WENSLEY CREEK: TERRAIN SURVEY WITH FOREST MANAGEMENT INTERPRETATIONS

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1.0 OBJECTIVES

A study was undertaken on approximately 1 500 ha of forest land in the Wensley Creek watershed, the principal water source for the village of Nakusp. The objectives of the survey were to identify those areas of the landscape which have a high sediment delivery potential, and to identify areas which are susceptible to damage through mass movement resulting from forest development activity.

This information is intended to be used in planning at the subunit level. It is not appropriate for operational planning.

The report outlines the rationale for the interpretations. This information (see Appendix 1) is intended to assist users in making a site specific evaluation of hazards. A brief discussion of survey procedures and the reliability of the maps and interpretations is also included.

2.0 SUMMARY

2.1 CONCLUSIONS

1. Naturally occurring mass movement activity within the study area is rare. Naturally occurring debris failures of small size were noted in only two units: 1) in the steep upper headwall area above Brouse Creek and, 2) in the steeply sloping unit located on the west side of Halfway Creek near the break in terrain where the creek becomes deeply incised.

   Despite the localized and infrequent occurrence of naturally occurring mass movement a high potential exists for inducing mass movements on slopes greater than 60% in steepness. Evidence of this potential is demonstrated by existing failures in logged portions of the west fork of Wensley Creek.

2. Within the study area slope angle is the critical factor determining the potential for induced instability.

   With the exception of the depth of surficial material, occasionally found to be less than one metre, other factors controlling slope instability are not limiting. Soils throughout the area, regardless of genetic origin, are non-cohesive, uniformly coarse textured and, with few exceptions, well drained.

3. The evaluation of development chance in the Halfway Creek drainage should consider the following terrain features:

   1. steep, long and uniform slopes which extend from the ridge crest to the stream channel in the lower portion of the drainage where the creek is exposed.

   2. the occurrence of potentially unstable canyon-like gullies incised in the slopes on the west-side of the creek. These gullies may constitute obstacles to road development.

   3. numerous shallow (0-1.5 m) gullies which extend to the upper slope on the east side of Halfway Creek. It is possible that these gullies occur as a result of seasonal surface and subsurface drainage.

   4. steep slopes with shallow soils and rock cliffs which are located on the east-side nose slope of the drainage.

2.2 RECOMMENDATIONS

These recommendations are not intended as inflexible rules but as guidelines to be considered with other factors in the decision-making process.

Existing mass movement and sedimentation within the study area is in most cases directly attributable to poor forest road construction practices. Suitable road construction and harvesting techniques will substantially reduce, but not eliminate, the potential for induced mass movement and stream sedimentation.

For specific recommendations pertaining to each hazard class see Section 6.0 or consult the interpretive map legends.

For the purpose of this report critical areas are considered to be terrain units located within 200 m of a perennial stream channel and which are classified as: 1) having HIGH or EXTREME mass movement hazard or, 2) a HIGH or EXTREME sediment yield hazard.

General Recommendations

- In critical areas and on sites wetter than well drained restrict road construction and harvesting activity to the period from July to October.

- Seasonal drainage channels, localized seeps and springs should be identified and located through a site specific investigation prior to road construction. To accomodate flows from these points proper drainage structures should be installed at the point of interception.

- On slopes greater than 60% full bench all roads.

- On steep (>60%), long (>200 m) uniform slopes locate haul roads and landings as high as possible on the slope. This will avoid a serious loss of toe-holding strength on the slope and avoid the interception of subsurface drainage.

- Avoid slope overloading with sidecast on slopes greater than 60%. This may require endhauling or placement by a backhoe (backcasting) of excavated material.

- Avoid cutbanks greater than two metres in height to minimize ditch sloughing. Cutbanks greater than two metres should be sloped to less than 70%.

- Crown road surfaces to avoid water accumulation.

- Avoid road locations in steep gully headwall areas.

- Following the completion of harvesting continue ditch maintenance or immediately put roads to bed.

- Grass seed exposed mineral soil surfaces using an erosion control mix on sites with an EXTREME sediment yield hazard. Areas with a HIGH sediment yield hazard, and in particular those areas within 200 m of a perennial stream channel should be considered for grass seeding on a site specific basis.

- Backhoe construction of roads may be necessary to avoid over-steepened cutbanks and excessive sidecast slopes.

Drainage Structures

- Culverts should be placed in natural drainage channels to preserve the original drainage network.

- Ensure adequate water barring of skid roads.

- Do not discharge water directly on to sidecast slopes. This may require the use of culvert extensions or aprons.

- Additional culverting is recommended in lower slope positions and on sites wetter than well drained.

- Drainage control in switchbacks, road junctions and landings is critical. Prevent water accumulation by directing water away from these points. Diverted water should not be discharged on to potentially unstable sites.

- Where possible, culverts should be placed at an angle so as to minimize the change in the direction of ditch water flow.

Harvesting

- Recommendations as to the choice of harvesting system in the different hazard class units are given in Section 6.0.

