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Yukon Land Use Planning

KLUANE TERRAIN HAZARD MAPPING STUDY

PHASE I REPORT

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Canada

Yukon Government

KLUANE TERRAIN HAZARD MAPPING STUDY

PHASE I REPORT

This project was completed for the Greater Kluane Land Use Plan. It is one of a number of resource inventory projects that were compiled as background information.

KLUANE TERRAIN HAZARD MAPPING STUDY
PHASE 1 REPORT

Prepared for
Yukon Land Use Planning Office

NORTHERN LAND USE PLANNING DIRECTORATE
YUKON REGION
JUL 10 1989
WHITEHORSE, Y.T.

Thurber Consultants Ltd.
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SUMMARY

In this study, terrain hazards are interpreted on aerial photographs and mapped in the Kluane Regional Planning Area of the southwest Yukon. The area is covered by roughly 650 aerial photos and includes 35,000 km^2 in the Coast and St. Elias Mountains and the Ruby and Dawson Ranges. Hazardous terrain was inventoried using the British Columbia Terrain Classification System. This information is compiled on 57 National Topographic Series (NTS) reduced to 1:100,000 scale. Areas of significant hazards are mapped on 14 1:50,000-scale NTS bases in preparation for field checking.

For regional planning guidance, the smaller-scale base maps are coded with a "stoplight" classification system using red, green, yellow colour codes for stop, go, caution situations.

Objective hazards in this mountain region include rock falls, snow avalanches, debris flows, areas distressed soil or bedrock, soil and bedrock landslides and braided streams which carry heavy loads of coarse material. These hazards are generally well defined and pose unconditional risks to property or life. Such hazards can either be avoided, controlled with expensive works or accepted on the basis of probability.

Subjective terrain hazards may result from disturbance of slopes which have active soil processes including cryoturbation (frost heave), solifluction (soil creep) and permafrost degradation. The risks imposed by subjective hazards are less obvious than objective hazards and their effects are conditional. Such risks can generally be reduced to acceptable levels with proper engineering and construction.

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1. INTRODUCTION

This is a mapping study of terrain hazards in the Kluane Regional Planning Area (KRPA) of the southwest Yukon (Figure 1). The study was authorized by Articles of Agreement signed by Thurber Consultants Ltd. (TCL) on May 17, 1989 based on TCL's proposal dated March 28, 1989. The KRPA includes the Kluane Wildlife Sanctuary (KWS) in three separate areas along the eastern boundary of Kluane National Park. Kluane National Park is not included within the study except where hazards within the park may affect the KRPA. The study area includes 56 1:50,000-scale National Topographic Series (NTS) maps (Figure 2). Compilation mapping of the regional bedrock geology is available at a scale of 1:1,000,000 (Gabrielse et al., 1980).

Terrain hazards are defined as naturally occurring geological and geomorphic processes and unstable conditions that present a risk to life and property (Ryder and MacLean, 1980, p. 1). Definitions of landslides in this report generally follow the nomenclature of Varnes (1978) and are given where first used.

2. SCOPE

The scope of the work is defined in Section S.W.3 of the Contract as follows:

> "The Contractor shall carry out terrain hazard mapping and assessment of the KRPA , which is approximately 35,000 square kilometers in the southwest part of the Yukon Territory (Figure 1). The project shall be carried out in two phases."

The terms of reference for the Phase 1 study, as defined in Section S.W.3.1 of the Contract, are as follows:

> "The Contractor shall identify the main hazard types (including landslide types) that are found in the Kluane Regional Planning Area (KRPA). It shall include inventory maps at a scale of 1:100,000 of hazard sites in the study region. This shall include identification of high hazard areas (or hot spots) within

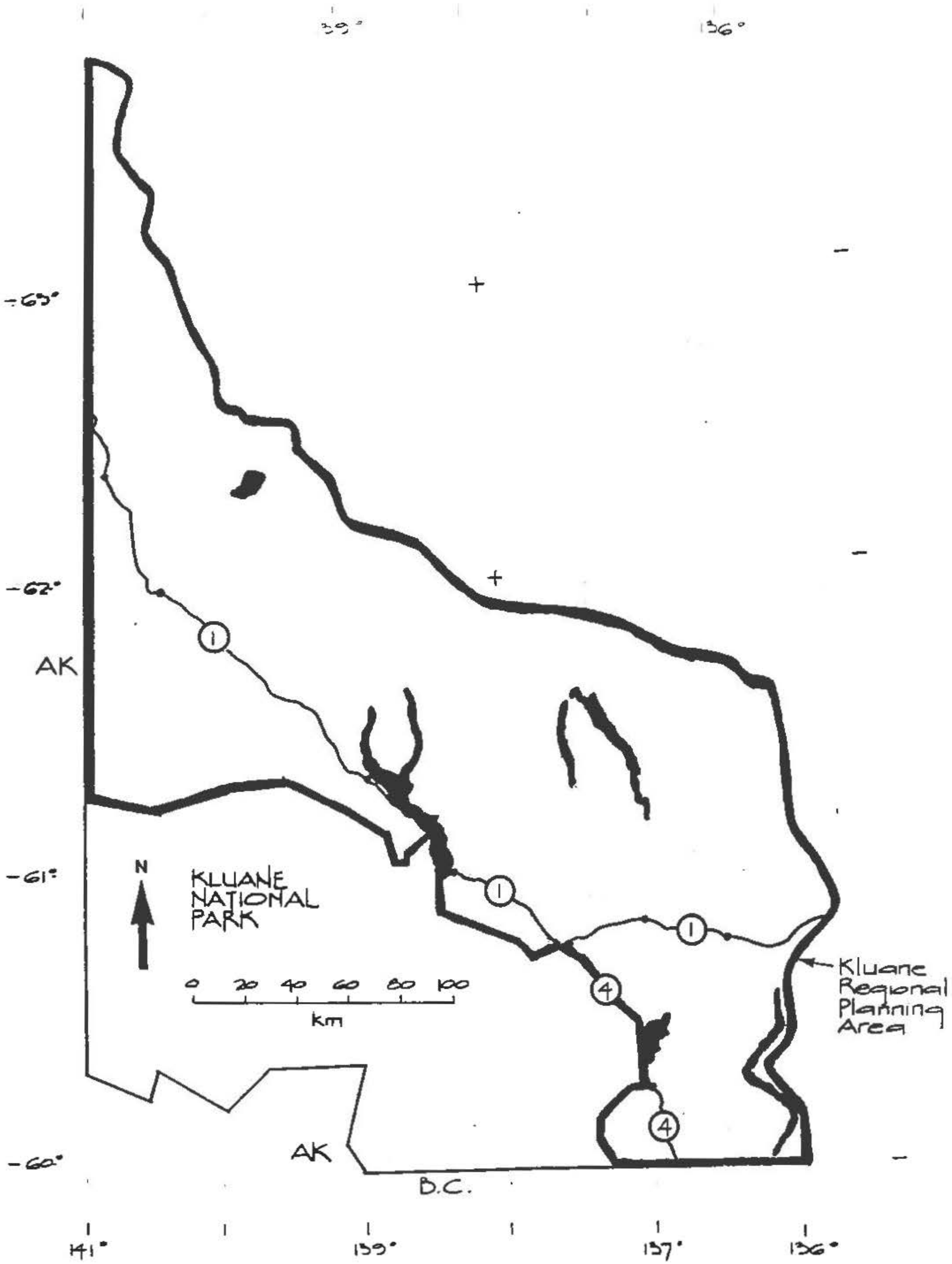
39°
136°
-63°
-62°
-61°
-60°
AK
AK
B.C.
KLUANE NATIONAL PARK
N
0 20 40 60 80 100
km
1
1
1
4
4
Kluane Regional Planning Area
141°
139°
137°
136°

