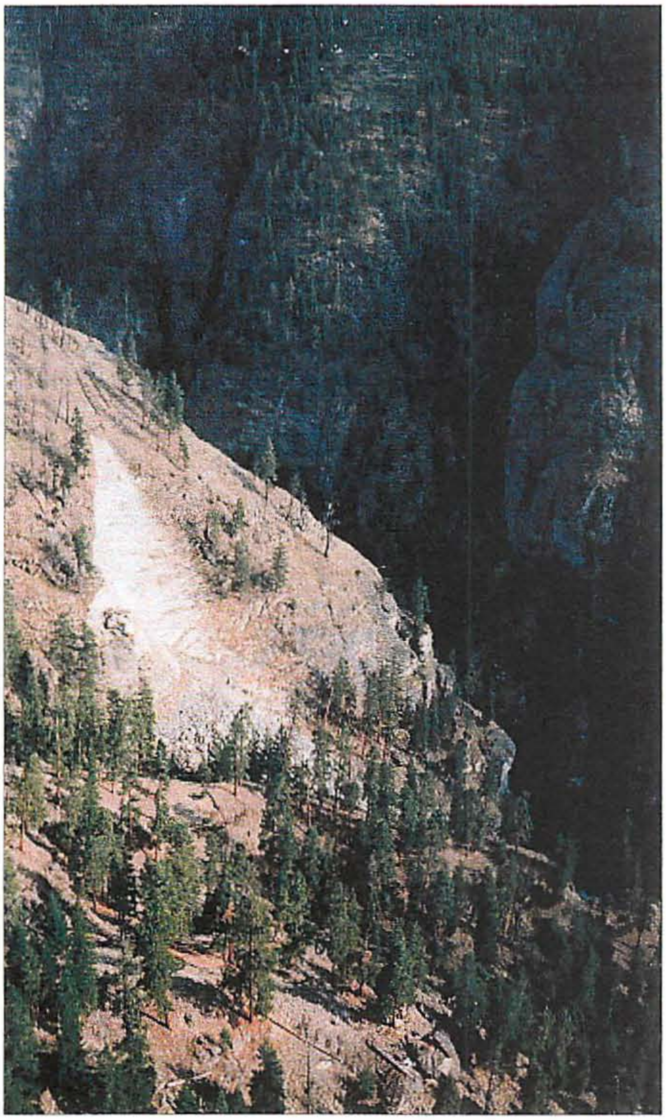

Detailed Terrain Stability Mapping In the Ellis Creek Community Watershed and the Steward Creek Watershed, Penticton Forest District, BC

Prepared for:
Ministry of Forests
Penticton Forest District
Small Business Forest Enterprise Program
102 Industrial Place
Penticton, BC
V2A 7G8

Prepared by:
Pottinger Gaherty Environmental Consultants Ltd.
#1200 1185 West Georgia Street
Vancouver, BC
V6E 4E6

PGL File #648-02.01

November 2000

Pottinger Gaherty
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ACKNOWLEDGEMENTS

The following people have contributed to the completion of this project:

- Ray Crampton, R.P.F., Penticton Forest District, SBFEP Planning Forester, was the Contract Officer.
- Tim Giles, P.Geo., Kamloops Forest District, Regional Geomorphologist, provided expert technical review.
- Fieldwork, photo interpretation, report preparation and QA/QC were conducted by Dave Tupper, Barbara Slezak and Susan Wilkins, of Pottinger Gaherty Environmental Consultants Ltd (PGL).
- Daria Dubé, M.Sc., an independent consulting geologist from Naramata, BC, provided field assistance.
- Map construction involved the efforts of Ian Blandford from PGL, with support from Andrew Neale of Digital Mapping in Victoria.

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1.0 Introduction

Small forestry operations within the Ellis Creek and Steward Creek watersheds are contracted by the Penticton Forest District Small Business Forest Enterprise Program (SBFEP). Regulations under the Forest Practices Code of BC (FPC) encourage operators to conduct terrain mapping and terrain stability hazard assessments within their harvest areas to avoid potential erosion problems that might arise as a result of forest operations. This detailed terrain stability mapping project of the Ellis Creek and Steward Creek watershed areas was completed for the Penticton Forest District SBFEP at Terrain Survey Intensity Level C (TSIL C). The project was completed to provincial Resources Inventory Committee (RIC) standards. Field work, air photo interpretation and map production were conducted by Pottinger Gaherty Environmental Consultants Ltd. (PGL).

Users of this report/these maps unfamiliar with terrain maps may wish to consult Terrain Information: A User's Guide to Terrain Maps in BC (Ryder & Howes, 1986).

2.0 Objectives

The objectives of this project were to:

1. Produce 1:20,000 scale maps that present detailed terrain, terrain stability, likelihood of landslide-induced debris entering streams, soil erosion potential, and sediment delivery potential of the Ellis Creek and Steward Creek watersheds based on roughly 1:15,000 scale photos;
2. Carry out field checking at TSIL C over the entire study area; and
3. Prepare a report that describes how the maps were made, surficial materials present, physiography of the area, and terrain hazards present, with recommendations regarding forest harvesting and land management.

3.0 Previous Work

Regional surficial geological mapping to date has been limited to the Okanagan Valley (Nasmith, 1962). Terrain stability mapping has been conducted on the adjoining Penticton Creek (Agra, 1998) and Shuttleworth and Vaseaux Creek (Maynard, 1999) watersheds for the Okanagan Falls Unit of Weyerhaeuser Canada Ltd.

Soils mapping of the region is limited to the production of a series of 1:125,000 land capability maps compiled by the Soil Research Institute of Agriculture Canada, Canada Department of Agriculture. 082E/SW and 082E/NW, 1980).

Bedrock geology has been most recently compiled for the area at a scale of 1:250,000 by the Geological Survey of Canada (Tempelman-Kluit, 1989).

4.0 Description of the Area

The study area includes two adjacent watersheds, Ellis Creek and Steward Creek, located east of Penticton, BC and the Okanagan Valley (Figures 1 and 2). The study area is roughly triangular in shape occupying a total area of 16,170ha. Five small parcels of private land totalling 480ha have been excluded from within the perimeter of the study area. The study area appears on 1:50,000 scale NTS maps 082E/6 and 082E/11, and covers portions of the following six 1:20,000 scale TRIM maps:

TRIM 082E.033	TRIM 082E.034
TRIM 082E.043	TRIM 082E.044
TRIM 082E.053	TRIM 082E.054

Ellis and Steward Creeks are tributaries of Okanagan Lake within the Okanagan River watershed. The entire Ellis Creek watershed, from 540m above sea level (a.s.l.), is a community watershed, inclusive of the North Ellis Creek and South Ellis Creek tributaries and the Ellis Creek penstock. The watershed is bound by the height of land that separates it from the Penticton Creek and Shuttleworth Creek watersheds to the north and south respectively. The east boundary is coincident with the divide between the Okanagan River and Kettle River watersheds. Steward Creek is a tributary of the Penticton Creek community watershed. It borders Ellis Creek to the northwest and occupies less than 1,500ha of the total study area.

The Ellis Creek and Penticton Creek community watersheds supply irrigation water to the orchard farmers in the Okanagan Valley area below. The Ellis Creek watershed is used as summer range for cattle and does not provide a potable water supply. Recreational use of the study area is fairly high. The Forest Service manages a number of recreational areas including the lookout and trails located at the Garnet Fire Interpretive Site and a camp area located at roughly 4km on the Beaverdell Road. The Carmi cross-country ski area is a cooperative project between the Penticton Outdoors Club and the Forest Service. The study area is used by hikers, mountain bikers, rock climbers,

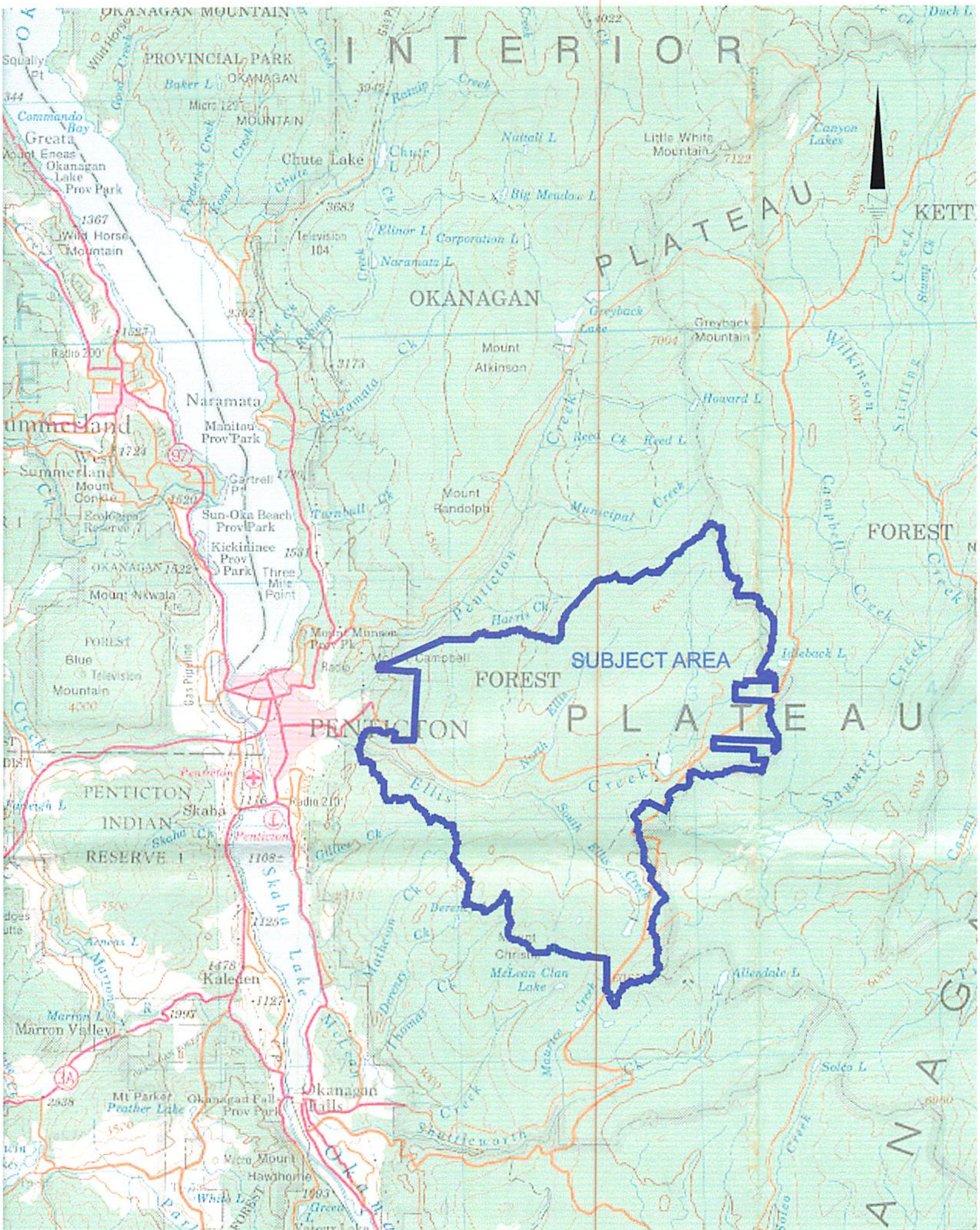

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Figure 1	
Location of the Ellis Creek Area in British Columbia	
Penticton Forest District	
648-02.01	November 2000