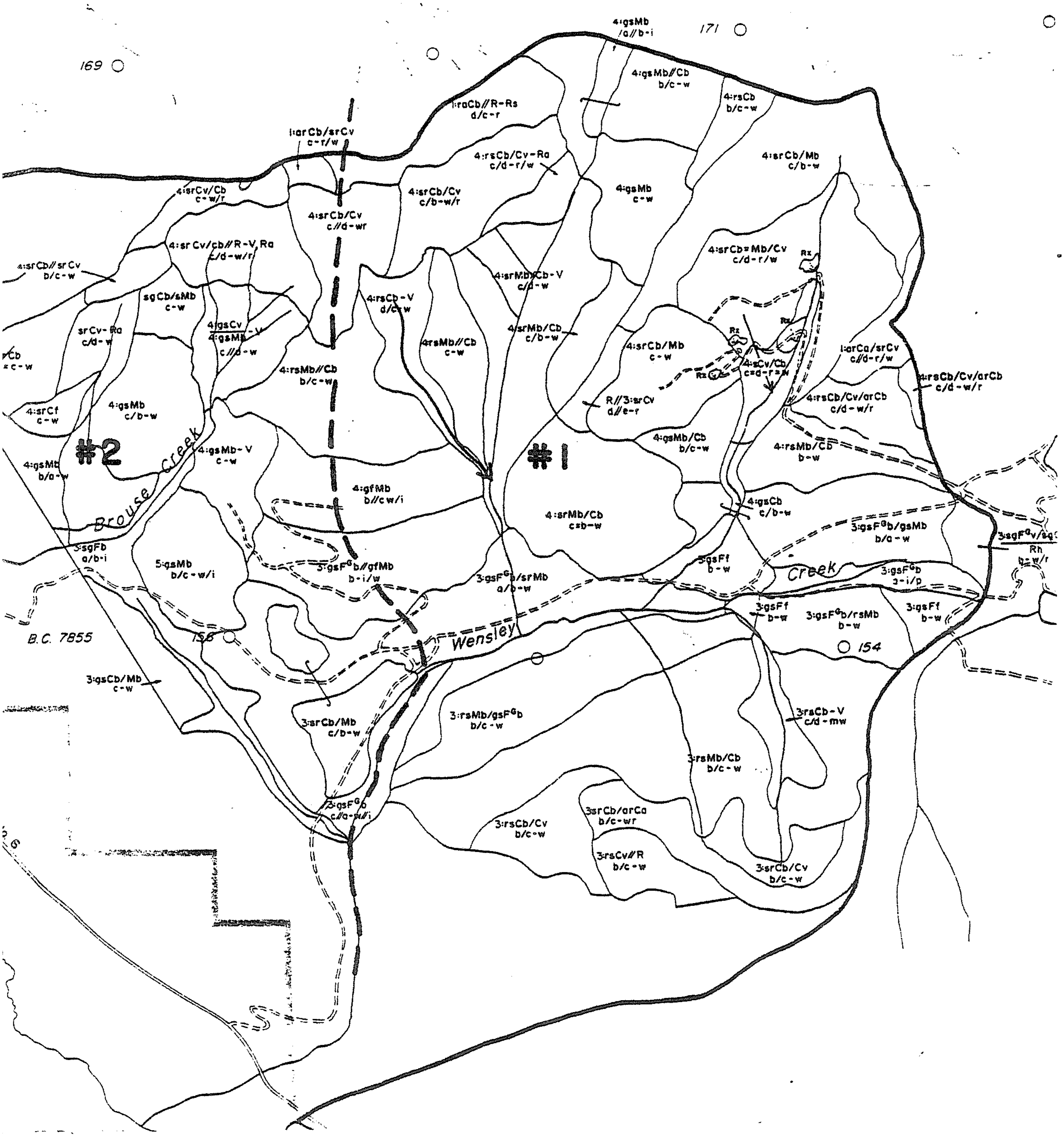
- In unstable terrain and on slopes greater than 60%, the location and size of landings is critical. Harvesting operations should be scheduled so as to minimize the size of landings by minimizing log storage requirements.

- Where snow logging is considered as a means of reducing soil disturbance in the more hazardous terrain units, a snowpack of at least one metre of "spring" snow will be required to achieve this objective.

- The sidecut on feeder skid roads should not exceed .5 m. The specific system applied to achieve this standard will vary depending on terrain conditions.

Map 1 Bedrock Location

Scale 1:20,000



3.0 BEDROCK

3.1 MANAGEMENT IMPLICATIONS

Bedrock throughout the area has good rippability and presents no engineering limitations.

3.2 TYPE AND LOCATION

Bedrock in the southern portion of the study areas was mapped by Hyndman (1968). Although bedrock was not systematically mapped in this investigation, field obeservations confirmed the occurrence of two major rock types which correspond to Units 9 and 15 described by Hyndman (1968). The approximate location of these rock types is shown on map no. 1.