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Fig. 1

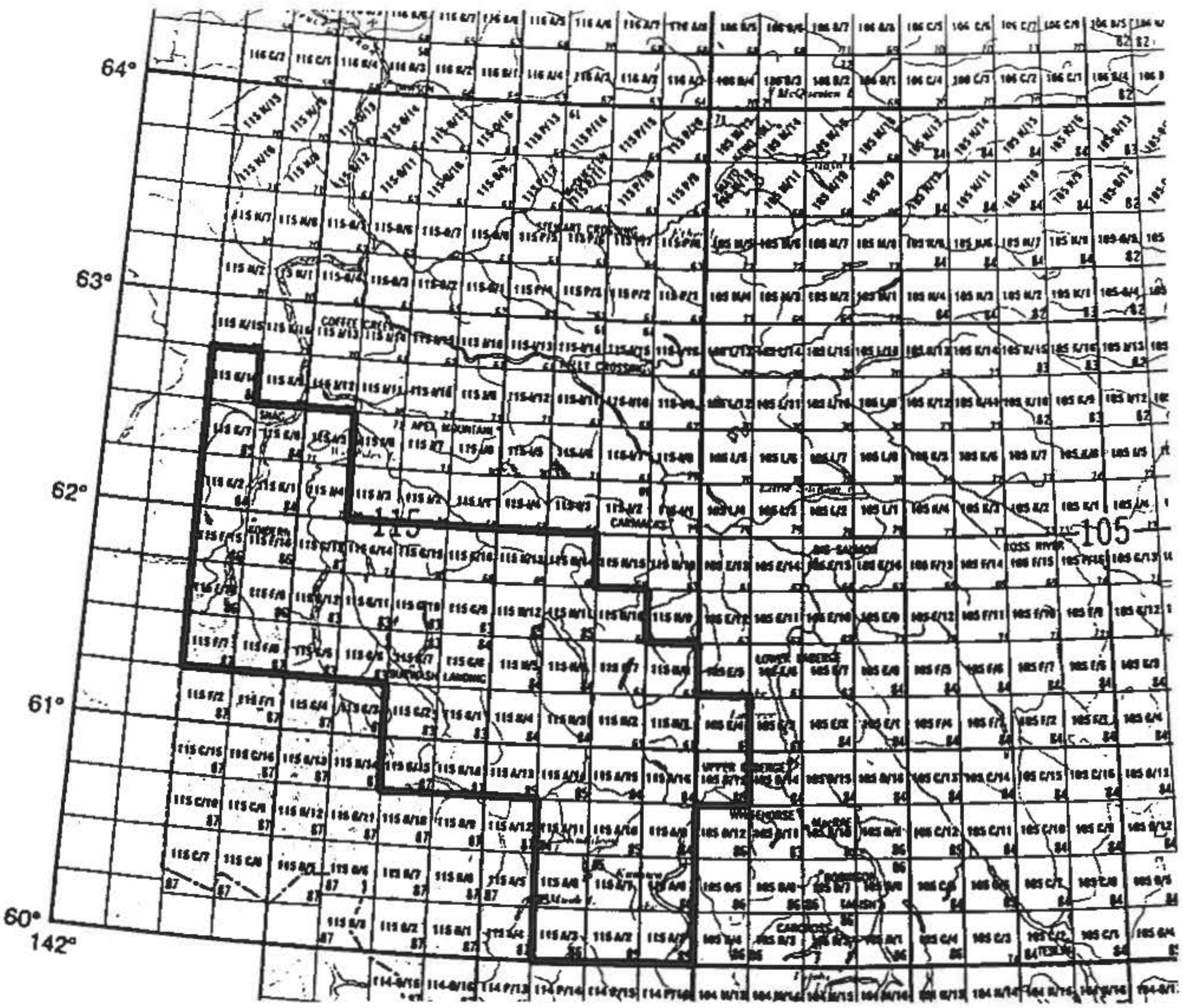
64°
63°
62°
61°
60°
142°
115
105
STEWART CROSSING
COFFEE CREEK
PELLY CROSSING
SNAG
APEX MOUNTAIN
CARMACKS
ROSS RIVER
BIG SALMON
LOWER LABERGE
UPPER LABERGE
WHITEHORSE
CARCROSS
TAGISH
TESLIN
McQuesten

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Fig. 2

the KRPA. The Contractor shall submit a report to the Departmental Representative based on a literature survey and the interpretation of approximately 766 aerial photographs provided by the Department. Progress map and textual evidence of project work shall be provided to the Department Representative. No field work shall be involved."

"A Meeting will be held in Whitehorse on, or shortly after July 15, 1989 between the Contractor, the Departmental Representatives and Scientific Authorities to review the work completed in Phase 1. A presentation to the Kluane Regional Planning Commission on the initial findings in Phase 1 shall be held during the Contractor's trip to Whitehorse for the review meeting."

"A report in both hard copy and floppy disc form written using WordPerfect 5.0 and on 5 1/4 or 3 1/2 disc) shall be submitted to the Departmental Representative by July 7, 1989, which shall discuss, in general terms, terrain hazards in the KRPA."

Phase 2 of the study includes field investigation and final reporting of the entire study.

3. PREVIOUS HAZARD ASSESSMENT

This hazard study is preceded by several others which focused on the southwestern limits of the KRPA. Clague (1979b and 1982) discussed the variety of natural hazards in the Shakwak Valley; his study is a basis for further work. He notes the following potential hazards which are directly or indirectly considered in this report:

a) A variety of landslides in which <u>bedrock</u> moves by falling, toppling, rotation, translation or other complex movements.

b) <u>Soil</u> landslides including rotational and translational movements and soil creep. Permafrost active-layer slides (Clague, 1982, p. 26) are included.

c) Debris flows meaning channelized movements of soil and other debris. Debris torrent is an equivalent term. As used in this report, debris floods are the runouts of debris flows (also see Appendix B.2).

d) Seismic shaking and ground rupture associated with earthquakes.

e) Permafrost degradation (also see Appendix B.3).