Pottinger Gaherty

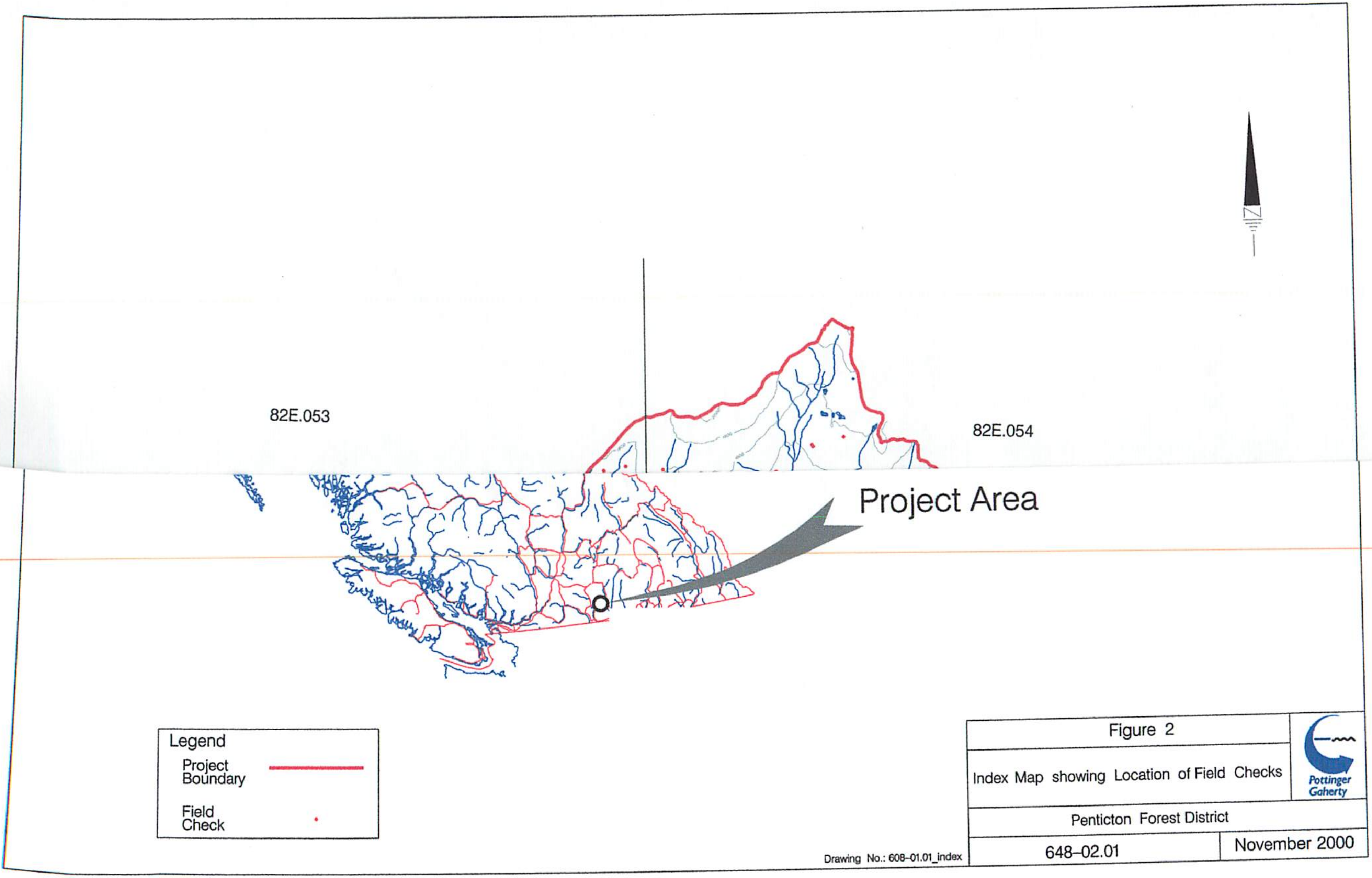

Figure 2

Index Map showing Location of Field Checks

Penticton Forest District

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cross-country skiers, 4x4 and all-terrain vehicle (ATV) enthusiasts and hunters. A bog located on a parcel of private land within the study area is actively being used for commercial peat production. The area is also used for target shooting and the illegal dumping of garbage.

Access to the study area is from the Beaverdell Public Road (locally known as the Carmi Road) which follows the main stem of Ellis Creek and bisects the study area into north and south portions of roughly equal size (Figure 1). The Beaverdell Road originates 6.3km east off Carmi Avenue from Main Street in central Penticton. The Ellis Creek study area boundary begins at 2.4km on the Beaverdell Road where it changes from pavement to gravel. The Beaverdell Road extends roughly 15km east-west across the full width of the study area to 36km on the Okanagan Falls (201) Forest Service Road (FSR). The 201 FSR runs from the south to the north, entering and leaving the study area at 24.4km and 40km respectively. Access to the study area is also possible via the 201 FSR from Okanagan Falls to the south or Highway 33 to the north. Approximately 60% - 70% of the study area is accessible by two wheel drive vehicles through a network of well-maintained gravel FSRs.

In 1996, the Garnet Fire swept over the west part of the study area, killing many of the trees. The point of origin was in the canyon, just inside the study area boundary.

4.1 Physiography

The study area is within the Okanagan Highlands subdivision of the Interior Plateau physiographic region (Figure 1; Photo 1). Elevations extend from 540m a.s.l. where Ellis Creek crosses the study area boundary to roughly 2,000m a.s.l. in both the north and south. The largely bedrock controlled topography can be divided into two general areas: the fluvial/glaciofluvial channel through Ellis Canyon along the lower sections of Ellis Creek and North Ellis Creek and the rolling highlands and glacially rounded mountains and ridges to the east and to the north and south respectively.

The upper edges of the Ellis Canyon ranges in elevation between 850m and 1200m a.s.l. and is in part defined by the forestry operability boundary (1999-2004 Forest Development Plan, Ministry of Forests). For this report the canyon area is defined as follows.

Along the north:

- Below 1,200m a.s.l. from the Ellis Canyon FSR bridge on Ellis Creek to North Ellis Creek, and;
- Below the Beaverdell Road from North Ellis Creek to the west boundary of the study area.

Along the south:

- Below the Ellis Canyon FSR from the bridge over Ellis Creek to opposite from the mouth of North Ellis Creek;
- Below 1,100m a.s.l. from the mouth of North Ellis Creek to opposite from the Ellis Canyon Lookout, and;
- Below 900m a.s.l. from opposite the Lookout to the west boundary of the study area.

Ellis Canyon is a steep, stream-cut bedrock channel ranging between 100 and 300 metres deep (Photo 2). Surficial deposits within the canyon are limited. In the lower sections, bedrock failures and minor rock fall contribute to cones of colluvium that are generally localized within gullies. Surficial deposits are more abundant in the upper sections of the canyon where paleo-channel sediments have been preserved under a compact veneer of moraine. Glaciofluvial terraces are common along the upper edges of the canyon.

Gently sloping topography of largely glacial origin exists over much of the study area between the elevations of 1,200m and 1,600m a.s.l. (Photo 1). The largest portion of this highland is situated between the main stem of Ellis Creek and South Ellis Creek. It is characterized by variably thick glaciolacustrine and till deposits surrounded at higher elevations by thick accumulations of glaciofluvial sands. In the northwest of the study area, the highland is strongly bedrock controlled, with rock drumlins locally evident on the surrounding ridges. A peat bog large enough to support commercial production occurs at the headwaters of Steward Creek, where a mantle of till and local glaciofluvial terraces even out the underlying bedrock topography.

The surrounding mountains and ridges follow a predominantly northeast orientation (azimuth 030°) throughout the study area. Elevations range from below 1,000m to 1,950m on Mount Christie to the south and 2,010m a.s.l. on an unnamed peak to the north. Bedrock exposures vary from less than 5% on the north slopes of Mount Christie to over 70% in the west part of the study area. The majority of the surficial deposits are moraine, although glaciofluvial terraces are common throughout.

Significant permanent stream channels within the study area are limited to Ellis Creek, North Ellis Creek and South Ellis Creek. The greatest flows are contributed from South Ellis Creek. Most of the secondary channels are ephemeral, including Steward Creek. Surface flows are likely limited in the area because of the low annual rates of precipitation and the generally high permeability of the soils. The Ellis, North Ellis and South Ellis Creeks below 1,500m a.s.l. are classified as fish streams on the 1999-2004 Forest Development Plan map for the area (Ministry of Forests).

4.2 Climate

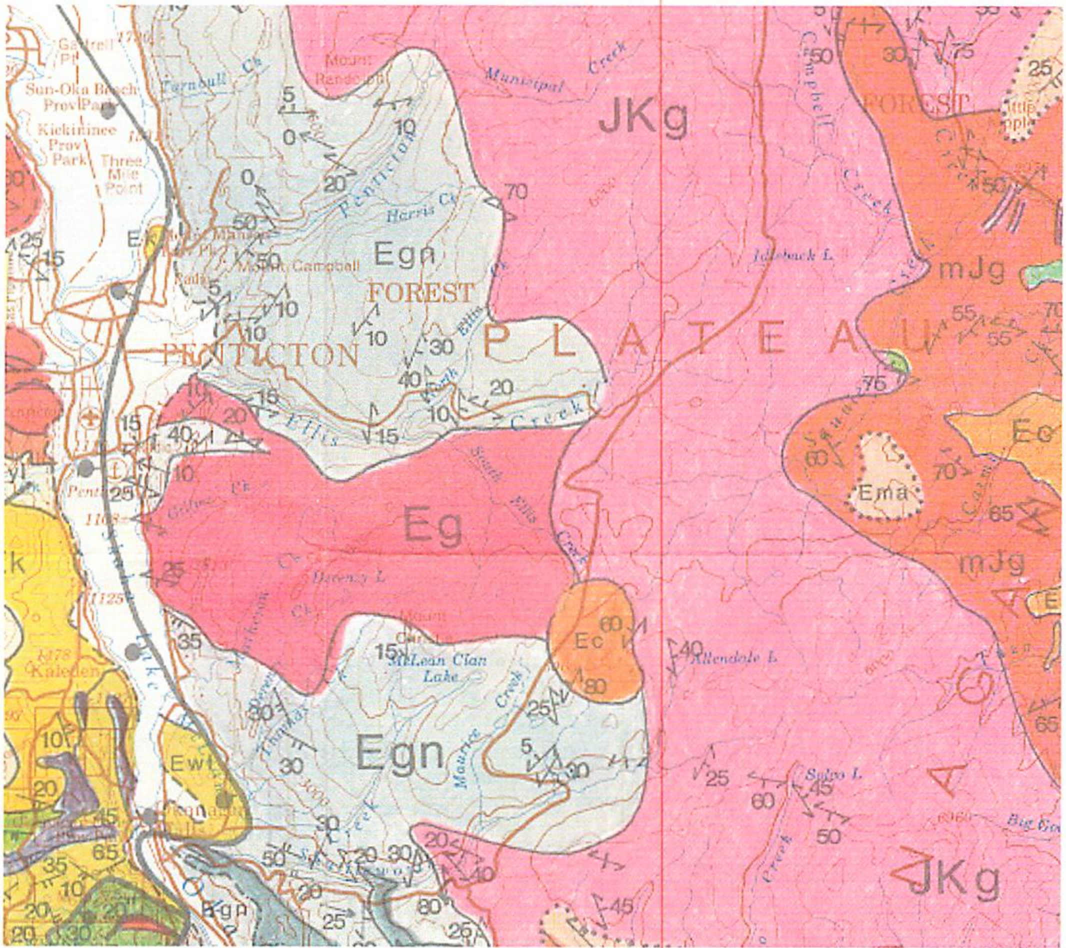
Light precipitation and a high frequency of clear skies characterize the relatively dry climate of the Okanagan region. Precipitation in the Okanagan Highlands is in the range of 30-50cm annually, greater than 50% of which accumulates in the winter months as snow. Run-off is greatest in April through June when the snowpack melts. Snow accumulations, and subsequently runoffs and retained groundwater, are expected to be greater on the slopes with north aspects.