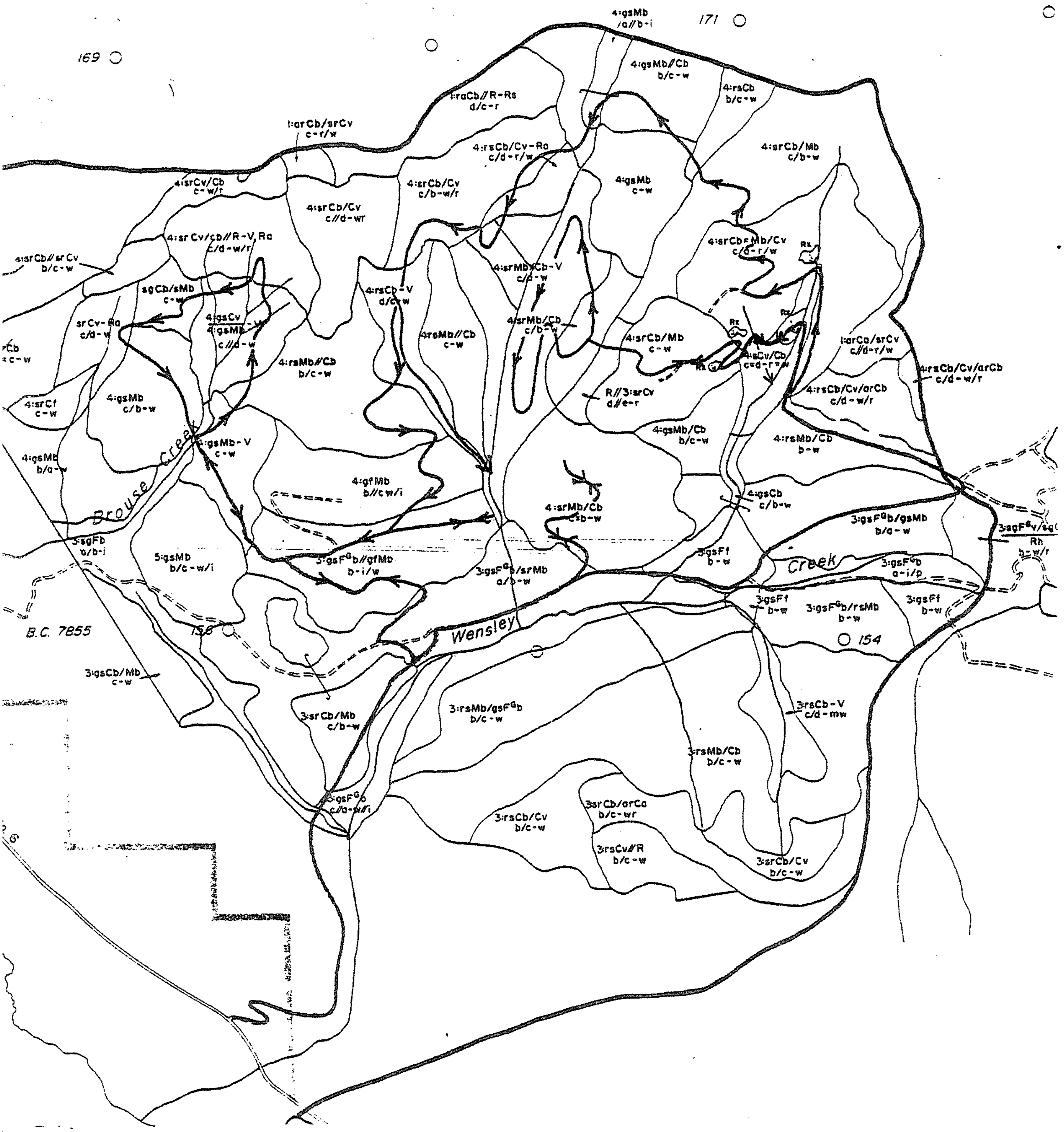
Rock type #1 is a fractured, light coloured, highly acid, intrusive rock (leuco-granite) associated with the Kuskanax Batholith. It is located in the northeast corner of the study area. Halfway and Wensley Creeks are incised in this strata. The contact dividing rock types 1 and 2 occurs at an undefined location between Halfway and Brouse Creeks.

Brouse Creek is incised in rock type #2 which is a dark green coloured amphibolite (metamorphic) rock. It is highly schistose, with visibly evident cleavage planes oriented with a near vertical dip.

Brouse Creek has a distinctly dendritic drainage pattern in contrast to the linear configuraton shown by Halfway and Wensley Creeks. This difference in drainage pattern is correlated with different bedrock types.

Figure 1 Location of Field Traverses

Scale 1:20,000



4.0 SURVEY AND MAPPING PROCEDURES

Following a review of the published, reconnaissance soil survey[1] for the area, terrain units were pretyped on black and white aerial photographs at a scale of 1:20,000. Field checking of the pretyped units was preceded by a vehicle reconnaissance of most of the accessible roads in the area. A total of four days were spent making foot and vehicle traverses from May 27-29, and on October 26, 1983. Ground inspections were concentrated in the areas known to be of interest for forest development. (See Figure 1.)

Terrain units were delineated according to the ELUC Terrain Classification system which was slightly modified to suit the specific objectives of the survey. The units typed on aerial photographs were transferred to a planimetric map base at a scale of 1:20,000 by means of a Kail plotter.

Two interpretive maps were derived from the terrain map according to the criteria outlined in Section 6.0 ("Hazard Classification"). The interpretive maps estimate the forest development hazards for mass movement and sediment yield.

