited by southeasterly flowing ice are preserved on the plateau immediately to the northeast of the study area. Meltwater flowed on, under and along the margins of the ice. Ice masses remained in the Fraser and Thompson valleys after the uplands became ice-free. Melting of ice from the valleys occurred sometime between 11 000 to 10 000 years BP.

During post-glacial time, alluvial fans have formed in valleys and on post-glacial terraces. Landslides and colluvial blankets have developed on both bedrock and Quaternary deposits. Volcanic ash, probably Mazama (6900 yr B.P.) occurs at shallow depths in isolated locations within alluvial fans and slopewash deposits. Field investigations indicate that it is uncommon within the study area.

(3) METHODS

(3.1) Terrain Mapping

Terrain mapping followed the standard British Columbia procedures for terrain classification (Howes and Kenk, 1988), mapping methodology (Ryder, 1994) and slope stability (5-class system, Forest Practices Code, 1995).

Preliminary terrain mapping was done by interpretation of 1:15 000 scale colour air photos (BCC 648 Nos. 43-45, 68-73, 180-183). Two days of field work with two field crews (i.e., 4 crew-days) were carried out on July 2nd and 3rd, 1995. Field work involved traversing representative polygons of different surficial materials and slopes, with attention focused on relatively steep slopes likely to be designated as stability classes IV or V. The study area was traversed on foot with helicopter support (Figure 1). The northern and western parts of the study area are

Scale 1:125 000

0 2.5 5

Kilometers

LEGEND

EOCENE

EK — KAMLOOPS GROUP-Mainly basalt and andesite; local rhyolite, breccia, tuff and sandstone

MIDDLE AND LATE CRETACEOUS

KSB — SPENCES BRIDGE GROUP-Intermediate, locally felsic and mafic flows and pyroclastics; sandstone, shale, conglomerate

Geological boundary (defined, approximate, assumed)

Foliation (inclined, vertical, unknown)

Bedding (inclined)

Fault (defined, approximate, assumed)

Figure 2 : Bedrock geology of the Murray Creek area (from Monger, J.W.H. and McMillan, W.J. GSC Map 42-1989).

accessible by road. All field observation sites are shown on the terrain maps. Formal site description forms completed for 59 sites (ST-25, BK-34) are presented in Appendix 3 (separate volume). Soil pits were dug where natural exposures such as slide scars or tree-throw hollows were not available for examination. Samples were collected at some sites for lab analysis.

Back in the office, terrain mapping on air photos was corrected in light of field observations. Soil drainage and slope classes were added, the latter based partly on field measurements and partly on 1:5000 scale topographic maps (10 m contour interval). Comparison with field measurements suggests that the topographic map is reliable, although some small, locally steep or gentle areas are not clearly represented by contours. Interpretations for slope stability and potential erosion were made according to criteria that are discussed in Section 6. Terrain polygon boundary lines were transferred to the 1:5000 scale map by hand, using topography as indicated by contour lines, creeks, forest openings and roads as guides. On-site symbols relevant to slope stability interpretation (e.g., landslides, scarps) were also added. In the lab, particle size analyses on selected till samples were completed to confirm hand texturing in the field.

Overlays and maps in digital format containing the terrain, slope stability and erosion potential information were produced by Hugh Hamilton Ltd., according to MoF specifications. These should be used in conjunction with the 1:5000 scale topographic maps.

(3.2) Mapping Reliability

Air photo interpretation and field checking for this project were carried out at a level of detail and reliability that is appropriate for 1:20 000 scale terrain mapping. Approximately 50% of polygons within operability limits were checked (ground check sites and visually inspected sites), conforming to the standard for TSIL B (Terrain Survey Intensity Level B). Maps are presented at a scale of 1:5000, however, to be compatible with the large scale maps used for planning purposes. For this reason, terrain polygons appear to be relatively large and the information that they portray is generalized when compared to the topographic details that are shown by the base map. Map users should be aware that many small areas (less than about 5 ha) of different materials, slope steepness and drainage conditions are unmapped.