Clague notes other potential hazards:

f) Floods triggered by heavy rain and snow melt.

g) Jökulhlaups (catastrophic floods generated by englacial meltwater) in the upper Slims, Donjek and White River valleys, p. 27-30.).

h) Inundation of the Haines Junction area by glacier-dammed Lake Alsek to a filling limit of about elevation 595 m.

i) Explosive volcanism near the Alaska-Yukon border (p. 34-35) and related accumulations of volcanic debris or ash falls.

This variety of natural hazards (with the addition of snow avalanches noted herein - see Appendix B.4) results from the complex climate and geology of the area (Oswald and Senyk, 1977) as well as the high activity of its geomorphic processes.

An assessment of rainfall and snow melt flood hazards (Item f) is beyond the scope of this photo study. Jökulhlaups may have severe effects in the braided reaches of the major stream valleys noted by Clague and mapped in this study. Clague (p. 31) notes that although jökuhlhaups may be very large, their probability of occurrence may be comparatively low and their downstream effects will be reduced by frictional attenuation of flow energy along braided stream beds. Such floods should be considered, as required, by detailed hydraulic studies.

The community of Haines Junction lies just above the probable flood limit (el. 595 M on NTS 115 A/13, see Clague and Rampton, 1982) of Glacial Lake Alsek. Although a study of local contours indicates a new glacial lake may not threaten lives in the community of Haines Junction, a more detailed study is required to evaluate possible shoreline effects.

Clague, (1982, p. 35) indicates there is a low probability of a damaging volcanic eruption in the region.

Terrain suitability evaluation for the communities of Champagne, Haines Junction, Destruction Bay and Burwash Landing have been reported and mapped by Terrain Analysis and Mapping Services Ltd. (1980). The comprehensive study of these communities is a model for future work.

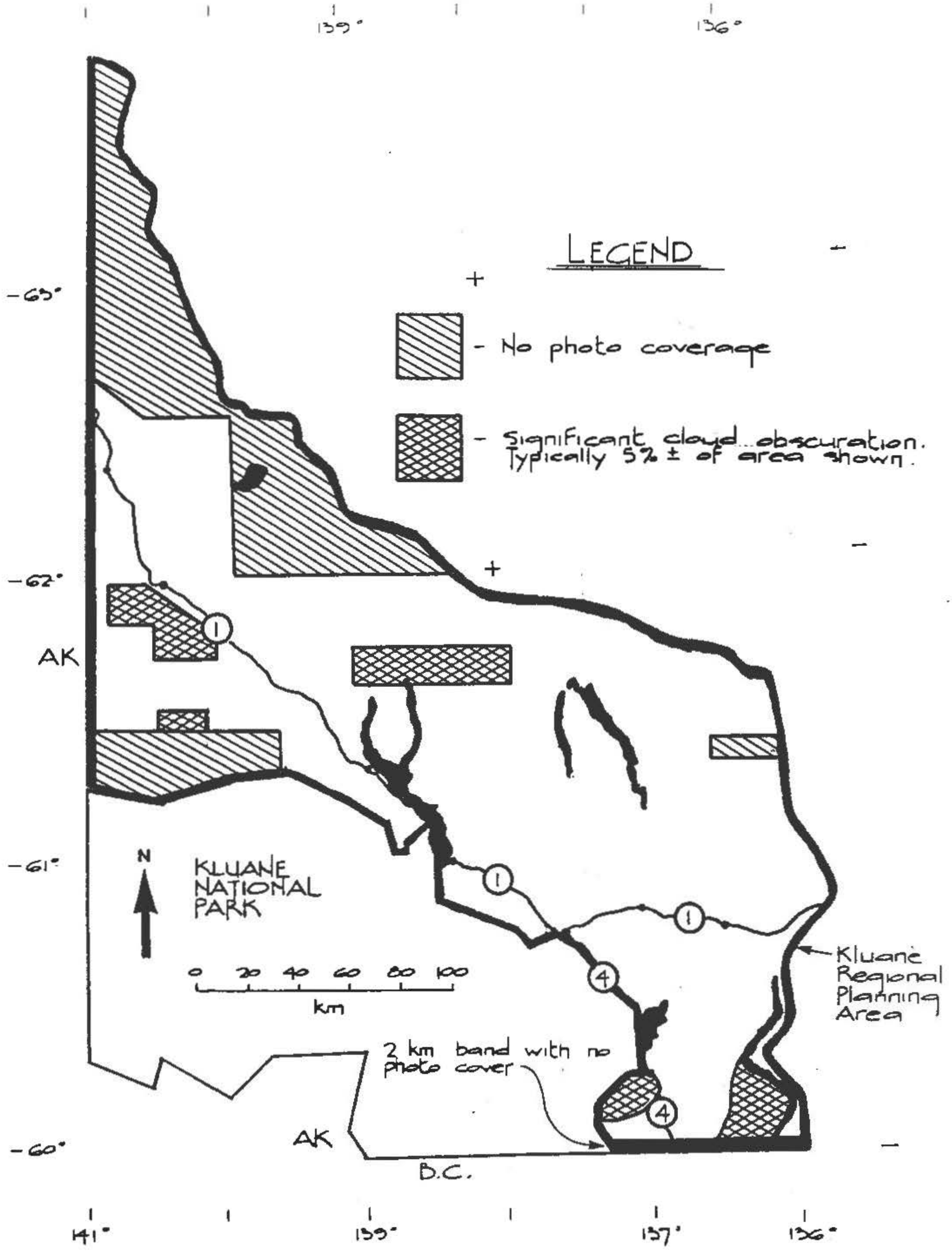
This (Phase 1) report addresses broadly defined landslide hazards, snow avalanche hazards and active-layer permafrost and seismic activity which influence slope hazards.

4. METHODOLOGY

In consultation with the Scientific Advisors early in Phase 1, it was decided that the aerial photo interpretive mapping would use the Terrain Classification System for British Columbia (Howes and Kenk, 1988). This classification system is ideally suited for reconnaissance work at a variety of mapping scales. In addition, literature has developed on its use for planning and hazard studies (Ryder and MacLean, 1980; Ryder and Howes , 1986 and Maynard, 1979) as well as for thematic mapping in a Geographic Information System (GIS) (Kenk et al., 1987).

Although approximately 766 photos were provided for the study, only 650 were required to cover the KRPA. These are small-scale photos (1:50,000 to 1:70,000 scale) taken 10 or more years ago (see photo reference). Aerial photo coverage is missing for some portions of the KRPA and there are obscuring shadows on some images (Figure 3).