[1] Soil Resources of the Lardeau Map Area.

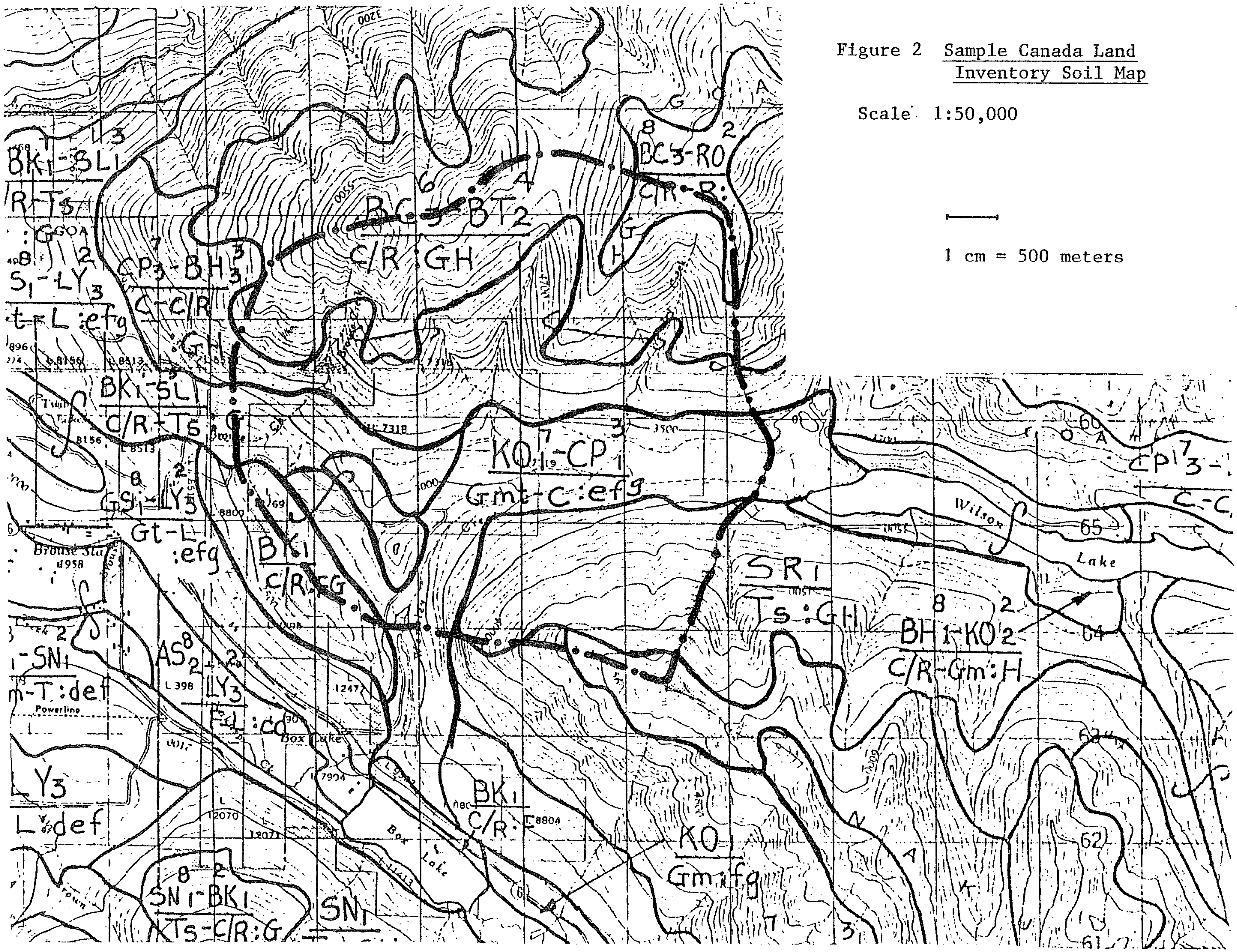
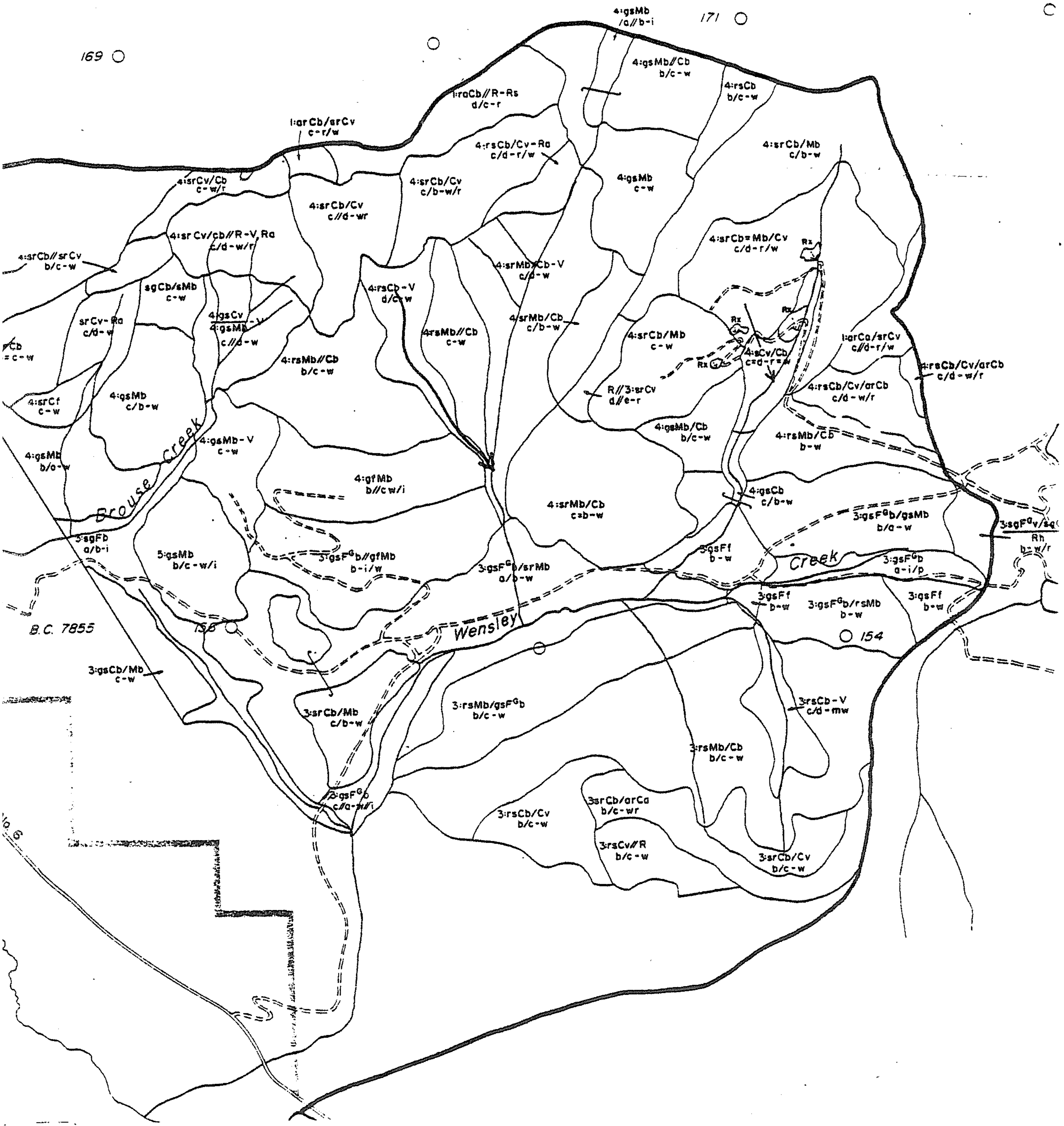