The study area extends with elevation up through three biogeoclimatic zones, from the ponderosa pine (pp) zone at the extreme lower elevations and the montane spruce (MS) zone at the higher elevations. The majority of the area falls within the interior Douglas-fir (iDf) biogeoclimatic zone. Forest cover consists predominantly of lodgepole pine with isolated pockets of mature interior Douglas-fir scattered throughout. Larch is also common in the east part of the study area. Ponderosa pine occurs at lower elevations. Alder is coincident with groundwater seeps throughout the area and black cottonwood was observed along the banks of South Ellis Creek.

4.3 Bedrock Geology

Bedrock geology of the study area has been mapped and described by the Geological Survey of Canada (Templeman-Kluit, 1989), as provided in Figure 3. The entire area is underlain by highly weather-resistant complex of granitoid intrusives or their sheared, metamorphic equivalents.

The east and north boundary areas are underlain by medium to coarse grained biotite granodiorite and granite of the Cretaceous and/or Jurassic Okanagan Batholith. Grading eastward into this is the Okanagan Gneiss, a massive, resistant hornblende-biotite granodiorite orthogneiss. The gneiss is considered the Eocene sheared and thermally overprinted equivalent of the



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EOCENE

Ec	*CORYELL SYENITE: alkalic to calc-alkalic, high level, pink and buff syenite and quartz monzonite and trachytic pink feldspar porphyry dykes: plutonic equivalent of the Marron Group especially the Kitley Lake Formation: gradational to pulaskite and to Shingle Creek Porphyry: probably includes JKg undifferentiated in East half of map area: poorly dated*
Egn	*"OKANAGAN GNEISS": massive, medium grey weathering, resistant hornblende-biotite granodiorite orthogneiss: strongly foliated: grades to mylonitic gneiss, mylonite and blastomylonite: minor amphibolite and paragneiss- minor schist: minor pegmatite and aplite: strongly chloritized along Okanagan Fault: grades eastward (and up the structural succession) to JKg, mJg and Pm units of which it is presumed as to the sheared equivalent: probably also includes sheared equivalents of the Anarchist Group: presumed sheared and thermally overprinted during the Eocene: Egn1 - quartz chlorite microbreccia and related altered rocks close to the Okanagan Fault*
Eg	*Hornblende granodiorite: massive, resistant, grey weathering, coarse grained, equigranular mesocratic with euhedral fresh black hornblende crystals; locally weakly foliated: age poorly constrained*

CRETACEOUS AND/OR JURASSIC

JKg	*OKANAGAN BATHOLITH: massive, light grey weathering, medium- to coarse-grained, equigranular to porphyritic, unfoliated to weakly foliated, fresh biotite granodiorite and granite: includes undifferentiated granodiorite of the Nelson suite: age poorly constrained*

SOURCE Geological Survey of Canada - MAP1736A

Figure 3	
Bedrock Geology Ellis Creek, Penticton, BC	
Penticton Forest District	Pottinger Gaherty
648-02.01	November 2000

Okanagan Batholith and underlies the northwestern half of the study area. The south portion of the study area is underlain by a hornblende granodiorite of likely Eocene age. A small oval stock of Eocene syenite to monzonite, referred to as Coryell Syenite, occurs at the far southeast corner of the study area. Occurrences of copper mineralization are associated with this stock.

The massive, resistant and coarse crystalline nature of the bedrock in the area is reflected in the generally coarse granular texture of the glacial materials encountered. Tills are typically composed of 20-30% coarse sand. Deposits of well sorted glaciolacustrine silt and fine sand are uncommon, and generally confined to lower elevation depressions and channels.

4.4 Geomorphic History

The geomorphic history of the Okanagan begins with the uplift of the Interior Plateau during late Cretaceous to early Tertiary time. Eocene volcanic rocks were also deposited over much of the region. From this time to the late Tertiary, a period of tectonic stability and ongoing erosion and deposition helped form a landscape of low relief. Deeply incised stream channels, similar to Ellis Canyon, were formed in many of the drainages in the region with a late Tertiary uplift. This same orogenic event formed the present day Okanagan Highland.

The majority of surficial material in the study area resulted from the advance and retreat of the last major glaciation, the Wisconsin. At its maximum roughly 15,000 years ago, piedmont glaciers had coalesced into the southeasterly-flowing Cordilleran Ice Sheet, overriding even the highest peaks in the area. A mantle of lodgement till was deposited at the base of the ice flow, covering the underlying topography and infilling depressions and valleys. In many areas of positive relief, sub-glacial erosion scoured the bedrock bare.

Retreat of the ice sheet began with stagnation and retreat of the ice front and down-melting of the ice surface. This probably resulted in the down-wasting of the ice occupying the highlands into stagnant discontinuous patches and the separation of the ice mass into larger valley glaciers occupying the Okanagan and Kettle valleys (Nasmith, 1962). In-situ melting resulted in the deposition of localized areas of ablation till. Meltwater from the retreating ice eroded the surficial and bedrock surface, collecting along temporary and pre-glacial drainages. The meltwater transported, deposited, re-transported and re-deposited again, large volumes of sediment. Large meltwater channels formed along the upper section of Ellis Creek and North Ellis Creek and the middle to lower sections of South Ellis Creek. Glaciofluvial deposits include kames, small tributary fan terraces and meltwater channel sediments. Lakes and ponds were temporarily impounded behind the retreating ice, forming localized, layered glaciolacustrine deposits of fine sand and silt. Elevated beach terraces of sand and gravel mark the descending lake levels. Erosion of the unvegetated land surface would have been most severe during the deglaciation process. The huge volumes of meltwater channelled into Ellis Canyon resulted in its further deepening and scouring.

Post-glacial surficial deposits are generally limited to fluvial and colluvial materials. They are less abundant in the area because of the generally shallow relief of the highlands, the competency of the bedrock, the low precipitation levels of the region and the generally rapid drainage of the soils. Fluvial deposits include stream terraces and small tributary fans. Colluvium, derived from minor rockfall and failures in both bedrock and surficial deposits, is most common in the steeper canyons and stream gullies.

4.5 Soils

Soil types have not been mapped for the Ellis Creek or Steward Creek watersheds. The soils are generally poorly developed. Gray Luvisols and Dystric Brunisols are likely present, as they are the dominant soils in the Okanagan Highlands (Resource Analysis Branch, 1978). Textures are commonly sandy, with 30%-50% coarse sand present in soils derived from glaciofluvial materials. Soils derived from tills are typically 10%-30% coarse sand and 40%-70% silt. Well sorted finer textures are not common, being limited to deposits of glaciolacustrine sediments which typically occur stratified at the base of coarser glaciofluvial materials. Soil drainage over most of the study area is generally classified as well to rapid. The most common limitation for drainage is shallow or bare rock.

Forest fire damaged the soils on the lower western slopes, burning off much of the humus horizon. The fire does not seem to have otherwise affected the soils or their susceptibility to erosion.

Regional land capability mapping indicates rock and soil moisture deficiency are the most common limitations to productive forestry in the study area (Canada Department of Agriculture. 082E/SW and 082E/NW, 1980).

5.0 Methodology

This terrain mapping project can be considered the first approximation of surficial mapping in the Ellis Creek and Steward Creek watersheds. The work completed was done in accordance with the standards laid out by the RIC in Guidelines and Standards to Terrain Mapping in BC (1996) and the applicable FPC guidebooks, specifically the Mapping and Assessing Terrain Stability Guidebook (MATS, 1999). The mapping was conducted at a Terrain Survey Intensity Level C.

5.1 General Description

Preliminary terrain mapping began with the interpretation of 44 stereo pairs of 1992 aerial photographs (approximate scale 1:15,000). A complete list of the photos used is provided in Appendix 2. The terrain mapping symbols used are in accordance with the BC system of terrain classification (Howes and Kenk, 1997).

Two crews completed field work from August 9 to 15, 2000 (total of 13 person days). Tim Giles, the Regional Geomorphologist, provided expert support in the field on August 11, 2000. Site photographs can be found in Appendix 1 and Field Data Forms can be found in Appendix 3.

Most traverses were vehicle-based. Approximately 60% - 70% of the study area is accessible by two-wheel drive trucks through a network of well maintained gravel FSRs. Access within the north portion of the area is possible on the Beaverdell Road, the Peat Bog Road, numerous secondary forestry roads and the Steward Creek, Ellis Creek, Upper Bobcat, Lower Bobcat and Ellis Carmi FSRs. The south portion of the study area is less developed and road access is restricted mostly to the Ellis Canyon, Derenzy and the 201 FSRs. Foot traverses of less than 2km provided access to most undeveloped and deactivated areas, specifically south of Derenzy Road. The need for ATV and helicopter support is limited, and none was used for this project. The locations of the field inspection sites are shown on Figure 2 and on the 1:20,000 terrain maps.

The entire 16,170ha of the Ellis Creek and Steward Creek watersheds required TSIL C field checking. A total of 706 polygons were mapped. A total of 219 field checks were completed. Two of the checks were outside of the study area and multiple checks were completed in 21 of the polygons, resulting in 184 polygons being field checked. Due to the uniform geomorphology of large areas within the study area, some polygons are large (exceeding 200ha) and were field checked at multiple locations.

The following table shows the breakdown of the field work.

Summary of Field Work

	Total No. of Polygons	No. of Field Checks	No. of Polygons Checked	% of Field Checks to Polygons	% of Polygons Field Checked
TSIL C	706	217	184	30.7%	26.1%
Outside Study Area		2			

After completion of the field work, the mapping on the photos was adjusted and then reviewed by the Regional Geomorphologist, Tim Giles. After completion of the Stage 2 review, the photo mapping was further refined and then digitally transferred to TRIM map format (see Section 5.3 for details).

5.2 Derivatives

Four map derivatives were prepared for the Ellis Creek and Steward Creek watersheds:

- Terrain Stability;
- Likelihood of Landslide-Induced Debris Entering Streams;
- Soil Erosion Potential; and
- Sediment Delivery Potential.

Criteria for the interpretation and rating of each of the map derivatives were prepared based on our experience with similar surficial materials elsewhere in the Interior of BC, and on consultations with the Regional Geomorphologist. Following field work, the criteria were fine-tuned to represent the site-specific conditions observed within the study area. The study area includes portions of five TRIM maps (listed in Section 4). To reduce the number of maps to work with, the study area was divided at a scale of 1:20,000 into area maps representing the north half and the south half. In addition terrain stability interpretations were presented on the terrain map, and landslide debris delivery potential, soil erosion potential and sediment delivery potential were presented on a second map. This makes for a total of four maps. Each of the derivative map interpretations is discussed individually below.