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

(4) SURFICIAL MATERIALS AND ASSOCIATED LANDFORMS

The following descriptions are based on observations of materials exposed in road cuts, tree-throw hollows and in soil pits ranging in depth from 0.2 to 1.0 metre. Material characteristics were recorded at specific sites, general observations were made continuously during traverses (see Appendix 3 for site forms and the terrain map for site locations), and samples were collected for further analysis.

(4.1) Till (M)

Till is material deposited directly by glacier ice. It typically consists of a fine-grained matrix (particles <2 mm) that surrounds and supports clasts (particles >2 mm) of a variety of sizes, shapes and rock types. Till characteristics such as texture (particle sizes) and consolidation (or bulk density) vary according to specific processes of deposition by glacier ice (e.g., subglacial vs. supraglacial tills).

Till is widespread throughout the study area on all but the steepest slopes. It is generally between 0.5 and 2 m in thickness, and thickness may vary abruptly over short distances (Mw). Till less than 1 metre in thickness (Mv) is present on convex slopes, spurs, and the crests of small hills, and till up to a few metres in thickness (Mb) underlies concavities and depressions. On flat and gently rolling terrain, bedrock mounds and hummocks have been partially buried by till, so that till is thin or absent on rises and thicker in depressions.

Highly consolidated and cohesive basal (subglacial) till is widespread in the study area (e.g., site S72, Photo 2). Particle size analysis indicates that the matrix texture is a sandy mud with a high clay content (30-49%). Clast content ranges from 20 to 40% by volume, and pebbles (2-64 mm), cobbles (64-256 mm) and boulders (>256 mm) are predominantly subangular to subrounded. Clasts consist of mainly volcanic rocks, with minor sedimentary and metamorphic types. The Munsell colour of till is dark brown (10YR4/3).

These basal tills are typically dense, and have very low permeability, although they contain water. Till overlying moderately steep ($>65\%$ (33°)) bedrock may slide during and following wet weather and snowmelt (Photos 3 and 4). Where roadcuts intersect the contact between till and bedrock, seepage may cause sloughing and recession of cut banks.

(4.2) Colluvium (C)

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

On slopes that are steeper than about 60% (31°) and downslope from bedrock outcrops, bedrock and till are commonly overlain by a thin covering of colluvium (Cv and Cvb). This material typically consists of loosely packed rubble or angular fragments with interstitial silty sand. It results from disintegration of local bedrock due to weathering, and slow downslope creep (rock creep) of the detached material. Colluvium in Cv terrain polygons is non-cohesive, highly porous and permeable.

Talus slopes (Ck) are accumulations of angular fragments at the base of cliffs that stand at the natural angle of repose, about 67% (34°). Talus material is similar to that of colluvial veneers, but much thicker and with fewer near-surface fines. In the study area, these materials were mapped in the transition zone below the cliffs west of site S72 and at the base of Lookout Point. Such terrain is relatively well drained and dry.

Colluvial fans (Cf) and gentle colluvial slopes (Cj) are formed at the foot of gullies by the accumulation of materials moved by landslides, small steep creeks, and slope wash. In the study area, colluvial fans mapped on the west side of Murray Creek consist of materials transported from the gullied east-facing slopes below Murray Peak. Colluvial deposits commonly rest upon stream terraces and floodplains (sites S76 and B83) and gently sloping till. These colluvial deposits commonly include damp sites, particularly on the lower parts of fans or colluvial slopes where the water table lies close to the surface.