Figure 2 Sample Canada Land Inventory Soil Map

Scale 1:50,000

1 cm = 500 meters

Figure 3 Sample of 1:20,000 Scale Terrain Map



5.0 MAP AND INTERPRETATION RELIABILITY, LIMITATIONS AND USE

The appropriate use of the information presented in this report and accompanying maps is contingent upon an understanding of the assumptions and extrapolations that were made in order to produce the final products.

The interpretive maps are derived from the information contained on the terrain map. An error in the terrain mapping may therefore result in an erroneous interpretation.

5.1 TERRAIN MAPPING

Approximately 35% of the map units in the study area were ground checked in the field by pedologists. Map unit boundaries were infrequently ground checked, and thus derived almost entirely by air photo interpretation. Because landscape and vegetation patterns tend to recur within a given locale, it is possible to extrapolate to areas that were not directly observed, based on field data and air photo reconnaissance. There is therefore, some opportunity for error, both in characterising the terrain units and in locating their boundaries. These errors are significant only when they change the interpretation of the map unit in question (e.g., identifying an area as low hazard when it may be moderate).

Map units should never be construed as "pure" and/or perfectly characterised. Mapped terrain units may contain up to 35% of unidentified constituents, providing such "inclusions" do not change the interpretation for the unit. Terrain units may also include up to 15% of other constituents that may change the interpretation for the unit. For example, a terrain unit interpreted to have a low mass movement hazard, might contain up to 15% of steeper sloped areas which would have a higher (e.g., moderate) hazard rating.

Map reliability is defined by the "survey intensity level" (SIL) concept. The survey intensity level relates closely to the level of generalization of map units, and hence the nature of map units and inclusions. Figures 2 and 3 are examples of how the survey intensity level affects the resulting map. Figure 2 is extracted from the manuscript Canada Land Inventory (CLI) map for the study area. The CLI was conducted at an SIL 4. It partitions the study area into about six landscape units. Figure 3 is extracted from the current survey map. Units on this map are smaller in actual area, although they may appear as large or larger than those on the CLI map because the scale is larger (i.e., 1:20,000 vs. 1:50,000).

The current survey was conducted at SIL 3 and partitions the study area into about 80 landscape units. The level of detail is considerably greater in this survey than in the CLI survey. Many of the units mapped in this survey would be considered "inclusions" of larger units in the CLI survey.