5.2.1 Terrain Stability

For each of the polygons, a stability rating was assigned based on a five-class (I, II, III, IV, V) system adjusted to comply with the dry climatic conditions of the Okanagan region. The criteria developed for terrain stability interpretations in the Ellis Creek and Steward Creek watersheds are provided in Table 1. The criteria are based on slope, texture, drainage, material thickness, and evidence of previous slope failure or problematic terrain (landslide headscarps, debris flow tracks, steep slopes, and gullied terrain). The terrain stability interpretations were done with forest harvesting in mind, although they should also be directly applicable to the needs of recreational and other resource users.

5.2.2 Likelihood of Landslide-Induced Debris Entering Streams

The potential for landslide debris entering a stream is rated on a scale of 1 to 3 for each of the polygons. Table 2 lists the criteria developed for landslide delivery potential interpretations in the study area. The criteria are based on slope, evidence landslide runout zone, presence or absence of gullies and their proximity to streams.

5.2.3 Soil Erosion Potential

For each of the polygons, a soil erosion potential rating was assigned using a five-class system ranging from very low to very high. The criteria developed for soil erosion potential interpretations are provided in Table 3. The criteria are based on slope, texture, drainage, and evidence of problematic terrain (landslide headscarps, debris flow tracks, steep slopes, and gullied terrain).

5.2.4 Sediment Delivery Potential

Polygons were assigned a sediment delivery classification ranging from very low to very high as described in Table 4. The criteria are based on distance between the polygon and an ephemeral or permanent stream, and characteristics of the terrain adjacent to the ephemeral or permanent stream.

TABLE 1
CRITERIA FOR TERRAIN STABILITY INTERPRETATION
Ministry of Forests, Penticton Forest District
PGL File 648-02.01

Dominant Texture	Surficial Material	General Description	TERRAIN STABILITY CLASS*				
			I No significant stability problems exist.	II Very low likelihood of landslides following road building or timber harvesting.	III Minor stability problems can develop. There is a low likelihood of landslide initiation following timber harvesting and road construction.	IV Moderate likelihood of landslide initiation following road building or timber harvesting.	V High likelihood of landslide initiation following road building or timber harvesting.. Failures present. All materials & landforms unstable
z, c, fine s	LG	Fine laminated glaciolacustrine sediments	<15%	20-30%	30-50%	>50% >30 %, L	F"e, L
s, z	LG, FG, E	Glaciolacustrine beach deposits, eolian deposits	<15%	20-30%	30-50%	>50%	F"c, F"u
sgb, sgd, g	C	Colluvium derived from glaciofluvial materials.	<30%	30-40%	40-60%	>60%, R"b Rb	R"b, F"c, F"u, F"e
sgb, sgd, g	FG	Glaciofluvial fans and terraces	<30%	30-40%	40-65%	>65% R"b	R"b, F"c, F"u
ag, bg	FG, FA	Meltwater and active channels	<30%	30-50%	50-70%	>70% R"b	R"b, F"c, F"u
zda, szb, sza, zgb	FG, C	Glaciofluvially reworked moraine, or colluvium derived from moraine.	<30%	30-50%	50-70%	>70%, R"b >30%, L	R"b, F"c, F"u, F"e, L
zda, szb, sza, zgb	M	Moraine	<30%	30-50%	50-70%	>70%, R"b, Fc, V >30%, L	R"b, F"c, F"u, F"e, L
a, b, s, r	Cv	Veneer of blocky colluvium, generally on rock	<30%	30-50%	50-70%	>70%, R"b, Rb	R"b, R"r
a, b, s, g	C, Cc	Blocky colluvium, often in cones	<30%	30-50%	50-70%	>70% Rb	R"b, R"r
bedrock	R	Rock outcrop	<30%	30-50%	50-70%	>70% R"b	R"b, R"r, V

* Based on 1999 MATS Guidebook

TABLE 2
CRITERIA FOR ASSESSING POTENTIAL OF LANDSLIDE-INDUCED DEBRIS ENTERING STREAMS
Ministry of Forests, Penticton Forest District
PGL File #648-02.01

Class	Distance to Stream From Toe of Polygon Slope	Gully Run-out	Landslide Evidence
1	>100m	Terminate in fans short of stream channel.	None in polygon.
2	50-100m	Fans partially truncated by stream.	Limited evidence of debris entering stream.
3	<50m	Gullies terminate directly in stream channel.	Clear evidence of landslides entering stream channel.

TABLE 3
CRITERIA FOR SOIL EROSION POTENTIAL INTERPRETATION
Ministry of Forests, Penticton Forest District
PGL File #648-02.01

Surface Erosion Potential Class	Soil Drainage	Dominant Texture	Surficial Material	General Description	Slope	Geomorphological Process
VL	v-p		Op, Od	Bogs, organic deposits.	0-5%	None
	v-p	bedrock	R	Rock outcrop.	All	None
L	p-m	z, c, fine s	LG	Fine laminated glaciolacustrine sediments.	<20%	None
	w-r	sgb, sgd, g	FG, LG	Glaciofluvial fans and terraces.	<30%	None
	w-r	s, z	LG, FG, E	Glaciolacustrine beach deposits, eolian deposits.	<30%	None
	w	a, b	Cv	Veneer of blocky colluvium, generally on rock.	All	None
	r	a, b	C, Cc	Blocky colluvium, often in cones.	All	None
	m-w	zda, szb, sza, zgb	M, FG, C	Moraine, glaciofluvially reworked moraine, or colluvium derived from moraine.	<30%	None
M	p-m	z, c, fine s	LG	Fine laminated glaciolacustrine sediments.	20 to 50%	None
	w-r	sgb, sgd, g	FG, LG	Glaciofluvial fans and terraces.	30 to 60%	None
	m-w	zda, szb, sza, zgb	M, FG, C	Moraine, glaciofluvially reworked moraine, or colluvium derived from moraine.	30 to 60%	None
	w-r	ag, bg	FG, FA, F	Meltwater and active channels.	>30%	None
H	w-r	s, z	LG, FG	Glaciolacustrine beach deposits.	>30%	None
	w-r	sgb, sgd, g	FG, LG	Glaciofluvial fans and terraces.	>60%	None
	m-w	zda, szb, sza, zgb	M, FG, C	Moraine, glaciofluvially reworked moraine, or colluvium derived from moraine.	>60%	None
VH	p-m	z, c, fine s	LG	Fine laminated glaciolacustrine sediments.	>50%	None
	i-w	zsg	C	Run-out zones below failed slopes of moraine and glaciofluvial deposits.	>20%	-R, -F, -V
	m-w		M, FG, R	Failed slopes.		-R" (except minor rockfall), -F", -P"

TABLE 4
CRITERIA FOR SEDIMENT DELIVERY POTENTIAL INTERPRETATION
Ministry of Forests, Penticton Forest District

Risk of Sediment Delivery to Streams	Proximity of Polygon to Stream Channel						
	Polygon not adjacent to stream channel.	Polygon includes or adjacent to ephemeral or perennial stream channel <1.5m wide, or lake.			Polygon includes or adjacent to perennial stream channel >1.5m wide, or lake.		
		Irregular or Benched Slopes	Uniform Slopes	Gullied Slopes	Irregular or Benched Slopes	Uniform Slopes	Gullied Slopes
vl	Gentle to steep slope (0->70%)	Gentle slope (0-30%)					
l		Moderate slope (30-70%)	Gentle slope (0-30%)		Gentle slope (0-30%)		
m		Steep slope (>70%)	Moderate slope (30-70%)		Moderate slope (30-70%)	Gentle slope (0-30%)	
h			Steep slope (>70%)	Moderate slope (30-70%)	Steep slope (>70%)	Moderate slope (30-70%)	
vh				Steep slope (>70%)		Steep slope (>70%)	Moderate to steep slope (30->70%)

5.3 Methods

Only methods associated with the typed air photo-to-map transfer and the GIS setup for the project are described in this report. GIS treatment of the polygon digital information was conducted in this project according to Resource Inventory Committee (Anon. 1997) standards.

GIS/Digital Mapping for the project consisted of 6 components:

1. Control Transfer
2. Photo Digitization
3. Translate Digital TRIM Data
4. Edit/Link of Polygon Attribute Labels
5. Hard Copy and Digital GIS Outputs
6. Project Management and Quality Control (ongoing)

The GIS technicians were provided with map legends for all terrain codes so they could develop editing checks for photo typing errors and for errors in the transfer of line work and polygon labels from aerial photographs at PGL. Paper copies of maps and the original aerial photographs were sent back to the photo-interpreters for clarification/cleanup as required, and any edits for photo-typing errors/inconsistencies were corrected prior to monorestitution line transfer and database creation.

Transcription errors in both line work and polygon labelling were then dealt with, in a final round of air photo reviews by the photo-interpreters at PGL. The errors encountered were minor and included, duplication of polygon numbers, line work that did not completely close-off polygons (in particular those where the study area boundary marked on the photos differed from the digital map boundary), and labelling errors.

5.4 Reliability of Mapping

The accuracy of the terrain mapping and reliability of map derivatives is dependent on a number of factors including the skill and experience of mappers, scale and quality of air photos used, type and density of vegetation, field access and length of time spent in the field, quality of base maps, type of terrain, and surficial materials present. The most relevant of these factors to this mapping project are discussed below:

1. The surficial materials and pattern of deposition within the area is complex. Particular difficulty arises with the delineation of glaciolacustrine veneers, as these deposits have no distinct visual pattern on air photos. Delineation of the glaciolacustrine boundary was based on the location of beach deposits, ground checks, and the use of elevational data to link these points. Some discrepancies may be noted with further ground-based inspections.

2. The real features of the land surface are always more complex and variable than can be depicted on even the largest scale maps. Although 1:15,000 scale mapping is very precise, local variability in terrain conditions such as drainage, till texture, slope morphology etc., will not be depicted at this mapping scale. Terrain features that do not make up at least 10% of the polygon are not included in the label. For example, in many areas a discontinuous cover of glaciolacustrine deposits over moraine was observed. These variations will create significant localized differences in terrain sensitivity. Detailed planning, i.e., cutblock boundaries and road alignments, will require ground checking, especially in moderate to high hazard areas.

3. Air photo quality for this project was variable. Some photos were very dark and made the delineation of terrain features more difficult. Large landform features (i.e., greater than can be depicted on several photos) are more difficult to detect on these smaller scale photos. Four photos are partially obscured by low level clouds, hindering interpretation in those areas (Line 2, photo 94 and Line 3, photos 74-76).

4. Errors within the TRIM dataset are minimal and for the most part are limited to stream and road classification errors. Some errors in slope classification are also expected. Slopes that are less than 40m in height are not well represented by the 20m contour intervals used.

Field access was a problem in some areas. However, the accuracy of the photo interpretations would not greatly increase as a result of more detailed field inspections.

6.0 Surficial Materials

The following sections provide a brief description of the surficial sediments, followed by a more specific description of the conditions found in the study area.

6.1 Moraine (M)

Morainal deposits, or till, are the material deposited directly by glacial ice. It is typically used to refer to basal till, which consists of ripped up rock and ground rock particles, including clay, silt, and sand, all deposited in a highly consolidated mixture at the base of a glacier. Basal till, forming the majority of the morainal deposits, typically forms smooth, even surfaces, filling in the irregularities of the underlying bedrock or other surficial materials. Ablation till refers to deposits of englacial material deposited from the in-situ wasting of stagnant glacial ice. Ablation till typically forms an undulating and pitted topography composed of loose gravel material, comparable to fluvial deposits.