Surficial geologic mapping at 1:100,000 scale (Rampton, 1979 a-e; Rampton and Paradis, 1981 a-c) is


139°
136°
LEGEND
▨ - No photo coverage
▩ - Significant cloud obscuration. Typically 5% ± of area shown.
-63°
-62°
-61°
-60°
AK
1
1
1
4
4
KLUANE NATIONAL PARK
N
0 20 40 60 80 100
km
2 km band with no photo cover
Kluane Regional Planning Area
AK
B.C.
141°
139°
137°
136°

16 - 10 - 18

Fig. 3

available for much of the study area (Figure 4). Rampton (1981) also mapped much of Kluane National Park at a published scale of 1:250,000. These geologic maps are an important source of information and should be used in √with the hazard maps in this study.
conjunction

Because of the large map area to be covered and the purpose of the study (i.e. to identify and map hazards), some discretion was required in determining the exact methodology of the work consistent with available information and constraints of time and photo quality. The methodology used in Phase 1 is as follows:

a) Terrain features were interpreted on the aerial photos and mapped and classified using the B. C. terrain classification system.

b) The 1:100,000-scale maps prepared for this study are specialized and edited to emphasize terrain hazards.

c) The map units were subjectively evaluated in terms of risk to property and life. Rockfalls, landslides, snow avalanches and the like were judged to present high risks. Active-layer permafrost, colluvial fans (including debris flows and fluvial processes, see definitions in Appendix B.2) and the like on moderate to shallow slopes (generally less than 2H:1V or 27° from horizontal) were judged to present comparatively moderate hazards. Areas with no apparent terrain hazards were unmapped or mapped only to clarify adjacent units.*

d) A "stoplight" system (see Varnes, 1974, p. 36) was used to color the mapped terrain units. Red (stop)

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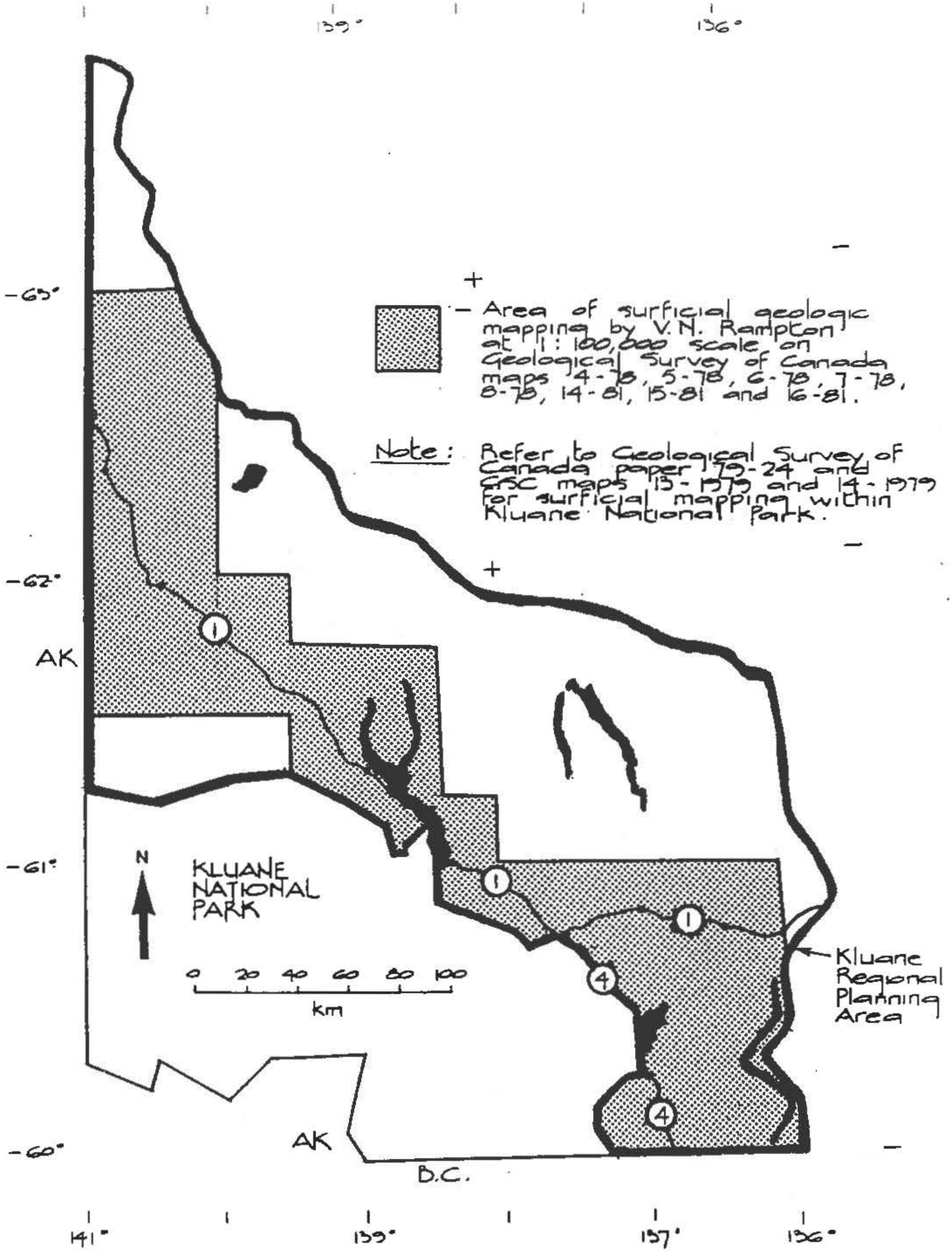
* "Hazardous" terrain should be distinguished from "difficult" terrain. Examples of difficult and restrictive terrain include muskeg, areas of soft silt or clay-rich soil and areas where there is a shortage of granular borrow for construction purposes (Hardy and Associates, 1984). Such areas may not be identified as "hazardous" in this study.



Note: Refer to Geological Survey of Canada paper 79-24 and GSC maps 13-1979 and 14-1979 for surficial mapping within Kluane National Park.

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Fig. 4

was applied to high hazard areas. Yellow (caution) was applied to moderate hazard areas. The colour green (go) is implied for terrain hazards in unmapped or otherwise uncolored areas.

e) Selected high risk (or potential high risk) areas were identified as "hot spots" requiring more detailed 1:50,000-scale mapping and possible field work. Most hot spots are in areas of human activity (e.g. along the Alaska Highway). Recent experience in British Columbia has raised public concern about the generation of lake flood waves by large landslides. Some hot spots are comparatively remote, shadow-obscured lake shore slopes worthy of field inspection. Some areas such as the Quill Creek Road corridor (115 G/5,6) were identified as hot spots by the Yukon Land Use Planning Office.

5. AREA DESCRIPTION OF TERRAIN HAZARDS

5.1 General

Hazardous terrain inventory maps of 1:100,000 scale and hot-spot maps of 1:50,000 scale are submitted in separate folios. Reference to these original maps may be required to understand descriptive information in this section. Appendix A is a list of hot spots in the major NTS blocks described in Sections 5.4 to 5.10. Appendix B contains the terrain map legend and interpretive information on colluvial surface materials and fans, permafrost, snow avalanches and geologic processes.

5.2 Permafrost

Hazardous terrain in this region is strongly influenced by the active layer of scattered and widespread discontinuous permafrost (Brown, et al., p. 32) as well as related alpine soil-geomorphic processes. Although it is difficult to define the limits of discontinuous permafrost by studying small-scale aerial photos, stability conditions are degraded on all north-facing slopes and several areas of thermokarst were observed in the northern KRPA.