5.2 INTERPRETATIONS

The interpretations in this report pertain exclusively to sediment yield and mass movement hazards. They have been formulated on the basis of the information collected at SIL 3. They are useful for local planning purposes, but ground checking is necessary prior to operational application in order to verify the terrain mapping and to identify uncharacterized inclusions in the mapped polygons (Section 5.1). This latter concern is particularly relevant in respect of "limiting inclusions". Interpretations for units that were ground checked in the course of this most recent survey are more reliable than those for units that were not.

The criteria used for deriving the interpretations for mass movement hazard and sediment delivery hazard are shown in Appendix 1.

5.3 TERRAIN MAP AND INTERPRETATION USE

It is important to note that this report and maps are not adequate for operational work. An operational map would be one produced on the basis of an SIL 1. However, mapping the whole study area at an operational scale is not advised, because it would be expensive and unnecessary. An optimal allocation of resources can be achieved by utilizing the results of this current survey to delineate areas of critical concern in which future investigation should be concentrated, should this be necessary.

6.0 HAZARD CLASSIFICATION

6.1 MASS MOVEMENT HAZARD CLASSIFICATION

Mass movement hazard in the Wensley Creek watershed area is rated on the basis of four qualitative classes. The four classes identify mass movement hazard and prescribe an operability constraint to the landscape unit (see Table 1). This interpretation evaluates the potential for a mass movement event to occur, but it does not estimate the potential impact of such an event. The model used to derive these classes is outlined in Appendix 1.

Map symbols designate a hazard class for each landscape unit and also provide supplementary information related to the nature and magnitude of hazard (see Map 3).

ASSUMPTIONS

This interpretation applies exclusively to mass movements of the debris avalanche-debris flow type. These are rapid, shallow (less than 3 m deep), hillslope failures, generally occurring in noncohesive soils. All soils in the Wensley Creek study area are noncohesive.

TABLE 1 MASS MOVEMENT HAZARD CLASSES

Hazard Class	Description	Recommendation
LOW	- Landscape units that are predominantly stable. - No instability limitations to clearcut harvesting or road construction.	- Conventional ground systems are appropriate for harvesting these units.
MODERATE	- Landscape units which are predominantly stable, but which may contain some (i.e., 15%) less stable areas. - The potential for induced instability exists on units of this hazard class, particularily on slopes greater than 60% or sites which are moderately well drained or wetter.	- Cable systems are recommended for harvesting these units, although ground systems which minimize soil disturbance may be appropriate in some cases. An on-site inspection will be required to make this determination.
HIGH	- Landscape units that are extremely sensitive to slope disturbance by road construction and harvesting activities, and which may contain some (i.e., 15%) of inoperable Extreme Hazard areas. - A high potential for induced instability exists.	- Cable systems are required for harvesting these units. - Logging systems must be critically evaluated on a site specific basis to assess their potential for induced slope instability in the unit and in adjacent units of higher instability. - Road development should be mininized in these units. Road location will require severe construction constraints. - Planning in these areas will require consultation with a soils-engineering specialist.
EXTREME	- Landscape units that show clear evidence of recent and recurrent mass movement activity throughout the unit; and landscape units which occur on extremely steep (>90%) slopes.	- In general mass movement hazard precludes timber harvesting and road developement. - Small inclusions of operable areas within these units may be determined through a site specific investigation by a qualified soils-engineering specialist.

6.2 SEDIMENT YIELD HAZARD CLASSIFICATION

Sediment yield hazard in the Wensley Creek watershed area is rated on the basis of four qualitative classes. The four classes identify sediment yield hazard and prescribe an operability constraint to the landscape unit (see Table 2). This interpretation evaluates the potential for sediment input into stream channels, it does not estimate the impact of sediment on water quality. The model used to derive these classes is outlined in Appendix 1.

Map symbols designate a hazard class for each landscape unit and also provide supplementary information related to the nature and magnitude of hazards (see Map 4).

ASSUMPTIONS

This interpretation assumes that the major sediment sources on forest land, not including sediment derived from mass movements, arise from haul road, landing, yarding road and skid trail surfaces, sidecast and cutbanks. Exposed mineral soil at these points is assumed to comprise less than 15% of the area of the map unit. Removal of vegetation, slash cover and/or humus layers from other points in cut-over areas will increase the hazard. Surface erosion on forest land depends primarily on the extent and continuity of exposed mineral soil surfaces, and the disruption of natural drainage channels. Sediment delivery hazard is assumed to relate directly to distance from the stream channel. This is a simplification of a complex process which is difficult to predict under conditions of channelized flow, (i.e., flow directed into ditches, along road surfaces, etc.).