Basal till is the most widespread surficial material in the study area, however, its abundance varies considerably from locality to locality. It is most abundant as mantles of varying thickness and blankets on the north facing slopes of Mount Christie from just below the rocky ridgelines down to roughly 1,200m a.s.l. (Photo 3), at higher elevations along the north boundary above 1,700m a.s.l., at the headwaters of Steward Creek (Photo 4) and along the east boundary. It also underlies glaciofluvial and glaciolacustrine deposits throughout much of the plateau area east of South Ellis Creek (Photo 5). Small pockets of till occur within depressions between the rock ribs and ridges that dominate the west slopes (Photo 6). A thick veneer of till is exposed in the scarps along the upper sections of Ellis Canyon.

Textures found in the basal till are dominated by a matrix of silt with 10%-50% coarse sand and abundant clasts of sub-angular to sub-rounded pebbles and cobbles of granitoid gneisses and intrusives (Photo 7). Clay is only present in minor proportions.

Large hummocky areas of poorly sorted gravelly sand in the east part of the study area could have possibly been classified as ablation till. They have been mapped, however, as being of glaciofluvial origin based on the presence of abundant meltwater channels and underlying deposits of glaciolacustrine sediments at their lower margins (see Section 6.2 below). The areas in question occur at the headwaters of Ellis Creek between roughly 1,500m and 1,700m a.s.l. and a rise of land along the east boundary, north of South Ellis Creek.

6.2 Glaciofluvial (FG)

Glaciofluvial deposits consist of unconsolidated and poorly bedded sand and gravel materials deposited by glacially fed stream channels. These deposits were found in meltwater channels that formed beneath and around the periphery of the retreating glacier ice sheets.

Glaciofluvial deposits range from large kame terraces at roughly 1,100m on the rim of Ellis Canyon (Photo 1) to more isolated smaller tributary fans at 1,600m a.s.l. (Photo 8). Meltwater channel sediments are abundant above roughly 1,600m a.s.l. on Ellis Creek and North Ellis Creek and above roughly 1,400m a.s.l. on South Ellis Creek. Common textures observed include coarse sand and rounded to sub-rounded gravel, cobbles and boulders. Cobble and boulders are predominantly granitoid in composition. Weak bedding is marked by rare discontinuous beds of silt and fine to coarse sand (Photo 9). Meltwater channels include ridged deposits of sub-angular to sub-rounded boulders (Photo 10). Eskers, the remnants of meltwater streams deposited at the base or within melting glacier ice, are infrequent on the plateau.

A near continuous mantle of glaciofluvial sediments extends across the gentle slopes at the headwaters of Ellis Creek between roughly 1,500m and 1,700m a.s.l. The deposits form a topography that is irregularly ridged and hummocky with abundant sinuous meltwater channels throughout. In the west along the Lower Bobcat FSR, the deposits directly overly bedrock and a thin mantle of till. In the east up the Ellis Carmi FSR, the deposits form a near continuous blanket greater than 2m thick with numerous kettle holes (Photo 11). Textures vary from gravelly-coarse sand to mostly boulders. The lower elevation margins of the deposits are underlain in a number of locations by glaciolacustrine sediments suggesting a glaciofluvial origin.

6.3 Glaciolacustrine (LG)

Glaciolacustrine deposits occur where fine-grained meltwater sediments were deposited in ice-dammed lakes or ponds. Glaciolacustrine deposits typically consist of interlayered fine sand, silt and clay.

Glaciolacustrine deposits have a limited aerial extent in the study area. None were observed more than 500m west of either North Ellis Creek or South Ellis Creek. Small local deposits located at 1,220m a.s.l. on Ellis Creek and 1,240m a.s.l. on North Ellis Creek, likely accumulated in water ponded by late stage stagnant ice. A similar, although slightly larger, glaciolacustrine deposit occurs just west of Ellis Creek at roughly 1,420m a.s.l.

Larger areas of flooding in the area south and north of the Ellis penstock between roughly 1,280m and 1,380m a.s.l. resulted in the deposition of a discontinuous veneer to locally thick blanket of irregularly bedded, silty to fine sandy glaciolacustrine sediments (Photo 12). Of particular note is a deposit of greater than 6m of well-sorted glaciofluvial sand exposed at roughly 11.6km on the Beaverdell Road at 1,320m a.s.l. (Photo 13). The largely quartz sands are crossbedded indicating progradational deposition. The falling level of the ice dammed lake is marked by descending raised beach terraces of well sorted white quartz sand to mixed sandy gravel distributed around the perimeter of the area (Photo 14). Similar glaciolacustrine deposits and raised beaches exist near the headwaters of South Ellis Creek between roughly 1,480m and 1,560m a.s.l.

The variability in the elevations of preserved glaciolacustrine deposits and beach terraces observed in the study area indicate that glacial lake levels fluctuated significantly with the receding valley glaciers. The largest glacial lake formed at an elevation of roughly 1,380m covering most of the highland east of where the Ellis Canyon FSR crosses Ellis Creek.

6.4 Colluvium (C)

Colluvium is the gravity-deposited debris that forms at the base of failing slopes of rock or surficial materials. It varies from fine silt and sand to gravel and boulders, depending on the nature of the source material and the associated processes of mass wastage.

Colluvial deposits are limited in extent within the study area. They are found primarily at the bases of the over-steepened slopes of Ellis Canyon along the lower reaches of Ellis Creek and North Ellis Creek below 1,200m a.s.l. Deposits of sand, gravel and angular boulders form steep cones on the lower slopes and gullies at the base of the rocky cliffs along the lower sections of North Ellis Creek and Ellis Creek. Colluvium from the failure of over-steepened surficial deposits of glacial till and glaciofluvial deposits forms convex fans along Ellis Creek from its confluence with North Ellis Creek (Photo 15). The fans are often truncated by the stream below.

Elsewhere in the study area, colluvial deposits are very localized, generally at the bases of small rock bluffs or glaciofluvial terraces.

6.5 Fluvial Materials (FA, F)

Recent fluvial deposits are most notable where they form the floodplains of the major streams and their larger tributaries in the study area. The fluvial deposits are divided into the deposits of active, or perennial, streams and ephemeral streams.

The only active streams in the study area at the time of the field investigation were the main stems of Ellis Creek, North Ellis Creek and South Ellis Creek (Photo 15). Steward Creek is ephemeral (Photo 16).

All the creek drainages, but specifically the ephemeral streams, are notably lacking in significant amounts of finer sediments. Fluvial deposits are dominated by sub-rounded to angular cobbles and boulders. Sand and gravel occur in small pools scattered along the active streams. The greatest abundance of finer sediments was observed along the upper section of Ellis Canyon where Ellis Creek undercuts steep surficial deposits.

Pre-Wisconsian deposits of coarse gravel to fine laminated silt are preserved at 1,180m a.s.l. under a thick veneer of moraine in the upper section of Ellis Canyon along Ellis Creek (Photo 17). A similar exposure of compact, laminated silt is exposed at the same elevation along the Ellis Canyon FSR roughly 450m west of Ellis Creek (field inspection site DWT-93).

6.6 Eolian Materials (E)

Eolian deposits are minor in the study area. Immediately following deglaciation of the area, the exposed unvegetated surfaces would have been susceptible to wind transport and redeposition. A thin veneer is likely present over much of the plateau area, but does not form a significant, easily recognizable strategraphic horizon. A small number of locations of fine, very well sorted quartz sand were noted that were likely deposited as dunes. The most notable of these occurs where the Beaverdell Road meets the 201 FSR (Photo 18).

6.7 Organic Materials (O)

Wetland areas of less than 8ha (typically less than 2ha) occur scattered throughout the study area, although they are more common on the plateau surrounding the Ellis Penstock and east of South Ellis Creek. They are considered stable and are for the most part flat.

6.8 Bedrock (R)

The percentage of bedrock exposure varies across the study area. Bedrock provides a strong control of many of the landforms, specifically in Ellis Canyon and on the ridges to the west and around the study area perimeter where exposure ranges between 20% and 80%. Surficial deposits obscure a majority of the bedrock geology in the east part of the area. Bedrock landforms vary from gentle rolling ribs to steep, abrupt rock drumlins and steep vertical cliffs over 100m high (Photos 1, 2, 3 and 19), and are composed of either granitoid gneiss or intrusive. The bedrock is highly competent and weather resistant.

6.9 Anthropogenic (A)

Landforms of anthropogenic origin include the 1.5ha earthfill dam at the Ellis penstock. A similar, although smaller, dam exists at the headwaters of South Ellis Creek on one of the private parcels of land excluded from the study area.

Flows from the Ellis penstock have been realigned through a spillway away from its natural channel and into a meltwater channel that formerly held an underfit stream. The result has been the dramatic undercutting of glaciolacustrine and glaciofluvial sediments along sections of the meltwater channel by the increased flows.

7.0 Results and Interpretation

The results and interpretation of our mapping is discussed by physiographic area, the Ellis Canyon and the surrounding highlands, including the mountains and ridges (see Section 4.1 for a more detailed description of the areas). Interpretations are provided for the terrain maps and derivatives: terrain stability, likelihood of landslide-induced debris entering streams, soil erosion potential, and sediment delivery potential.

A number of factors contribute to higher thresholds being used for the derivative criteria presented in this study as compared to those used for other regions of British Columbia. These factors include the dry climate of the

Okanagan region, the generally well draining soils present, the highly competent bedrock and the low relief of much of the Ellis Creek study area.

7.1 Ellis Canyon

The present day Ellis Canyon is the most significant topographic feature in the study area. It is the least accessible, the most geomorphologically active and has the greatest limitations to forest harvesting in the study area.

The canyon can be sub-divided into two parts. The lower slopes of Ellis Creek below its confluence with North Ellis Creek and the north wall of North Ellis Creek below 1,200m a.s.l. are dominated by steep rock cliffs and colluvium filled gullies (Photo 19). The canyon rim is capped by moderate to steep slopes of colluvium, moraine and glaciofluvial terraces (Photos 19 and 20). The slopes of Ellis Creek above North Ellis Creek and the lower sections of South Ellis Creek, both to roughly 1,200m a.s.l., are dominated by moderate to steep slopes composed of pre-Wisconsian channel deposits, moraine, glaciofluvial sediments and colluvium (Photos 15, 17 and 21).

Terrain stability issues occur along most sections of the canyon. Okanagan Gneiss exposed along the lower sections is highly competent. Most failures are limited to minor rockfall, although large rockslides do occur. A slide visible from the Ellis Canyon Lookout is coincident with deforestation caused by the Garnet forest fire (Photo 19). The slopes of moraine, glaciofluvial terraces and colluvium above the canyon rim are considered potentially unstable and exhibit some ravelling and soil creep (Photos 19 and 20). Stream undercutting along the upper sections of the canyon has resulted in large cliff sections of continually failing surficial materials (Photo 15). The banks of the stream channels along the entire length of the canyon are also continually being eroded by lateral creek erosion. These specifically include run-out areas of colluvium below failing scarps of bedrock or surficial materials.

The likelihood of landslide-induced debris entering streams is high along most of Ellis Canyon based on the proximity of the active channel and both the steepness and general instability of the slopes. Soil erosion potential is limited in the lower canyon sections due to the lack of transportable material and the generally rapid drainage of most of the surface materials that are present. Soil erosion potential is much higher along the upper canyon where surficial materials are exposed. Sediment delivery potential is variable along the canyon depending on the proximity of the active stream and the slope gradient. Generally, sediment delivery potential is higher along the canyon than in the surrounding highland areas.