(4.3) Glaciofluvial Gravels (F^G)

Glaciofluvial sediments were deposited by glacial meltwater streams. These sediments are exposed in the roadcut at the southwest corner of the study area (site S76) where a ridge consisting of bedded sands and gravels at least four metres thick is partially overlain by a veneer of colluvium. This is most likely a kame deposit (formed in contact with stagnant ice). The source of the overlying colluvium is a bedrock slump about 1300 metres upslope. In general, glaciofluvial materials are well drained and give rise to relatively dry sites. Areas mapped as glaciofluvial (F^G) material are potential sources of aggregate.

(4.4) Fluvial Materials (F, F^A)

Fluvial (alluvial) gravels have been deposited in post-glacial time by streams. Murray Creek and its tributaries drain the eastern slopes of the Clear Range and the basalt flows of the Thompson Plateau. These creeks are generally narrow (approximately 3-5 m wide) and gravelly. Fluvial gravels and sands are loose, non-cohesive, and highly porous and permeable. Associated terrain units, such as floodplains and parts of fans that are close to stream-level, have high water tables and are moderately to imperfectly drained. Fluvial terraces stand above present day creek-levels and are relatively well drained and dry, and good locations for roads and landings.

(4.5) Organic Materials (O)

Organic soils (Ov, Op: peat bogs, swamps) form where decaying plant material accumulates in very poorly drained areas. In the study area, organic soils were mapped along the valley bottom by Murray Creek, and in major depressions on the uplands. In both areas, drainage is impeded by the underlying substrate (basal till and bedrock). At other locations, organic soils have developed at poorly drained sites that are too small to show on the terrain map. These are gully floors, hillside concavities, and depressions on effectively impermeable bedrock and till.

(4.6) Bedrock (R)

Bedrock is shown on the terrain map where it outcrops or lies very close (less than a few centimetres) to the land surface. Bedrock outcrops are also common in terrain units shown as Cv, Mv, Mw and Mvb.

The volcanic bedrock fractures readily along planes of weakness (joints) that function as slip planes. Deep-seated slumping and sliding was identified on this rock type (sites S56 and B73). A rock stability specialist should be consulted prior to forest activities (i.e., road construction or logging) through steep outcrops of this rock type.

(4.7) Volcanic Materials (V)

This category includes unconsolidated pyroclastic deposits. In the Murray Creek area, the presence of Mazama tephra (=volcanic ash; 6900 years BP) is rare, but a 10 cm thick capping of fine ash was identified in the soil pit at site S69. No other occurrence of ash was found in the study area. Volcanic ash may be easily displaced during logging activities because it is loose and easily moved, and if surface runoff develops, then it is more erodible than other surficial materials.

(5) ACTIVE GEOMORPHOLOGICAL PROCESSES

(5.1) Slow Mass Movement (-F, -F")

Slow mass movement (failing) refers to slope failures where movement occurs slowly (imperceptibly) and/or where displaced material moves short distances downslope. The symbol -F" is used to indicate initiation zones, and -F is used for deposition zones. Small slumps and slides in till along gully sidewalls, and unstable bedrock with tension cracks are included in this category.

Areas showing signs of failing (-F) were mapped in the central part of the study area (e.g., site B74), southwest of cutblock 36 (site B57) and east of cutblock 52. In each area, weathered volcanic rock is transported downslope by rock creep and slumping.

Slumping in bedrock (-Fm) was mapped near the east one-third of cutblock 52 (sites S55 and S56, Photo 5). Near these sites, numerous tension cracks were seen, and the terrain is very hummocky and ridged in places. At the headscarp of this bedrock slump (site S56), till approximately 1.5 to 2.0 metres thick is underlain by fine grained basalts (Photo 6). Deep weathering, perhaps due to retained water on the flat surface above this outcrop, has contributed to slumping here.

Slumping in surficial materials (-Fx, -Fu) was mapped at sites S72 and B75 in the central part of the study area. Here, hummocks and lobes consisting of reworked till were formed as this material was transported slowly downslope by a sliding or flowing action (Photo 7).