TABLE 2 SEDIMENT YIELD HAZARD CLASSES

Hazard Class	Description	Recommendation
LOW	- Landscape units which have no to slight sediment yield potential. - No limitations to clearcut harvesting or road construction.	- Conventional ground systems are appropriate for harvesting these units. Cable systems or ground systems which minimize soil disturbance are desirable on slopes greater than 50%
MODERATE	- Landscape units which have moderate sediment yield potential. These units may have a HIGH surface erosion potential, but a location which mitigates potential stream sedimentation. Alternatively, the unit may be located in proximity to a stream channel, but the surface erosion hazard is LOW.	- Conventional ground systems are appropriate for harvesting these units, however, cable systems or ground systems which minimize soil disturbance may be desirable in some circumstances, in particular, all sites with a high sediment delivery potential, and sites with slopes greater than 50%. - Special consideration should be given to road location and maintenance in these units.
HIGH	- Landscape units which have a high sediment yield potential. These units may have an EXTREME surface erosion potential, but a location which mitigates potential stream sedimentation. Alternatively the unit may be located in proximity to a stream channel, but the surface erosion hazard is HIGH. - A high potential for stream sedimentation exists.	- Cable systems or ground systems which minimize soil disturbance are required for harvesting these units. Inclusions of moderate hazard areas may be identified through a site specific investigation. Consultation with a soils-engineering specialist may be desirable. - Development activity should be limited to the dry season or on a suitable snowpack. - Road development should be minimized in these units. Road location and drainage control will require critical evaluation and may require special engineering practices.
EXTREME	- Landscape units which have an extremely high sediment yield potential. These units have an EXTREME surface erosion potential, and are located in close proximity to stream channels.	- Sediment yield hazard will, in general, preclude operation in these units. Inclusions of operable areas may be identified through a site specific investigation carried out by a qualified soils-engineering specialist.

Appendix 1

RATIONALE USED FOR DEFINING MASS MOVEMENT AND SEDIMENT YIELD HAZARDS

1.0 MASS MOVEMENT HAZARD MODEL

The determination of mass movement hazard is a two step process which considers primary and secondary factors influencing the interpretation. An outline of all the factors influencing mass movement hazard is shown in Table 3. This table presents the interpretive model in an idealized form, showing each factor varying along a continuum from low to high. Specific class limits for each of the primary factors are defined in Table 4.

The procedure for determining mass movement hazard is as follows:

1. Make a preliminary determination of hazard class by considering the factors of primary importance as shown in Table 4*. The final hazard rating will not be less than the preliminary hazard classification.
2. Consider the factors of secondary importance outlined in Table 3 and increase the hazard rating if necessary. This will require a subjective evaluation of the relative importance of each factor on a site specific basis.

*All soils in the Wensley Creek study area are non-cohesive, therefore only a single rating table for non-cohesive soils is presented.

TABLE 3 MASS MOVEMENT EVALUATION TABLE

FACTOR	MASS MOVEMENT HAZARD LOW 1	2	3	HIGH 4
Primary Factors				
1. Evidence of recent and recurring mass movement	no →			yes
2. Slope steepeness (%)	0-30 →	30-70 →		70+
3. Soil drainage	rapid →	mod. well →		very poor
4. Depth to an impervious layer	>1 m →			<1 m
5. Soil texture	coarse textured, non-cohesive →			fine textured, cohesive[1]
Secondary Factors				
6. Coarse fragment (%)	100 →	50 →		0
7. Bedrock structure	massive, or bedding plane oriented perpendicular to the slope →			highly fractured, or bedding planes oriented parallel to the slope
8. Slope uniformity	short slopes, broken by benches, ridges, or large hummocks →			long, uniform slopes
9. Genetic material	well consolidated fine textured till →			permeable, coarse textured colluvium and glacio-fluvial material

[1]Cohesiveness relates to the clay content of the soil. Cohesive soils can be inferred from CSSC textures (see Figure 4) as follows:
cohesive: SCL, SiCL, CL, SiC, C, SC, HC
noncohesive: Si, SiL, L, SL, LS, S