It should be assumed that permafrost activity or related alpine active-layer processes including cryoturbation (frost heave) and solifluction (soil creep) affect the shallow stability of slopes throughout the area (Appendix B.3). These processes are important considerations in yellow-coloured ("caution") map areas where subjective hazards prevail.

The numerous rock glaciers in the KRPA exhibit flow behaviour caused by buried or interstitial ice. Such features (where mapped separately) are identified as objective hazards (coloured red).

5.3 Seismic Activity

The KRPA is in an area of high seismic risk (National Research Council of Canada, 1985, p. 221-241). The geologic literature has a number of references to strong earthquake activity and surface disturbances along fault traces (Eisbacher and Hopkins, 1977 and Clague, 1979, 1982). Like active layer permafrost processes, earthquake hazards can be minimized by engineering design and construction.

Earthquakes can generate landslides. Large landslides can be triggered by small earthquakes as in the case of the Hope Landslide of British Columbia in 1965 (Wetmiller and Evans, in press). Although not all landslides are triggered by earthquakes, areas of sensitive soil (e.g. saturated silts and sands) and distressed slopes within the KRPA should be assessed for the possibility of failures triggered by seismic activity.

Clague (1982, p. 26) notes the front of the actively prograding Slims River delta at the south end of Kluane Lake is subject to subaqueous landsliding or liquefaction which could affect the Alaska Highway crossing.

5.4 NTS Blocks 105 D and E

This area includes two map sheets 105 D/13 and E/4 at the eastern limit of the KRPA in the broad valleys of the east-flowing Takhini River and its tributary, Thirty-seven Mile Creek. Except for small areas of possible snow avalanching and eroded slopes along the Takhini River, the potential hazards in this area are generally subjective and result from active-layer soil processes.

5.5 NTS Block 115 A

This is the southern portion of the KRPA and includes 13 NTS sheets. Photo coverage is missing for a 2 km-wide band just north of the B.C. - Yukon border. Heavy shadow obscures a number of steep slopes on the available photo coverage (Figure 3).

A variety of slope hazards occurs in the area, with active soil processes predominating. Debris flow and debris flood fans are identified in hot spots along the Haines Highway north and south of the Takhanne crossing. There is large bedrock failure high above the Haines Highway south of the Takhanne. Other hot spots include areas of bedrock distress on high, shadow-obscured slopes north of the Takhanne River and east of the Tatshenshini River.

Heavily shadowed and severely fractured slopes above Kusawa Lake should be closely inspected to evaluate the possibility of landsliding into the lake.

5.6 NTS Block 115 B

This area includes two NTS maps (115 B/15,16) within the KWS. The upland area east of Vulcan Creek is a hot spot with bedrock landslides along the lower Slims River. Several debris flow and debris flood fans along the Alaska Highway are fed from sources in the alpine uplands on sheet 115 B/16 (Clague, 1982 and Gustafson, 1986).

See Appendix B.3 for a description of a debris flow that blocked the Alaska Highway in this area.

5.7 NTS Block 115 F

This area includes 6 NTS sheets mostly within the KWS. Shadows obscure steep slopes in a number of areas. Much of the area has very steep alpine terrain with widespread rockfall, snow avalanches, debris flows and several landslides. An interesting ancient landslide is located on the south shore to Tepee Lake (NTS 115 F/9).

The heavily braided Generc River is fed by the stagnating snout of the Klutlan Glacier (NTS 115 F/10). This river supplies much coarse bed load material to the White River which continues a braided course to a canyon on 115 F/9. The Generc River may be affected by jökulhlaups (Clague, 1982).

Debris flow and debris flood hazards are interpreted in a hot spot along the Alaska Highway on the west side of Miles Ridge (115 F/15). The photo detail in this area is limited by a stereo gap between adjacent flight lines.

5.8 NTS Block 115 G

This area of 15 NTS sheets has a variety of hazardous terrain with several hot spots mapped at 1:50,000 scale. The western portion of the area includes hot spots mapped within the KWS and Kluane National Park. Features in the park pose landslide, debris flow and debris flood hazards along the Alaska Highway on the west shore of Kluane Lake (Clague, 1981, 1982).

An exceptionally large landslide fan is located within the park just north of Congden Creek (115 G/2). This slide apparently diverted the course of the unnamed creek which now drains into Dutch Harbor on Kluane Lake. The old creek is blocked with slide debris and may contain organic material which could date this large landslide.

Several other hot spots are defined at significant landslides on steep shadowed slopes above Kluane and Tincup Lakes.

The narrow mine road corridor along Quill Creek (115 G/5,6) may be affected by snow avalanches. A shadowed, but apparently unstable, slope within the hot spot corridor and several nearby landslides are features of interest.

An area of faulting noted by Eisbacher and Hopkins (1977) is also described by Clague (1982). It is herein mapped as suspect slope distress. A possibly related series of fault traces lies just to the east and should be investigated to determine their possible significance to the seismic history of the area (Clague, 1979).

The Burwash and Duke River uplands (115 G/6) are an area of special interest because of widespread evidence of weak rock and fine grained soil deformation. Extraordinary "badland" gullied terrain occurs in the area of Amphitheatre Mountain (NTS 115 G/6, see Eisbacher and Hopkins, 1977).

5.9 NTS Block 115 H

This large area of 13 map sheets has comparatively subdued alpine terrain with snow avalanches, rock fall and debris flow and flood hazards. Active soil processes are very common. There is photo evidence of permafrost in the northern portion of this area.

Shadows obscure a significant number of steep slopes in the area and there is one photo-cover gap on the eastern limits of the KRPA (Figure 3). There is no detailed mapping of hot spots in this area.

5.10 NTS Blocks 115 J and K

This area includes 7 NTS maps in the northern area of photo coverage where the Alaska Highway reaches the Yukon-Alaska border (Figure 1). Shallow, active-layer, colluvial processes are dominant although avalanches, rockfalls and landslides are noted in high mountains maps 115 K/1 and 2. There is photo evidence for permafrost in the muskeg lowlands of the area.

Hot spot mapping at 1:50,000 scale is limited to a small area along the Alaska Highway where possible debris torrent and flood fans connect with 115 F/15 to the south.

6. GUIDELINES FOR DETAILED HAZARD EVALUATION

The procedures for assessing terrain hazards are somewhat formalized in British Columbia and the discussion presented in this section concerning objective terrain hazards is based on B.C. experience. It assumed that avoidance or proper engineering or construction is required to meet subjective or conditional hazards.

Consideration of landslide and snow avalanche and flood hazards is required under Section 734 of the B.C. Municipal Act which states that no subdivision approval or home improvements can be granted if a threat of such hazards exists. No waivers of liability are allowed because of third party concerns.