7.2 Highlands

Compared to the Ellis Canyon area, the highlands and surrounding mountains and ridges have a relatively subdued topography (Photo 1), but are complex in their geomorphology. Gentle slopes dominate the area. Moderate-gradient slopes are common at higher elevations on the north slopes of Mount Christie and adjoining ridges. Steep-gradient slopes are generally limited to slopes of less than 50m along channel gullies, low bedrock ridges and glaciofluvial terraces and ridges. Surficial deposits of moraine, glaciofluvial sediments, glaciolacustrine sediments dominate the area (Photos 3, 5, 6 and 13) and gently rolling to steeply ridged bedrock exposures are common on the west slopes bordering the Okanagan Valley and high elevation ridges (Photo 2). Fluvial deposits are confined to active and ephemeral stream channels. Organic sediments (bogs and wetlands) and eolian deposits occupy a low percentage of the area, predominantly in the east central portion of the study area.

The highland can be divided into areas of generally south and north aspects. The slopes north of Ellis Creek are generally south facing and have a high percentage of rapid draining glaciofluvial cover (Photos 5 and 11). The north facing slopes of Mount Christie and the adjoining ridges are predominantly covered by a mantle of moderate to well draining compact moraine (Photos 3 and 5). Snowpack on the north aspect slopes is likely greater because of reduced sun exposure resulting in the south portion of the study area having higher runoffs of surface water and groundwater. This combination of slightly lower soil permeability and greater runoff raises the potential for slope failure and sediment delivery. Greater attention is required in the installation of ditches, culverts and waterbars on the north facing slopes within the South Ellis Creek watershed during harvesting and road construction.

Terrain stability issues are limited in the highland areas. Areas of concern include moderate to steep slopes of moraine where groundwater seepage and surface water collects, typically at the base of long slopes that have been cut by meltwater channels. These conditions occur on the north slopes of Mount Christie, in particular along South Ellis Creek and its tributaries. In one instance along the east bank of South Ellis Creek, poor management of surface water runoff and groundwater seepage along an old road is concentrating flows (Photo 21; field inspection site DWT-99), resulting in a slow mass movement roughly 70m downslope (Photo 22; field inspection site DWT-84). The failure has occurred on a slope with a gradient of only 50%.

Poorly consolidated glaciolacustrine and glaciofluvial sediments are particularly susceptible to undercutting by excess runoff flows. These conditions are limited, as most streams in the plateau are underfit relative to the channel they occupy. Undercutting occurs during seasonally elevated flows along the meltwater channel now used as a spillway for the Ellis Penstock (Photo 23). Steep rock cliffs formed by glacial meltwater occur along the ridges that form the study area boundary. Stability issues are largely limited to minor rockfall. Sandy glaciofluvial deposits are susceptible to minor ravelling along road cuts (Photo 11).

The potential for landslide-induced debris entering a stream is limited by the lack of stream drainages with landslide prone slopes. These are mostly located along South Ellis and North Ellis Creeks between 1,200m and 1,600m a.s.l. Soil erosion potential is generally low to very low throughout most of the area due to its generally low topographic relief. Soil erosion is also limited by the generally well to rapid draining soils present. Areas of concern are limited to poorly constructed roads and ditches on moderate to steeper slopes of fine glaciofluvial, glaciolacustrine and moraine materials. These include old roads constructed down the fall line of the slope (field inspection site DWT-16) or with poor drainage control (Photo 21; field inspection site DWT-99). Eolian transport of sand is a potential risk in the study area if soil and vegetation covers are removed over a significant area. Sediment delivery potential is similarly limited by the lack of significant drainages in the area and the generally low topographic relief.

8.0 Conclusions and Recommendations

Our conclusions and recommendations are discussed by physiographic area (Ellis Canyon and the surrounding highlands as described in Sections 4.1, 7.1 and 7.2), highlighting the surficial materials and conditions of most concern. Recommendations are provided with a focus on Class IV slopes where harvesting could proceed if well planned and assessed by a qualified professional. Further reference should be made to the recommendations for management of landslide prone terrain outlined in Chatwin, et.al. (1991), and the User's Guide to Terrain Maps in BC (Ryder and Howes, 1986).

The following section contains general management recommendations. These recommendations may or may not be required and/or subject to modification depending on the results of cutblock-level assessments and/or regulatory conditions that exist at the time forest development planning is taking place. As regulatory conditions are constantly evolving, users of this report and accompanying maps should consult the most recent FPC regulations and guidelines prior to making any decisions regarding forest development planning based on information contained herein. Any significant slope failure events or significant environmental changes that have occurred since the writing of this report should also be taken into consideration.

8.1 Ellis Canyon

The potentially operable forest harvesting areas within Ellis Canyon are largely limited to the moderate to steep slopes of moraine, glaciofluvial terraces and minor colluvium around the rim of the canyon. These slopes host scattered stands of mature interior Douglas-fir. Harvesting may be feasible using high lead techniques from the top of the slope. Soil erosion potential is highest on these slopes. Sediment delivery potential is somewhat reduced by a lack of immediate proximity of these slopes to the creek below.

For the area of Ellis Canyon below roughly 1,200m a.s.l., the following recommendations are made:

1. Any moderate to steep upper slopes (gradients >60%) along the canyon require a Terrain Stability Field Assessment (TSFA) by a Qualified Registered Professional (QRP) before harvesting is undertaken.
2. Harvesting in the headwalls of the rock gullies should be avoided.
3. Any moderate to steep upper slopes (gradients 40%-60%) along the canyon require a TSFA by a QRP before road building is undertaken. Road building should be avoided on the moraine and glaciofluvial terrace slopes at the rim of the canyon where gradients exceed 60%.
4. Disturbances to soils should be minimized, and reseeding of any bare patches should be undertaken immediately. Specific care should be taken to not yard harvested logs in such a way as to create vertical ruts or channels in the surface materials.
5. Surface water runoff should be channelled away from the slope face.
6. A TSFA by a QRP should be required before harvesting is undertaken on moderately steep to steep slopes (gradients >50%) underlain by moraine or fine glaciolacustrine sediments where groundwater seepage is observed.

Extension of the operability boundary east to include the steep, unstable cliffs of surficial material below 1,200m a.s.l. between the mouth of South Ellis Creek and the Ellis Canyon FSR bridges on both Ellis and South Ellis Creeks is also recommended (Photos 15 and 17).

8.2 Highlands

A limited number of areas on the highland and surrounding peaks pose risks for slope instability, landslide-induced debris delivery, surface erosion or sediment delivery problems. As a result, a limited number of areas are not suitable for harvesting and road building. These are steep meltwater channel gullies cut into bedrock, in some places through surficial cover materials, that occur west and east of North Ellis Creek and along the ridges that form the study area boundary. Areas that require in-field professional inspections prior to road building or harvesting include the moderate to steep slopes (slope gradients of >50%) of moraine and glaciolacustrine sediments on the north slope of Mount Christie where surface water runoff and groundwater seepage are present. Culverting, ditching and the installation of waterbars will need to be well designed and properly maintained in all areas where seepage is encountered. Other areas include the steep slopes of old meltwater channels and glaciolacustrine and glaciofluvial terraces.

For the highland areas of the Ellis Creek and Steward Creek watersheds, the following recommendations are made:

1. Road layout in Class IV terrain should be investigated in the field by a QRP before road building is undertaken. The length of roads on Class IV terrain on the plateau should be minimized. Road construction should be avoided in Class V terrain.
2. Areas identified for harvesting in Class IV and V terrain should be investigated by a QRP prior to harvesting.
3. Moderate to steep slopes (gradients >40%) of moraine and fine glaciolacustrine sediments where evidence of seepage of surface water runoff is observed, specifically along meltwater channels associated with Ellis, North Ellis and South Ellis Creeks and their tributaries, should be investigated by a QRP before road building is undertaken.
4. Ditches and culverts in this region will require regular inspection and maintenance.
5. Harvesting should minimize disturbance to ground cover, specifically in areas underlain by fine sand and silt that would be susceptible to eolian

processes. Exposure of bare soil should be minimized to prevent erosion problems and reseeding should occur immediately following disturbance.

6. Road building and harvesting on glaciolacustrine deposits should be limited to slopes of gradients of less than 50% and 65% respectively.

In addition to the above recommendations, it is suggested that an inventory be done of the older, secondary forestry roads in the area. Roads without adequate surface water control measures should be deactivated to standards in keeping with the FPC, specifically in areas of groundwater seepage and surface water runoff on the north facing slopes of Mount Christie. More specifically, waterbars should be installed at the first opportunity on the secondary road above the Ellis Canyon FSR in the lower section of the South Ellis Creek drainage (field inspection site DWT-99). A road running up the fall line of the slope located above the Beaverdell Road just west of North Ellis Creek also requires deactivation (field inspection site DWT-16).

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Respectfully submitted,

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APPENDIX 1

SITE PHOTOGRAPHS

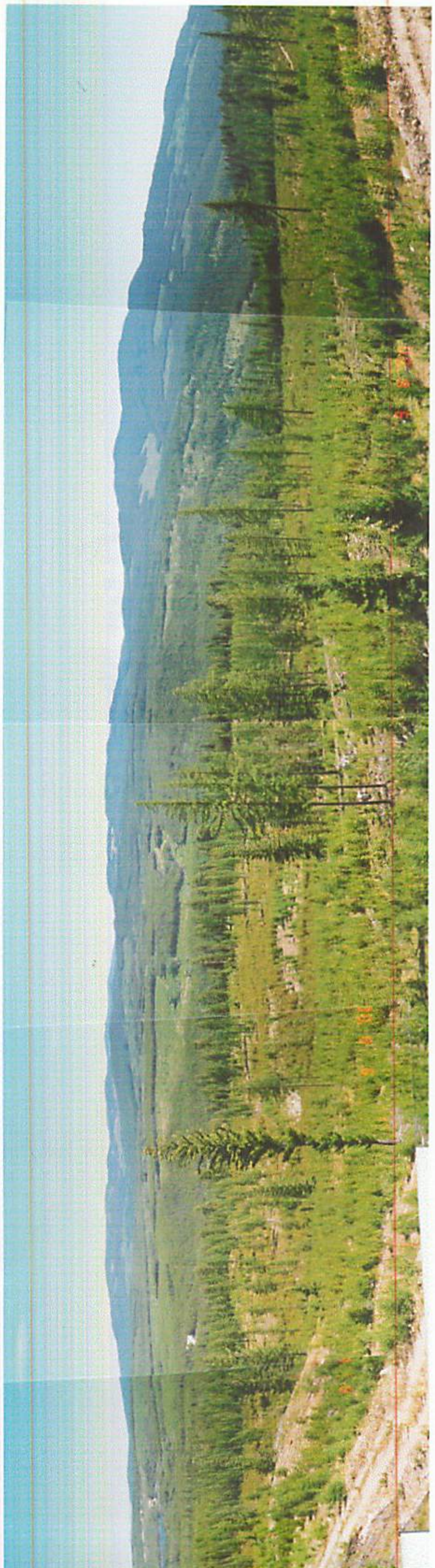


Photo 1 - View to south overlooking Ellis Creek watershed with Mount Christie on the skyline to the right side. The Ellis penstock is situated at the extreme left. Note the gentle rolling topography to the central highland area and the glaciofluvial terrace (field inspection site DWT-129) extending across the foreground to the far right.