(5.2) Rapid Mass Movement (-R, -R")

Rapid mass movement includes falling, bouncing, rolling, sliding, or flowing of dry, moist or saturated debris derived from surficial material or bedrock. The symbol -R" is used to indicate initiation zones, and -R is used for runout zones. Slides are triggered by heavy rain onto ground that is already saturated, and result from loss of soil strength due to high pore water pressure (Photo 8). Recent and/or recurrent debris slides (-R"s) occur along the steep slopes east of Murray Creek both below (site S74, Photo 3) and above (site S70, Photo 4) the clearcut. Steep (65-70%) rock, overlain by thin, fine textured till is exposed near the headscarp at both sites. The contact between bedrock and till is the shear plane where sliding occurs.

Rock slides (-R"r) and rock fall (-R"b) are less extensive than debris slides and are mapped in the central part of the study area and east of cutblock 52. At site B73, highly fractured volcanic rocks are exposed at the top of a large rock slide with rubbly talus accumulating at the base of outcrops (Photo 1). At site S56, rock fall occurs at the headscarp of a deep-seated slump block in basalts .

(5.3) Gully Erosion (-V)

Gullies are small ravines with a V-shaped cross section formed in drift and bedrock. In most places, gullies are vegetated and presently "inactive". Their presence is an indicator of former slope erosion however, and thus the symbol -V serves to identify potentially erodible materials, such as till (e.g., Mb-V, Mk-V). Gully erosion was mapped on the till-covered midslopes beside Murray Creek (e.g., sites B67 and S73). These slopes are potentially unstable areas, especially the the gully walls, because the water table is near or at the surface here during rainstorms and the fine textured tills have a high likelihood of sliding on slopes $>65\%$ (33^{o}).

(6) INTERPRETATIONS FOR SLOPE STABILITY AND EROSION POTENTIAL

Ratings for slope stability and potential surface erosion are presented on a map overlay. "Slope stability" refers to gravitationally-induced mass movement, i.e., slumps, slides and debris flows; "erosion" refers to the removal of material particle by particle by running water. Criteria used to assess slope stability and potential erosion are shown in Tables 6.1 and 6.2. Definitions for slope stability and erosion potential classes are shown in Table 6.3.

Criteria are based chiefly on slope steepness, soil drainage, and material texture. It should be noted, however, that criteria were used as guidelines only: each terrain polygon was rated individually in order to permit additional local factors to be taken into account when necessary. These include:

- *Slope smoothness/irregularity*: the "bumps" on irregular slopes are usually formed by near-surface bedrock. This acts to pin surficial materials in place, thus the potential for instability is less than on a slope of similar overall steepness but with a smoother profile.

- *Moisture*: in general, wet slopes are more unstable and more erodible than dry ones. High pore water pressure, such as that which develops in a perched water table in weathered till, leads to reduction in normal stress and slope failure. Overland flow, which develops more readily in wet than dry areas, leads to surface erosion.

- *Slope position*: in general, lower slopes and concavities are relatively wet because they receive moisture from a large area upslope; thus they tend to be potentially unstable if steep, and erodible even on moderate slopes.

In general, the majority of polygons are rated as stability class IV, but as a percentage of total area, stability class II is the most extensive. Steep slopes and areas of complex topography that include short steep slopes are rated as class IV. The gently rolling surface of the uplands is stable. Stability class V terrain is located on steep slopes adjacent to Murray Creek, in the transition zone near site B73, and near cutblock 52. These areas are affected by mass movement (i.e., debris slides/flows, rock slides, slumping).

With regard to surface erosion potential, most of the study area is rated low to high. In general, high ratings were given to polygons with slope steepness class 3 or higher, fine textured materials (e.g., till), and moist sites. Very high ratings were given to polygons with slope steepness class 4 or 5 which are experiencing active mass movements and covered by fine textured materials.