In general, the B.C. Ministry of Transportation and Highways (MoTH) gives preliminary subdivision approval, while the B.C. Ministry of Environment (MoEP) gives approval in areas of flooding and colluvial-alluvial fans including debris torrents and flood activity. Regional and local planning agencies develop guidelines for development which allows for input from the required agencies as well as advice from geotechnical consultants with an accepted specialty in terrain hazard studies. Elected officials determine what terrain-hazard risk (possibly expressed as a probability of occurrence) is acceptable for residential and commercial development.

The B.C. Provincial Emergency Preparedness (PEP) program, sponsored by the B.C. Solicitor General's office, prepares warnings and emergency responses to terrain hazards. PEP is currently (June 1989) engaged in planning and information programs for two large, and potentially damaging landslides which were recently discovered.

In British Columbia, flood-control works are normally designed to protect from a storm event with a recurrence of 1 in 200 years This means that such works have a 0.5% probability of being tested to the design limit on an annual basis.

The determination of the probability of landslide activity is more complex than flood analysis. This is because landslide occurrences (excepting water-laden debris torrents and floods) may not be triggered by storm events or follow hydraulic activity which can be analyzed statistically. Landslides may be triggered unexpectedly and behave in complex and sometimes unexpected ways. Factors of safety are normally applied in probability considerations, engineering analysis and determination of landslide run outs or set backs. Uncertainties regarding landslide activity imply that acceptance of landslide risk should be based on more conservative criteria than flood risk.

MoTH sends a form letter to subdivision applicants who are perceived to be at risk from terrain hazards in British Columbia. The letter gives development proponents good basic advice and a guideline for the probability of a landslide occurrence. The slightly edited letter reads as follows:

> "The Approving Officer believes that a geologic hazard exists and it does not appear in the public interest to approve the (subdivision) proposal as submitted. If you wish to explore this aspect further, you should engage a Professional Engineer experienced in geotechnical engineering. He may be able to recommend portions of the land for development, subject in some cases to permanent protective works. You should note that in many cases works are not economic and can often cost more than the total development is worth. A full study (may be expensive). If you decide to explore this further, it may be prudent to engage him to do a preliminary overview study (before a more detailed study). Such a preliminary study would likely include a review of air photos, regional reports on surficial geology, contour maps etc. and may not always need a site visit. If you then believe it is worth proceeding with a full study, you should ask him to identify the nature, extent and probable frequency of the (hazard) and to recommend permanent protective works or detailed building lines etc. It is difficult to quantify the frequency of occurrence of hazards but (your engineer) should be asked to think in terms of a 10% probability in 50 years, equivalent to 0.2% probability on an annual basis."

The MoTH letter deals with probability of landslide occurrence. It is important to note that the probability of property damage or loss of life is less than that of the occurrence. Theoretically, the risk of damage or injury can be reduced or eliminated by avoidance within a property, building design and limiting the duration of exposure.

The recognition of landslides on the ground and on aerial photographs is a specialist activity. Terrain hazard investigation is an increasingly specialized branch of geotechnical engineering and engineering geology. The determination of landslide probabilities requires consideration of a wide variety of physical evidence and much careful judgement. Investigations of snow avalanches is a separate, but related, field for which the procedures are more established (Perla and Martinelli, Jr., 1976) but still require specialist skills.

Hot spots on the 1:50,000-scale maps and areas of yellow or red on the 1:100,000-scale maps require geotechnical concern over terrain hazards. Red areas are hot spots requiring detailed evaluation and specialist skill in assessing objective hazards including landslides, snow avalanches, debris flows and related processes.

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RAMPTON, V. N, and S. PARADIS, 1981a: Surficial Geology and Geomorphology; Taye Lake, Yukon Territory. Geological Survey of Canada Map 14-1981, Scale 1:100,000.

RAMPTON, V. N. and S. PARADIS, 1981b: Surficial Geology and Geomorphology; Frederick Lake, Yukon Territory. Geological Survey of Canada Map 15-1981, Scale 1:100,000.

RAMPTON, V. N. and S. PARADIS, 1981c: Surficial Geology and Geomorphology; Pine Lake, Yukon Territory. Geological Survey of Canada Map 16-1981, Scale 1:100,000.

RYDER, J. M. and D. E. HOWES: Terrain information: a user's guide to terrain maps in British Columbia. Surveys and Mapping Branch, Province of British Columbia, 16 p.

RYDER, J. M. and B. MacLEAN, 1980: Guide to the preparation of a geologic hazards map. Working report for the British Columbia Ministry of Environment, Resource Analysis Branch. 17 p.

TERRAIN ANALYSIS AND MAPPING SERVICES LTD., 1980: Geologic and hydrogeologic interpretations of Destruction Bay, Burwash Landing and Champagne, Yukon Territories. Report for the Canada-Yukon General Subsidiary Agreement on Renewable Resource Information and Tourist Industry Development. 130 p and 1:20,000-scale terrain maps.

VARNES, D. J., 1974: The logic of geological maps, with reference to their interpretation and use for engineering purposes. United States Geological Survey Professional Paper 837. 48 p.

VARNES, D. J., 1978: Slope movement types and processes, *in* Landslides: Analysis and Control. United States National Academy of Sciences, Transportation Research Board Special Report 176. Edited by R. L. Schuster and R. J. Krizek, p. 12-34.

WETMILLER and S. G. EVANS, 1989: Analysis of earthquakes associated with the 1965 Hope Landslide and their effects on slope stability on the site. Canadian Geotechnical Journal, *in press*.

AERIAL PHOTOS

(Refer to photo index sheets at 1:250,000 scale)

ROLL NUMBER	FRAMES	DATE	APPROXIMATE SCALE (VARIES)	NTS BLOCK
A22997	001-170	8/72	1:70,000	115 A,F,G,H
A22999	131-183	8/72		
A23000	007-223	8/72	1:70,000	115 A,F,G,H
	228-244			
A23001	001-020	8/72	1:70,000	115 A
	023-042			
	171-234			
A24763	008-017	8/77	1:70,000	115 B, C
	065-072			
	082-089			
	139-147			
A25192	119-125	7/79	1:57,000	105 D
	159-156			
	219-266			
A25264	070-078	8/79	1:50,000	105 D
	112-120			
	180-189			
A25265	017-026	8/79	1:50,000	105 D
	178-185			
	205-212			
A25275	021-030	8/79	1:50,000	105 D
	040-049			
	083-090			
	100-108			
A25287	177-209	8/79	1:59,000	115 J and K
A25288	019-029	8/79	1:59,000	115 J and K
	030-065			
A25549	161-166	8/80	1:59,000	115 J and K
	168-172			

N.B. Photo scales are computed from flight information on some aerial photos and data provided by the National Air Photo Library in Ottawa.