Photo 2 - View to south of lower Ellis Canyon and bedrock hillocks typical of the west part of the Study area.

Photo 3 - Rolling topography typical of the lower slopes of Mount Christie. Note bedrock controlled mantle of moraine (field inspection site DWT-110).

Photo 4 - View to west looking into the Steward Creek watershed from Ellis Creek FSR near the north boundary of the study area. Note gentle rolling topography of bedrock controlled moraine (field inspection site DWT-118).

Photo 5 - Glaciofluvial blanket over moraine located at roughly 32km on the 201 FSR. Note rills developed in moraine (field inspection site DWT-120).

Photo 6 - Rolling bedrock ridges and moraine infilled depressions typical of the northwest part of the study area. Located on the Steward Creek FSR (field inspection site DWT-14).

Photo 7 - Exposure of moraine with plus and minus 2mm fractions shown. Minus 2mm fraction is comprised predominantly of silt with less than 20% sand (field inspection site DWT-11).

Photo 8 - Isolated glaciofluvial fan deposited directly on bedrock located at an elevation of 1,550m a.s.l. on the Ellis Creek FSR. (field inspection site DWT-125)

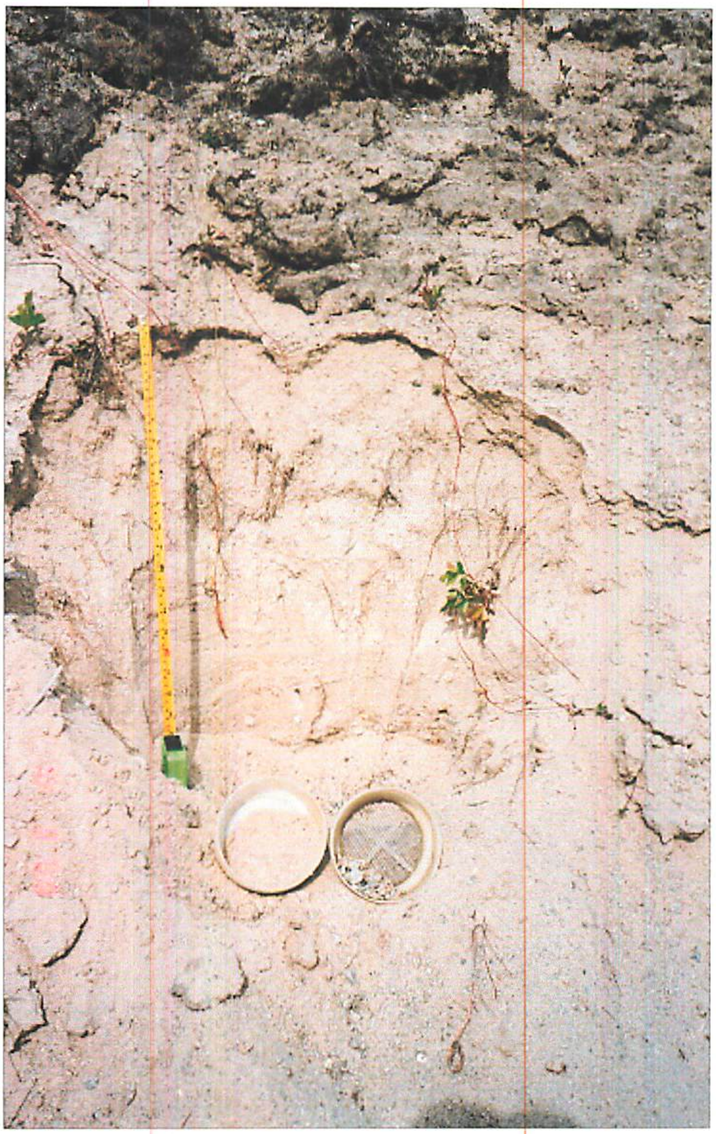


Photo 9 - Exposure of glaciofluvial sand and gravel with plus and minus 2mm fractions shown. Minus 2mm fraction is composed predominantly of medium grained sand with minor silt. Note weak bedding in the exposure. Sediments shown overlie glaciolacustrine sediments shown in Photo 12. Location is at roughly 1km on the Ellis Creek FSR (field inspection site DWT-20).

Photo 10 - Glaciofluvial deposit of boulders mark meltwater channel along the edge of the present Ellis Creek channel. Located near the Ellis Canyon FSR bridge (field inspection site DWT-59).

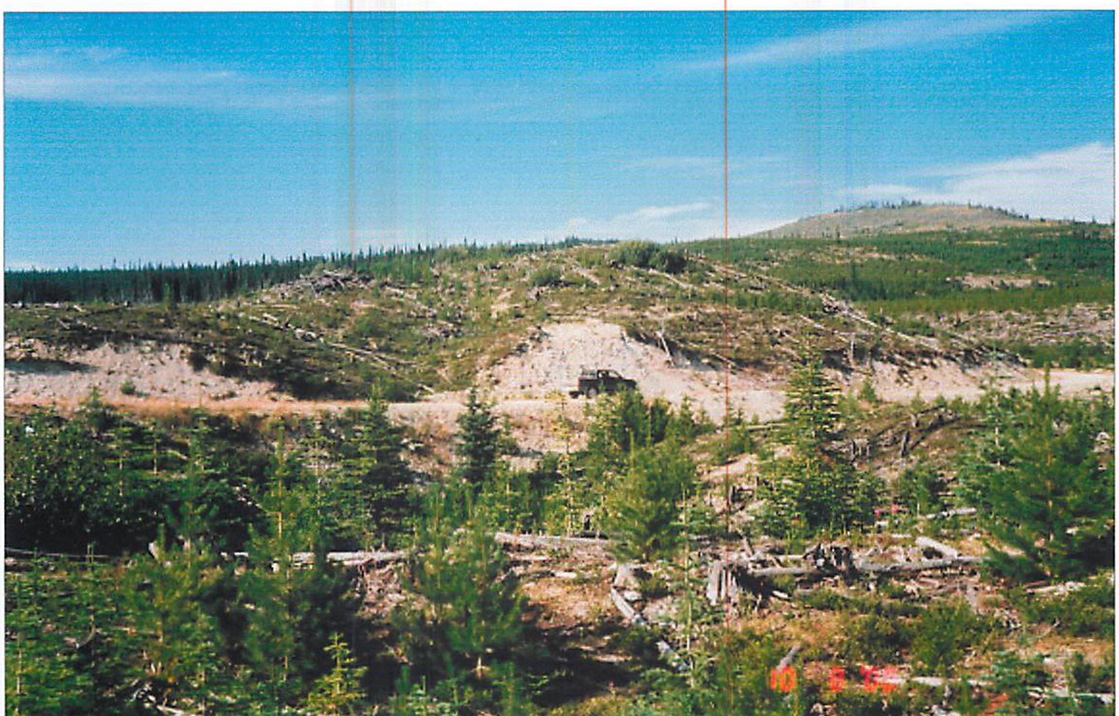


Photo 11 - Glaciofluvial deposits typical of the mid-elevation slopes surrounding the headwaters of Ellis Creek. Note abundant boulders in road-cut exposures and large kettle depression in foreground. Located at an elevation of 1,640m a.s.l. on the Ellis Carmi FSR (field inspection site DD-75).

Photo 12 - Exposure of glaciolacustrine silt and fine sand with plus and minus 2mm fractions shown. Entire exposure is composed of silt and minor fine grained sand. Note weak bedding in the exposure. Sediments shown underlie glaciofluvial sediments shown in Photo 11. Location is at roughly 1km on the Ellis Creek FSR (field inspection site DWT-20).

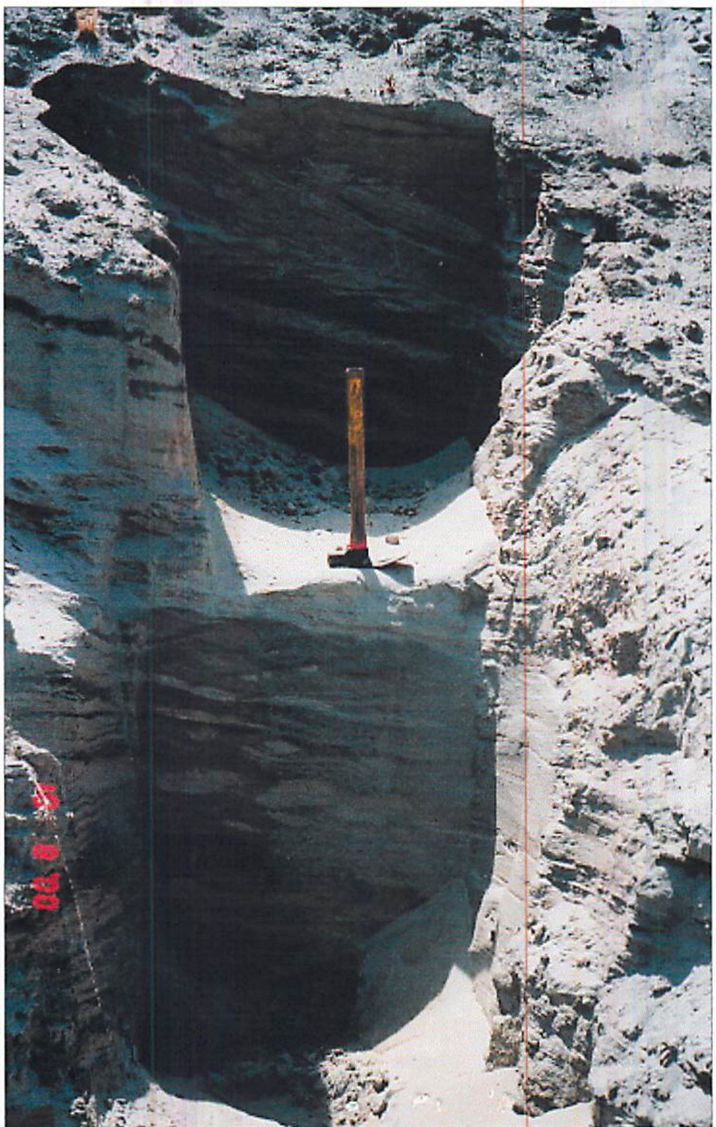


Photo 13 - Exposure of glaciolacustrine sand looking south. Total depth of deposit is greater than 6m. Note cross bedding indicating progradational deposition from left to right (east to west). Location is at roughly 12km on the Beaverdell Road (field inspection site DWT-17).

Photo 14 - Raised beach deposit of gravel and sand located just east of 27.5km on the 201 FSR
(field inspection site DWT-121).