Table 6.1: Guidelines for Assessment of Slope Stability

Slope Stability Classes	Dominant Slope Class*	Material and Landforms	Dominant Texture	Active Processes	Soil Drainage	Slope Morphology
I	1 and 2	F^{G}tu; Cf; Ff	g; sr, g	none	poorly drained and wet soils are relatively susceptible; polygons with slopes within 5 or 7% of an upper class boundary may be assigned to the next highest class	slopes with irregular or benched topography controlled by bedrock are relatively stable; units with slopes close to a lower class boundary may be assigned to the next lowest class.
	1&2 mixed	Mv, Mb; Cv; R	\$s, s; sr	none		
II	2	Mv, Mb	s\$	none		
	2 and 3	Cf; F^{G}; R	sr; g;	none		
III	3	Mv, Mb; Cv	\$s; sr	none		
	4	Ca, Ck, R, F^{G}	sr, x; g	none		
IV	4 and 5	Mv, Mb, Cv, Cb	all	-V, -R"b		
	4 and 5	Rk, Rs				
V	any gradient	all	all	-F, -R"d, -R"s **		

* Slope classes are defined as follows: Class 1: 0-5% (0-3°); Class 2: 5-27% (3-15°); Class 3: 27-49% (15-26°); Class 4: 49-70% (26-35°); Class 5: over 70% (35°).

** Refers to the initiation zones of rapid mass wasting (mostly debris flows) and slow failure, and active gullies.

Table 6.2: Guidelines for Assessment of Erosion Potential

Dominant Texture* or Material	Typical Material	Slope Steepness Classes 1 (0-5%)	2 (5-27%)	3 (27-49%)	4 (49-70%)	5 (>70%)
organics	Op, Ob	VL	L	-	-	-
c, m	W^{G}v, L^{G}v	L,M	M	H	VH	VH
fine s, coarse \$	L^{G}, Mv, Mw, Cv	L	M	H	H,VH	VH
coarse s, xs	Cv, F, F^{G}, Mv, Mw, Mb, Vv	VL,L	L,M	M,H	H	H,VH
d\$s	Mw, Mb, Mv	VL,L	M	M	M,H	H
g, ds, r	F, F^{G}, Mv, Mb	VL,L	M	M	M,H	H,M
a, b	Ck, Cv, Cb	VL	VL	L	L	M,L
R (resistant rock)	R	VL	VL	VL	VL	VL

* Refer to Appendix 2 for definitions of texture symbols.

Table 6.3: Definitions for Slope Stability and Erosion Potential Classes

SLOPE STABILITY CLASSES	
I	No problems of instability expected.
II	No significant problems of instability expected.
III	Minor instability problems may develop in some areas; wet areas should be treated with caution.
IV	Terrain polygons include potentially unstable terrain; special precautions necessary.
V	Terrain polygons include unstable terrain; avoid these areas.

EROSION POTENTIAL CLASSES	
VL (very low, none)	No problems of erosion expected on flat or gently sloping terrain, organic soils and floodplain. Erosion of banks and channels may be initiated by the disturbance of streams.
L (low)	Chances of rilling or sheet erosion and subsequent sedimentation of lakes and streams are generally low, although care is required to avoid erosion along ditches with steep gradients. No significant problems of erosion expected.
M (moderate)	Problems of erosion associated with logging are similar to but less than terrain rated "high", although problems may develop if water flows unchecked along steep ditches, roadways, or on other bare soil surfaces. Exposures of fine textured till near creeks should be avoided.
H (high)	Expect problems of erosion to develop on bare soils and compacted surfaces along roads and ditches, on cut slopes adjacent to landings, and on disturbed soil in cut blocks. Take precautions necessary to minimize erosion as appropriate, such as immediate reseeding of exposed mineral soil. Site inspection by geomorphologist recommended.
VH (very high)	Natural movement of fine sediments into adjacent creeks. Potential erosion more severe than in "high" category. Site inspection by geomorphologist recommended.

(Source: modified from Forest Practices Code, 1995).