Appendix A

HOT SPOT IDENTIFICATION (BY NTS BLOCK)

Block	Sheet	Description
105D		No hot spots mapped at 1:50,000 scale.
105E		No hot spots mapped at 1:50,000 scale.
115A	1(E)	Heavy shadow area on the west side of Kusawa Lake.
	2(SW)	Landslide, debris flow hazards along Haines Highway.
	2(E)	Suspect failure on shadowed slope north of Takhanne River.**
	2(N)	Debris flows on Vand Creek fan along Haines Highway.
	3(E)	Suspect failure on shadowed slope west of Tatshenshini River.
	8(E)	Unstable rock mass and highly fractured colluvial slopes on north side of Kusawa Lake.
	11(E)	Unstable rock masses and suspect fractures north of pass to the east of Granite Lake.**
115B	15(NE)	Vulcan Creek area and unstable slopes to the east above the Alaska Highway. Connects with 115 G/2 to the north.
	16(NW)	Unstable slopes east of Vulcan Creek and sources for debris torrent and flood hazards in the same area. Connects to 115 G/1 to the north.

** = no apparent threat to property or life

Block	Sheet	Description
115F	15(NE)	Debris flow and flood hazards along Alaska Highway on west side of Miles Ridge. Definition is limited by 500 m-wide gap in photo coverage with next flight line to the north (115 K/2).
115G	1(W)	Debris flow and flood hazards along Alaska Highway including Silver Creek. Connects to 116 B/16 to the south.
	2(E)	Extensive landslide, debris flow and flood hazards along Alaska Highway as far north as Congden Creek area.
	5(NE)	Quill Creek road corridor.
	6(NW)	Quill Creek road corridor including shadowed, apparently unstable slope and nearby landslide areas - possibly related to Holocene activity on the nearby Denali Fault System.
	6(SE)	"Holocene Faults" described by Eisbacher and Hopkins (1977) in Ptarmigan Creek drainage area. Other fault traces lie just east of their ridge-crest features. These features are of geologic interest.**
	6 (Central) SPECIAL NOTE:	Although terrain hazards in the Burwash and Duke River Uplands are mapped at scale of 1:100,000, there is much evidence of weak-rock and fine-grained soil deformation throughout the area. (See Eisbacher and Hopkins, 1977). The presently available 1:70,000-scale aerial photos are generally inadequate to map this area's terrain hazards at a scale of 1:50,000. **

** = no apparent threat to property or life

Appendix A (Cont'd)

Block	Sheet	Description
115G	10(SE)	Suspect failure on shadowed slope above east side of Talbot Arm - Kluane Lake.
	11(N)	Slump failure on shadowed slope above east side of Tincup Lake.
115H		No hot spots mapped at 1:50,000 scale.
115J		No hot spots mapped at 1:50,000 scale.
115K	2(E)	Debris flow and flood hazard connects to 115 F/15 to the south. Area of interest is obscured by fiducial marks on photo margins.

Appendix B

TERRAIN MAP LEGEND AND INTERPRETIVE INFORMATION

B.1 COLLUVIAL SURFACE MATERIALS

Colluvium ("C") is the predominant surface material on the study maps. It is defined as "Material that has reached its present positions as a result of direct, gravity-induced movement involving no agent of transportation such as water or ice, although the moving material may have contained water or ice." From the British Columbia Terrain Classification System (BCTCS), 1989, p. 11). Also see Ryder and Howes (1986).

Consistent with the specialized purpose of the inventory maps (Section 3, item 2), colluvium is broadly defined to include any near-surface soil material (mineral or organic) that may be subject to slope movements. Colluvium is often associated with grouped active-layer or alpine soil processes (see Appendix B.2) in this study. For information on the geologic origin of surface materials in the study area, refer to surficial geologic maps by Rampton (1978-1981 and Rampton and Paradis, 1981).

B.2 COLLUVIAL FANS AND APRONS

A colluvial fan can be a talus cone or rock fall fan. This study also classifies fans which appear (on aerial photos) to be affected by debris flows (rapid flowage of mud and coarse debris down a channeled course) as colluvial fans. Debris floods are runouts of sediment laden, muddy water at the foot of a debris flow channel. Debris flows and debris floods are transitional with fluvial processes but are classified as moderate to high hazards.

Many colluvial fans mapped on the 1:100,000 inventory sheets may, upon closer inspection or field investigations, be recognized as fluvial (alluvial) fans.

The lower case letter "a" as in "Ca" should be read as apron or colluvial apron respectively and taken to mean a series of coalescing fans.

B.3 DESCRIPTION OF A DEBRIS FLOW

At the south end of Kluane Lake a debris flow blocked the Alaska Highway at Mile 1057.1 in 1967. Hughes et al. (1972) offer a good description of a debris flow on a colluvial fan:

> "A small debris flow blocked the Alaska Highway in the summer of 1967 following a period of intense rainfall. The flow originated near the headwall of a small ravine at an elevation of about 5,200 feet (1,585 m). It then proceeded down the ravine and along the creek bed on the alluvial-fan at the mouth of the ravine. Three to five foot (1 m to 1.5 m) levees were built along the edges of the creek and some vegetation was uprooted and moved down the creek. The debris flow finally spread out as a fan at the break in slope near the highway, which here is at an elevation of 2,570 feet (785 m). The flow material is composed mainly of diorite boulders up to 8 feet (2.4 m) in diameter with a sandy silt matrix."

B.4 PERMAFROST and RELATED PROCESSES

The BCTCS (1989, p. 53) uses a "-X " symbol to map permafrost processes. The classification system also uses the symbol "-Z " for general periglacial processes including solifluction, cryoturbation and nivation. Because slope stability processes in the KRPA are so strongly conditioned by alpine activity, the symbol "-Z " is used extensively for all active-layer processes.

B.5 SNOW AVALANCHES

Snow avalanche tracks and run outs may be poorly defined on open alpine slopes and unforested and lowlands with scrub tundra growth. Snow avalanche hazards (marked by the BCTCS symbol "-A") may be over estimated throughout the KRPA. Variable snowfall patterns may also complicate the recognition of snow avalanche hazards.

B.6 GEOLOGICAL PROCESS SYMBOLS

The following geologic process symbols from the BCTCS (1989, p. 39) are widely used in this study:

Erosional Processes:

-V for gully erosion

Fluvial Processes:

-B for braiding channel;
-J for anastamosing channel;

Mass Movement Processes:

-A for snow avalanching;
-F for slow mass movements (e.g. distressed bedrock slope)
-R for rapid mass movements (e.g. rock falls or debris flows)

Periglacial Processes

-S for solifluction;
-Z for group alpine processes including frost heave and solifluction.

B.7 UNDIFFERENTIATED SURFACE MATERIAL AND STEEP SLOPES

Undifferentiated geologic materials are identified by "U" which should be interpreted to mean more than one type of surface material (including bedrock) outcropping on an slope. The symbol U is often associated with surface expression symbol "s" (steep) and geologic process symbols -V (gullying) and -F (slow mass movements) as in Us-VF.

Some areas of colluvium (C) may also be associated with the symbol "s" as in Cs-AV meaning steep colluvial slope with snow avalanches and gullying.