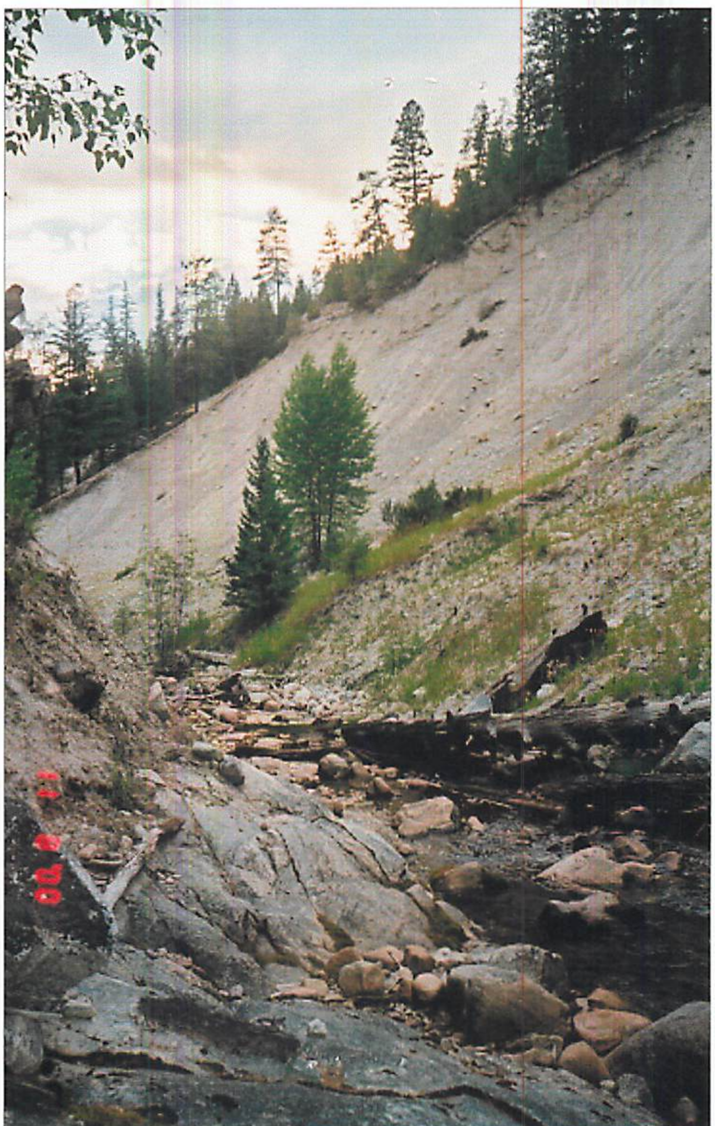


Photo 15 - Cliff exposure of moraine and colluvium in the upper section of Ellis Canyon on Ellis Creek. Note the bedrock in foreground and low amounts of fine sediments in the creek bed in spite of colluvial debris being cut by the creek. Located roughly 300m upstream from the mouth of South Ellis Creek (field inspection site DWT-29).

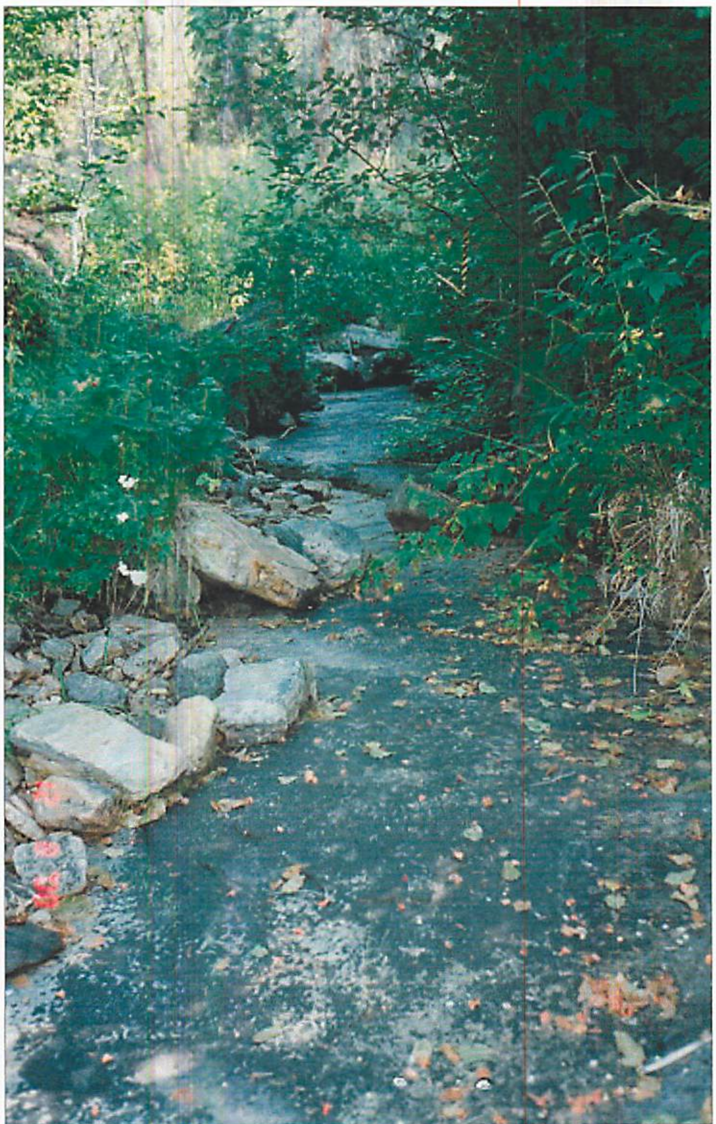


Photo 16 - Main channel of Steward Creek at an elevation of 1,120m a.s.l. (field inspection site DWT-30). Note the lack of fine sediments and dry, shallow bedrock basement.

Photo 17 - Blanket of moraine overlying Pre-Wisconsian sediments of silt, sand, gravel and (not in picture) cobbles and boulders. Note hammer resting on horizon of fine sand. Moraine displays a fabric perpendicular to the eroded face of the underlying sediments. Located roughly 500m upstream of the mouth of South Ellis Creek (field inspection site DWT-28).

Photo 18 - Eolian sand deposit located at the junction of the Beaverdell Road and the 201 FSR (field inspection site DWT-132). Roadcuts in the background composed of sand with 10% to 20% gravel.

Photo 19 - Steep rock cliffs and gullies of Lower Ellis Canyon viewed from the Ellis Canyon Lookout (field inspection site DWT-24). Note large rockslide on ridge to left and moderate slopes above the rim of the canyon covered with a veneer of moraine and colluvium.

Photo 20 - Mantle of moraine, glaciofluvial sediments and colluvium material forming a moderate slope above the rim of the canyon. Note bedrock exposure to right. Located below Forest Service campground at the Carmi cross-country ski area(field inspection site DWT-51).

Photo 21 - Old road in South Ellis Creek watershed not properly deactivated (field inspection site DWT99). Note meltwater channel in roadbed and lack of waterbars of culverts. Area was logged some time prior to the 1960s. Site is located roughly 70m upslope from failure shown in Photo 22.

Photo 22 - Slow mass wasting failure in moraine on east bank of meltwater channel located roughly 400m upstream from the South Ellis Creek bridge (field inspection site DWT-84). Site is located roughly 70m downslope from road shown in Photo 21.

Photo 23 - Meltwater channel where flows from Ellis penstock spillway have undercut glaciolacustrine sediments (field inspection site DWT-18).Note sedimentation in streambed. Located at roughly 12km on the Beaverdell Road at the same site as Photo 13.

APPENDIX 2

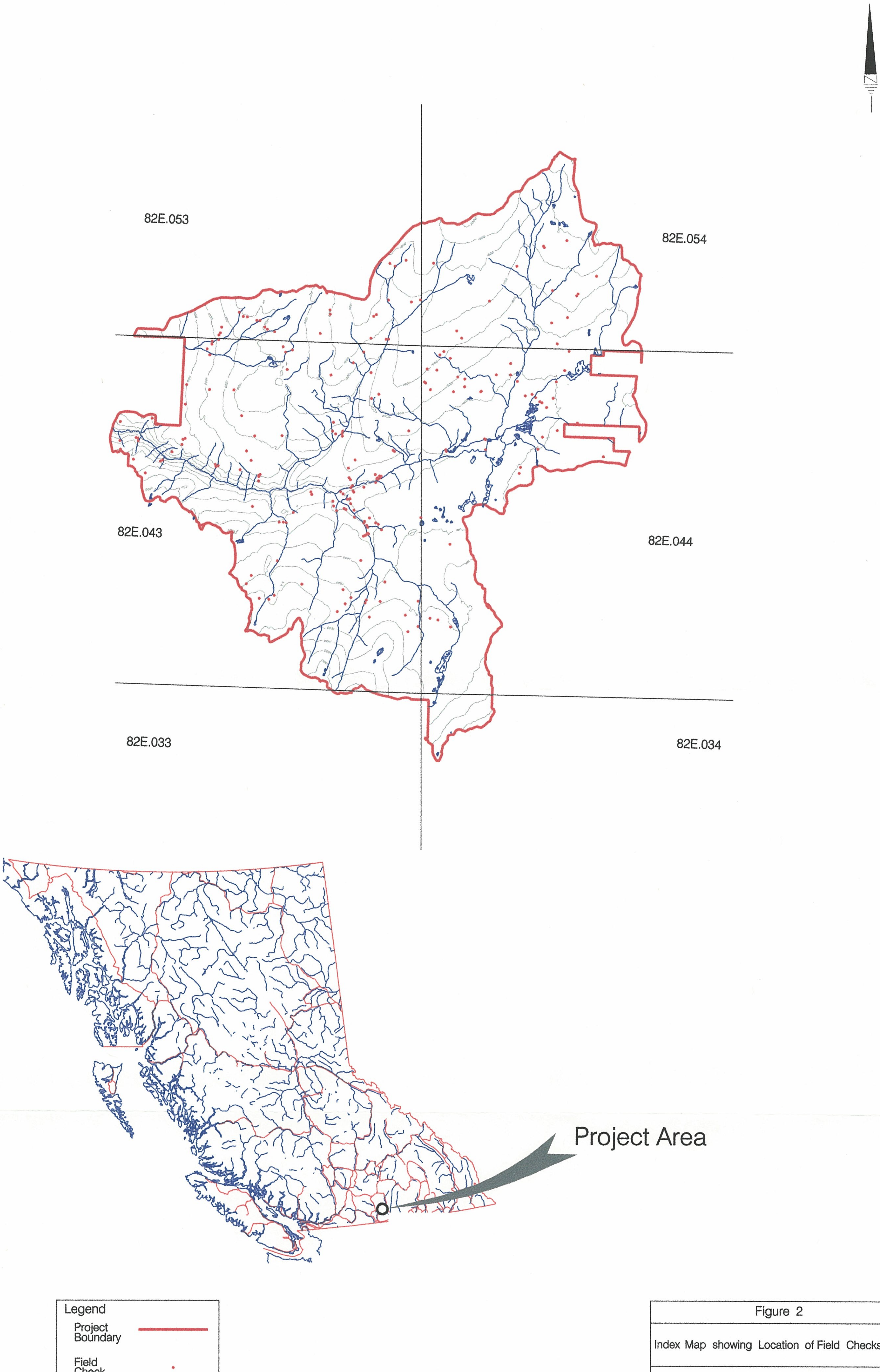
LIST OF AERIAL PHOTOGRAPHS USED

The following is a list of the 1:20,000 aerial photographs used for interpretation of the terrain of the Ellis Creek and Steward Creek watersheds. They are organized based on the line numbers assigned for this project from north to south.

Project Flight Line No.	Flight Line No.	Photo No.	Total No.
Line 1	30BCC92090	125-128	4
Line 2	30BCC92090	99-91	9
Line 3	30BCC92085	83-69	15
Line 4	30BCC92085	37-53	17
Line 5	30BCC92085	26-10	17
Line 6	30BCC92084	193-203	11
Line 7	30BCC92084	179-169	11
Line 8	30BCC92084	137-145	9
Line 9	30BCC92084	116-112	5
			98

APPENDIX 3

FIELD DATA FORMS



Drawing No.: 608-01.01_index

Figure 2	
Index Map showing Location of Field Checks	
Penticton Forest District	
648-02.01	November 2000