When using these ratings, it is essential to bear in mind that conditions are locally variable. The ratings (and information on the terrain map) indicate the writer's impression of typical conditions for each terrain polygon, but locally steeper slopes, wetter soils, emergence of water from seepage zones, and clayey materials give rise to areas that are potentially more unstable and/or more erodible than their surroundings. Consequently, persons marking road alignments and cutblock boundaries should recognize and take account of these local conditions.

In complex terrain with both gentle and steep slopes, more than one stability and/or erosion potential class may have been used. In such a case, the higher class applies to areas of relatively steep slope.

(7) RECOMMENDATIONS

(7.1) General Recommendations

Recommendations that are standard for erodible or unstable terrain are listed below.

(1) Bare, compacted surfaces, such as cat tracks and skid trails, even on gentle slopes, are particularly vulnerable to erosion by running water. Care should be taken to avoid leaving tracks (depressions) aligned in the downhill direction that will channel runoff water and initiate gully erosion. Scarification of smoothed and compacted surfaces will increase infiltration rates and reduce erosion hazard.

(2) Grass seeding may be an effective means of reducing erosion potential on bare surfaces such as unused landings, cut banks, and other disturbed areas.

(3) Sloughing of cut banks along roads may develop due to emergence of shallow subsurface water Ditches should be inspected regularly and cleaned or otherwise maintained when necessary.

(4) Construction of roads on steep slopes (>60%) should be minimized, but where unavoidable, all appropriate measures should be used to prevent soil and site degradation (full bench and end-haul, no diversion of natural drainage paths.)

(5) Road construction should be avoided during wet weather and when the ground is wet due to snowmelt. The fine textured tills when wet may reduce the trafficability (capacity to support moving vehicles) of the soil.

(6) Where class IV terrain occurs within areas where forestry operations are planned, on-site inspections by a slope stability specialist should be carried out in order to determine more precisely the nature of the instability and the extent of the unstable areas.

(7) Class V terrain is unstable and should be avoided.

(7.2) Specific Recommendations

In general, the road alignments in the Murray Creek area are located on stable (class I-III) terrain with moderate to low surface erosion potential. None of the proposed cutblocks are located in class V terrain, with the exception of the eastern one-third of cutblock 52. Here, the headscarp of a major landslide was mapped. An inspection by a terrain stability specialist (i.e., P.Geo. or P.Eng.) is required prior to any logging activity in this area to assess the activity of this slide. If this slide is slowly moving, then possibly, this part of the cutblock should be abandoned and left in its natural state. If the slide is stationary (inactive), then logging could effect little change.

Some of the proposed roads and cut blocks are in terrain rated high for surface erosion potential. Logging activity in high erosion potential areas must be carefully planned to avoid unnecessary soil loss. Wet soils and/or organic soils may be rated moderate for erosion potential hazard, even on relatively gentle slopes. Where these soils exist in some proposed cutblocks (blocks 25, 36, 43 and 46), the hazard can be offset by adequate planning of drainage measures along roads and minimizing disturbance of soil. Road construction techniques and drainage installations appropriate to local conditions should not increase terrain instability or potential erosion.

(8) CONCLUSIONS

Field and air photo observations suggest that terrain in the Murray Creek area is more susceptible to erosion than to instability. However, ground observations suggests that the fine textured tills in the study area are susceptible to failure where bedrock is close to the surface on slopes >65% (33^o), and where drainage is concentrated (e.g., steep toe-slopes). In general, proposed road alignments and cutblocks in the Murray Creek area are located on stable terrain with low to moderate surface erosion potential. However, the eastern one-third of cutblock 52 is located beside the headscarp of a major landslide (stability class V). Inspection of this area by a slope stability specialist is required (i.e., P.Geo. or P.Eng.) prior to any logging activity (road building or harvesting).

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APPENDIX 1: ANNOTATED PHOTOGRAPHS

Photo 1. Site B73. Highly fractured basalts at headscarp of old landslide.