TEXTURE ①

(Particle sizes based upon Unified Soil Classification System and N.R.C. Field Description)

Specific Clastic Terms:

a	blocks	angular 203 mm plus
b	bouldery	203mm plus
k	cobbly	76 — 203mm
p	gravelly	5 — 76mm
s	sandy	.075 — 5mm
$	silty	.002 → .075mm
c	clayey	minus — .002mm

Common (Grouped) Classes:

d	mixture of fragments	
r	rubbly	angular cobbles and boulders
g	mixture of gravel and coarser	
-s-	silt and sand	mixture $ and s
f	fines	mixture $ and c

Organic Soils

e fibric **u** mesic **h** humic

Well-sorted materials are described by the use of a single textural term; less well-sorted and poorly sorted materials are described using two textural terms with the subordinate textural term given first.

SURFACE FORM ③

a	moderate slope unidirectional 15-26° (apron)	l	level
b	blanket	m	rolling
d	depression	p	plain
c	cone	r	ridged
f	fan	s	steep
h	hummocky (15-35°)	t	terraced
j	gentle slope	u	undulating (hills-hollows to 15°)
k	moderately steep uidirectional (26 - 35°)	v	veneer

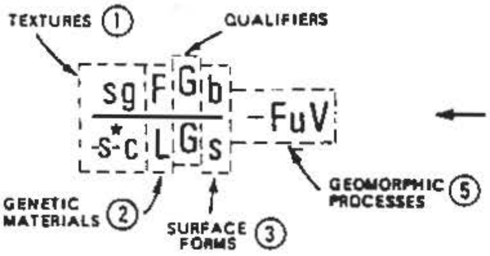
The use of two (or rarely three) surface forms together implies there is a mixing of discrete forms and not a combination of intermediate forms. Blanket indicates deposits greater than 1 metre thick; veneer indicates deposits less then 1 metre thick. The use of s is reserved for erosional slopes generally greater than 26° on both consolidated and unconsolidated materials.

SURFICIAL MATERIAL ②

A	Anthropogenic▲	M	Morainal (Till)
C	Colluvial▲	O	Organic▲
D	Weathered Bedrock	R	Bedrock
E	Eolian	U	Undifferentiated
F	Fluvial (Alluvial)	V	Volcanic
F^G	Glaciofluvial	W	Marine
I	Glacier Ice▲	W^G	Glaciomarine
L	Glaciolacustrine		
L^G	Lacustrine		

▲ Materials for which formative processes are assumed to be active; all others are assumed inactive. In areas mapped by photo interpretation with little or no fieldwork, textures of surficial materials may not be shown. Textures are then assumed to lie within a range defined in a supporting document.

EXAMPLE



The horizontal bar indicates the upper material overlies the lower material.

Interpretation: A blanket of sandy gravel and coarser glaciofluvial material (outwash) overlies water-bearing silt-sand and clayey glaciolacustrine (glacial-lake) deposits in steep erosional slopes. The entire unit is subject to soil slumps and active gullying.

QUALIFIER ④

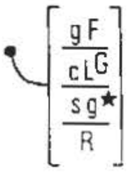
These superscripts are used to qualify genetic materials or geomorphic processes.

G	Glacial	B	Bog	Reserved for organic genetic materials
A	Active (contemporary)	F	Fen	
I	Inactive (has ceased)	S	Swamp	

Superscript modifiers A and I are used only where process states are contrary to the assumptions made for genetic materials and geomorphic processes.

SITE-SPECIFIC STRATIGRAPHY

Brackets tied to point locations shown stratigraphic details at significant exposures. Locations typically consist of isolated sections on steep erosional slopes. Asterisk (★) shows units with seepage. Materials may be texturally and/or genetically identifiable. Unit thickness not given or implied.



Example:

Gravelly alluvium (texturally and genetically identifiable) overlying clayey glaciolacustrine deposits overlying water-bearing sandy gravel (texturally identifiable); the entire sequence rests on bedrock.

GEOMORPHIC PROCESSES ⑤

▲ Geomorphic processes assumed to be active: others are assumed inactive.

ARCTIC, ALPINE AND PERIGLACIAL PROCESSES	– C	Cryoturbated ▲
	– N	Nivated ▲
	– S	Soliflucted ▲
	– Z	Grouped (–C, –N, –S) ▲
	– X	Permafrost ▲
	– H	Kettled
	– T	Thermokarst ▲
FLUVIAL PROCESSES	– B	Braided ▲
	– E	Channelled by Meltwater
	– J	Anastomosing ▲
	– M	Meandering ▲
	– U	Flooded ▲
	– I	Irregularly sinuous ▲
MISCELLANEOUS EROSION PROCESSES	– D	Deflated ▲
	– K	Karst ▲
	– P	Piping ▲
	– V	Gullied ▲
	– W	Washed ▲

MASS MOVEMENT PROCESSES

All of these processes are assumed to be active

–A Snow Avalanched

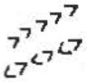
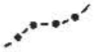
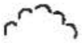
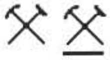
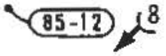
–F Extremely slow to moderate rates of failure in soil and bedrock
- c soil creep
- g rock creep
- e earthflow
- u soil slump
- m rock slump
- s debris slide
- r rockslide

–R Moderate to extremely rapid rates of failure in soil and bedrock (1.5m/d to > 3m/s)
- m rock slump
- s debris slide
- r rockslide
- d debris flow
- t debris torrent
- a debris avalanche
- f rockfall
- x rock avalanche

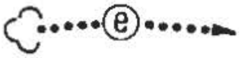
Where possible, lower case letters are given as subscripts to –F or –R. In some cases more than one subscript may be used.

ON-SITE SYMBOLS

These and other symbols are used to show features of special interest and limited extent.

	Drumlin, crag-and-tail or drumlinoid ridge
	Glacial fluting or striae
	Esker. Known and unknown direction of depositional flow
	Large glacial meltwater channel
	Small glacial meltwater channel
	Moraine ridge
	Cirque
	Erosional escarpment
	Landslide escarpment
	Snow avalanche track. Runout limits are not implied.
	Borrow pit: active and inactive
	Mine or quarry: active and inactive
	Observation of frozen ground or ground ice; observation of thaw
	Spring or seep; saline seep
	Numbered sample location; numbered photo orientation

Linear Landslide Symbols and Mass Movement Types

	Rapid mass movement (debris torrent) with known point source
	Slow mass movement (earthflow) with landslide escarpment source

Limits of landslide runout are not implied by these symbols

COMPOSITE UNITS

=	Units are of roughly equal extent (1:1)
/	Unit to the left is more extensive than the unit to the right (approx. 2:1)
//	Unit to the left is much more extensive than the one to the right (>2:1)

Modified by Thurber Consultants Ltd. from "Terrain Classification System British Columbia", B.C. Ministry of Environment Manual 10.

TERRAIN MAPPING LEGEND

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CALGARY EDMONTON VANCOUVER VICTORIA