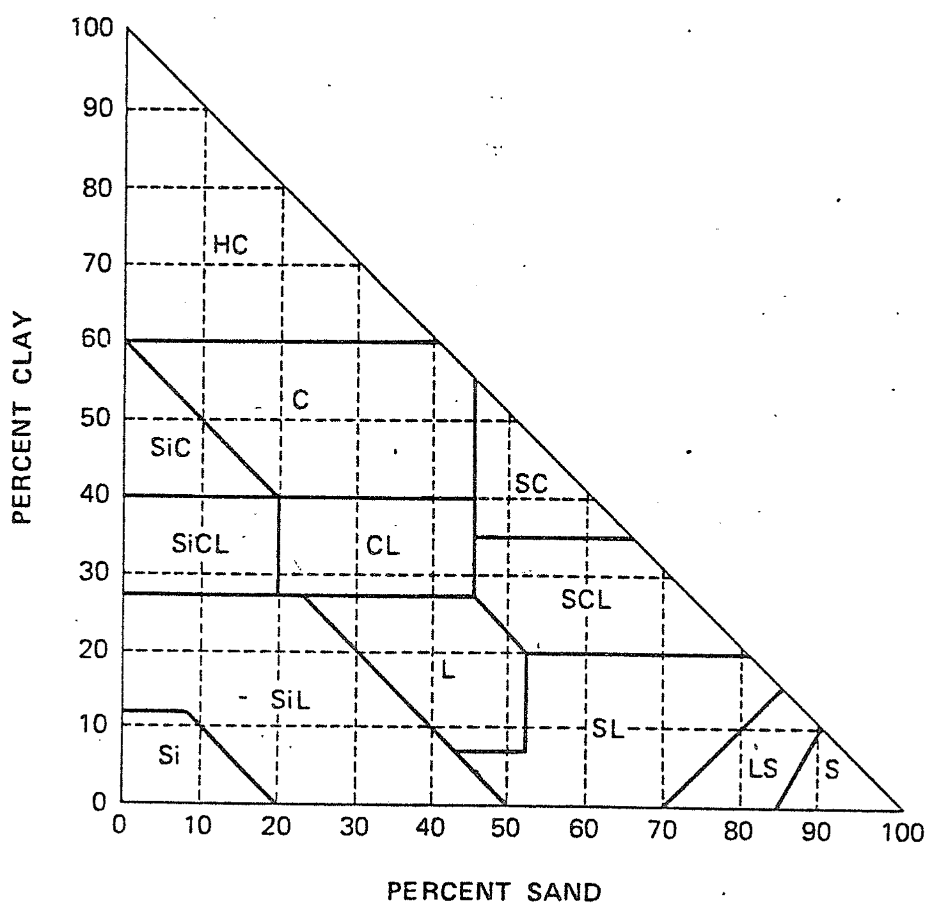
TABLE 4

PRELIMINARY MASS MOVEMENT HAZARD RATING FOR NON-COHESIVE SOILS

Evidence of Recent and Recurring Mass Movement	Slope %	Soil Drainage Class[1]	Depth to an Impervious Layer	Preliminary Hazard Class
Yes	All	All	All	E
No	0-30	All	All	L
	31-50	r,w	All	L
		mw,i	> 1 m	L
			< 1 m	M
		p,vp	All	M
	51-70	r,w	All	M
		mw,i	> 1 m	M
			< 1 m	H
		p,vp	All	H
	71-90	r,w	All	H
		mw,i	> 1 m	H
			< 1 m	E
		p,vp	All	E
	91 +	All	All	E

1 r = rapidly, w = well, mw = moderately well, i = imperfectly, p = poorly vp = very poorly (See Terrain map legend for a definition of classes.)

Figure 4 Soil Textural Triangle



Appendix 2

2.0 SEDIMENT YIELD HAZARD MODEL

The determination of Sediment Yield Hazard is a three step process based on an assessment of the surface erosion hazard and the sediment delivery potential of the site:

1. determine the sediment delivery potential using Table 5.
2. determine the surface erosion hazard using Table 6.
3. derive the sediment yield hazard from Table 7 by considering both the sediment delivery and surface erosion hazards.

TABLE 5

SEDIMENT DELIVERY POTENTIAL[1]

Distance from a Perennial Stream (metres)	Steepness of the Slope Seperating the Unit from the Stream Channel	Sediment Delivery Hazard
0-200[2]	ALL SLOPES	H
200-400[2]	31+%	H
	0 - 30%	M
400-800	31+%	M
	0 - 30%	L
800[2]	ALL SLOPES	L

[1]Adapted from Utzig, Wells and Warner (1983)

[2]Assumes that greater than 30% of the map unit is at this distance from a perennial stream, otherwise use the most dominant slope distance.

[3]Assumes that 100% of the map unit is greater than 800 m from the stream, otherwise use the 400-800 m slope distance class.

TABLE 6

SURFACE EROSION HAZARD[1]

Soil Texture[2]	Coarse Fragment %	Slope %	Soil Drainage: rapid, well	Soil Drainage: moderate, imperfect	Soil Drainage: poor, very poor
1. All	76+	all	L	L	L
HC,SC,C,SCL	51+	all	L	L	L
2. HC,SC,C,SCL	0-50	0-30	L	M	M
		31-50	L	M	M
		51-70	M	H	H
		71+	M	H	H
3. SiCL,CL,SiC, SL,LS,S,L	36-75	0-30	L	M	M
		31-50	M	M	H
		51-70	H	H	E
		71+	H	E	E
4. SiCL,CL,SiC,SL, LS,S,L	0-35	0-30	M	H	H
		31-50	H	H	E
		51+	H	E	E
Si, SiL	36-75	0-30	M	H	H
		31-50	H	H	E
		51+	H	E	E
5. Si, SiL	0-35	0-15	M	H	H
		16-30	H	E	E
		31-50	E	E	E
		51+	E	E	E

[1]based on properties of the surface soil (0-50 cm) texture, assuming that exposed mineral soil is limited to road, landing and skid trail surfaces, sidecast and cutbanks. Removal of vegetation, slash cover and/or humus layers will increase the hazard.

[2]CSSC textures are assumed (see Figure 4). For the purpose of classifying soil texture for this interpretation, very fine sand should be considered as silt. Particle size analysis data is recommended for making this determination.

TABLE 7

SEDIMENT YIELD HAZARD

Sediment Delivery Potential	Surface Erosion Hazard	Sediment Yield Hazard
L	ALL CLASSES	LOW
M	L,M	LOW
	H	MODERATE
	E	HIGH
H	L,M	MODERATE
	H	HIGH
	E	EXTREME

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WENSLEY CREEK: MASS MOVEMENT HAZARD MAP
(1:20,000)

WENSLEY CREEK: SEDIMENT YIELD HAZARD MAP
(1:20,000)

WENSLEY CREEK: TERRAIN MAP (1:20,000)