Photo 2. Fine textured till in 1 metre deep soil pit at site S72. Note the low clast content.

Photo 3. Recent slide at site S74 in thin till, below recent cutblock east of Murray Creek.

Photo 4. Slide in thin till below site S70. Slope above headscarp is approximately 65%.

Photo 5. Headscarp of deep-seated slump in basalts at site S56, near cutblock 52.

Photo 6. Site S56, 1-2 metres of till overlying basalt plateau.

Photo 7. Toe of slump in recent clearcut by site S72. Note the sharp break in slope between the lobe and flat till blanket.

Photo 8. Headscarp of a recent slump at site B77 in till. Under appropriate conditions this material will slide as in Photos 3 and 4.

APPENDIX 2: TERRAIN MAP LEGEND - MURRAY CREEK AREA

(1) TERRAIN UNIT SYMBOLS

Simple Terrain Units: e.g., texture → aCk-R ← process

surficial material ↗ ↖ surface expression

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

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

e.g., Cv·Rs indicates that "Cv" and "Rs" are of roughly equal extent

Cv/Rs indicates that "Cv" is more extensive than "Rs" (about 2/1 or 3/2)

Cv//Rs indicates that Cv is much more extensive than Rs (about 3/1 or 4/1)

Stratigraphic Units: Groups of letters are arranged one above the other where one or more kinds of surficial material overlie a different material or bedrock:

e.g., Mv over Rr indicates that "Mv" overlies "Rr".

/Mv over Rr indicates that Rr is partially buried by Mv

Slope Stability and Erosion Potential: Roman numerals for slope stability and upper case letters for erosion potential separated by a ".", e.g., I.L

(2) MATERIALS

C	Colluvium	M	Till
F	Fluvial materials	O	Organic materials
F^{A}	"Active" fluvial materials	R	Bedrock
F^{G}	Glaciofluvial gravels	V	Volcanic materials

Materials followed by an '*' indicates that the material is overlain by a veneer of sandy volcanic ash.

(3) TEXTURE

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

(4) SURFACE EXPRESSION

a	moderate slope(s)	k	moderately steep slope	t	terrace(s)
b	blanket	m	rolling topography	u	undulating topography
f	fan	p	plain	v	veneer
h	hummocky	r	ridges	w	variable thickness
j	gentle slope(s)	s	steep slope(s)		

(5) GEOLOGICAL PROCESSES AND MASS MOVEMENT SUB-CLASSES

F	Slow Mass Movement	Fx	Slump-Earthflow	Rr	Rockslide
F"	Slow Mass Movement (Initiation Zone)	R	Rapid Mass Movement	Rs	Debris slide
Fm	Slump in Bedrock	R"	Rapid Mass Movement (Initiation Zone)	V	Gully Erosion
Fu	Slump in Surficial Materials	Rb	Rock Fall		

(6) SOIL DRAINAGE CLASSES

r	rapidly drained	m	moderately well drained	p	poorly drained
w	well drained	i	imperfectly drained	v	very poorly drained

Where two drainage classes are shown, e.g., "wi", then no intermediate classes are present; if the symbols are separated by a dash, e.g., "w-i", then all intermediate classes are present.

(7) SLOPE CLASSES

1	0-3° (0-5%)	3	15-26° (27-49%)	5	>35° (>70%)
2	3-15° (5-27%)	4	26-35° (49-70%)		

(8) ON-SITE SYMBOLS AND BOUNDARY LINES

Boundary lines:

- definite boundary ————
- indefinite boundary – – – –
- assumed or arbitrary boundary ....
- study area boundary ━━━━

On-site Symbols:

- ⊙ S10 observation site
- visual inspection site
- meltwater channels: small (flow direction unknown)
- landslide scars: headwall scar only
- scarp in surficial materials
- small landslide: headwall scar and track