October 22, 2008 File: 4-1-5

Fraser Valley Regional District
45950 Cheam Avenue
Chilliwack, BC V2P 1N6

Attention: Mr. G. Daneluz, Manager of Forward Plans

FINAL OVERVIEW GEOTECHNICAL HAZARD ASSESSMENT REPORT – ELECTORAL AREA F (HATZIC VALLEY), FRASER VALLEY REGIONAL DISTRICT

Dear Sir:

Qcd Geotechnics (Qcd) is pleased to submit this report on geotechnical (geologic) hazards in Electoral Area F. The work was conducted in accordance with my proposal dated March 6, 2007 and a Service Agreement between the Fraser Valley Regional District (FVRD) and Qcd dated March 12, 2007.

Use of this report is subject to Qcd's Statement of General Conditions in Appendix D.

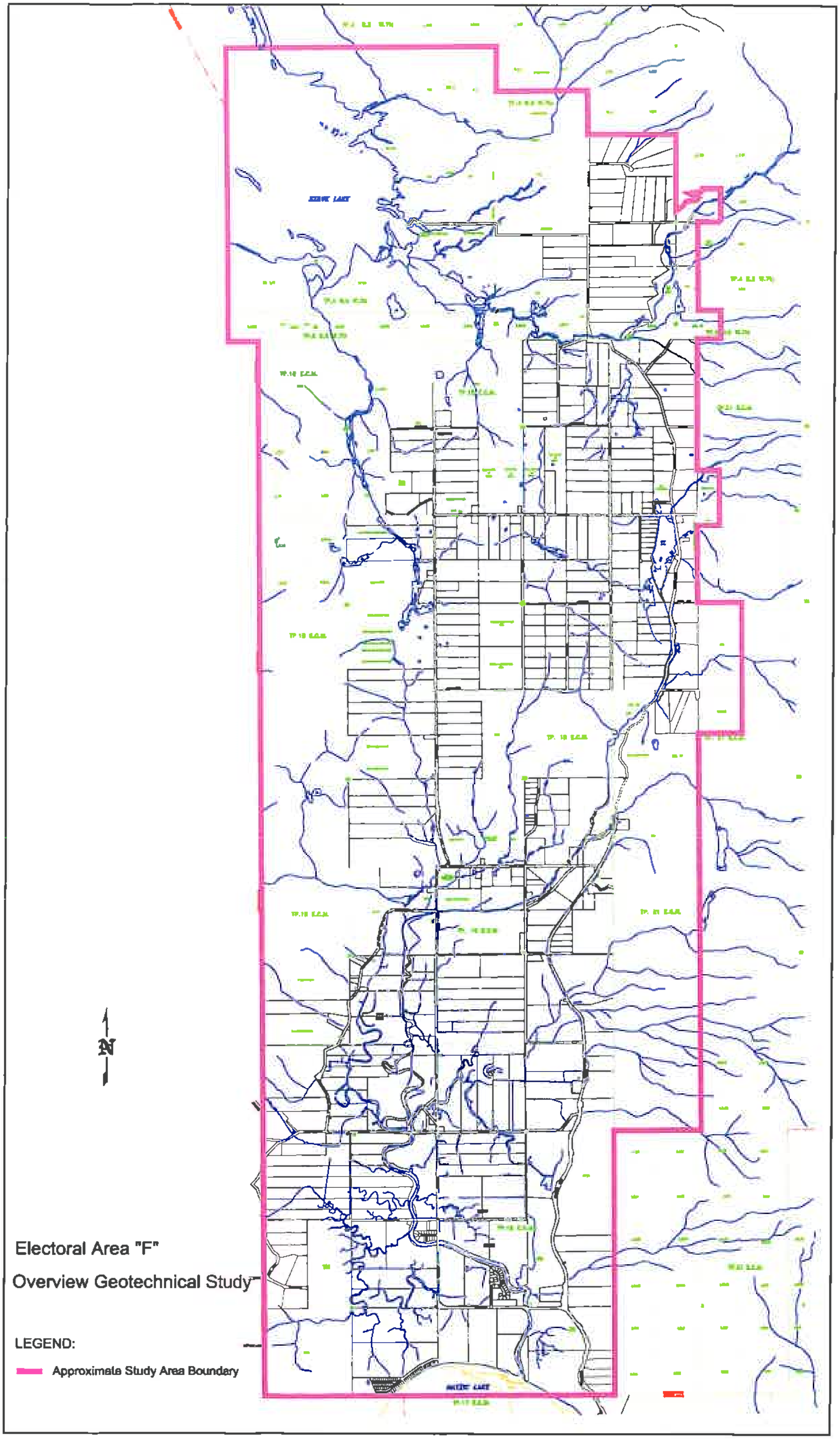
1. INTRODUCTION

The study area (Figure 1) comprises an 80 km^2 rural-residential area in the southern Coast Mountains of BC. The focus of the study is a valley floor that extends south from Stave Lake to Hatzic Lake, an oxbow lake in the Fraser River floodplain. The valley is confined by steep mountain slopes on the east and west sides. Destructive debris flows and debris floods have initiated on high slopes and run out beyond their base. One flow killed a farmer some 50 years ago. Mountain creeks and the Fraser River have flooded portions of the north and south lowlands.

1.1 Purpose of Work

The work is to guide FVRD development and building permit reviews in potential hazard areas. The report and its maps will also direct the attention of and guide Qualified Professionals (professional engineers and geoscientists; hereinafter *QPs*) who conduct hazard assessments to support these permit applications. Findings will also assist in emergency response planning.

Figure 1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LEGEND:
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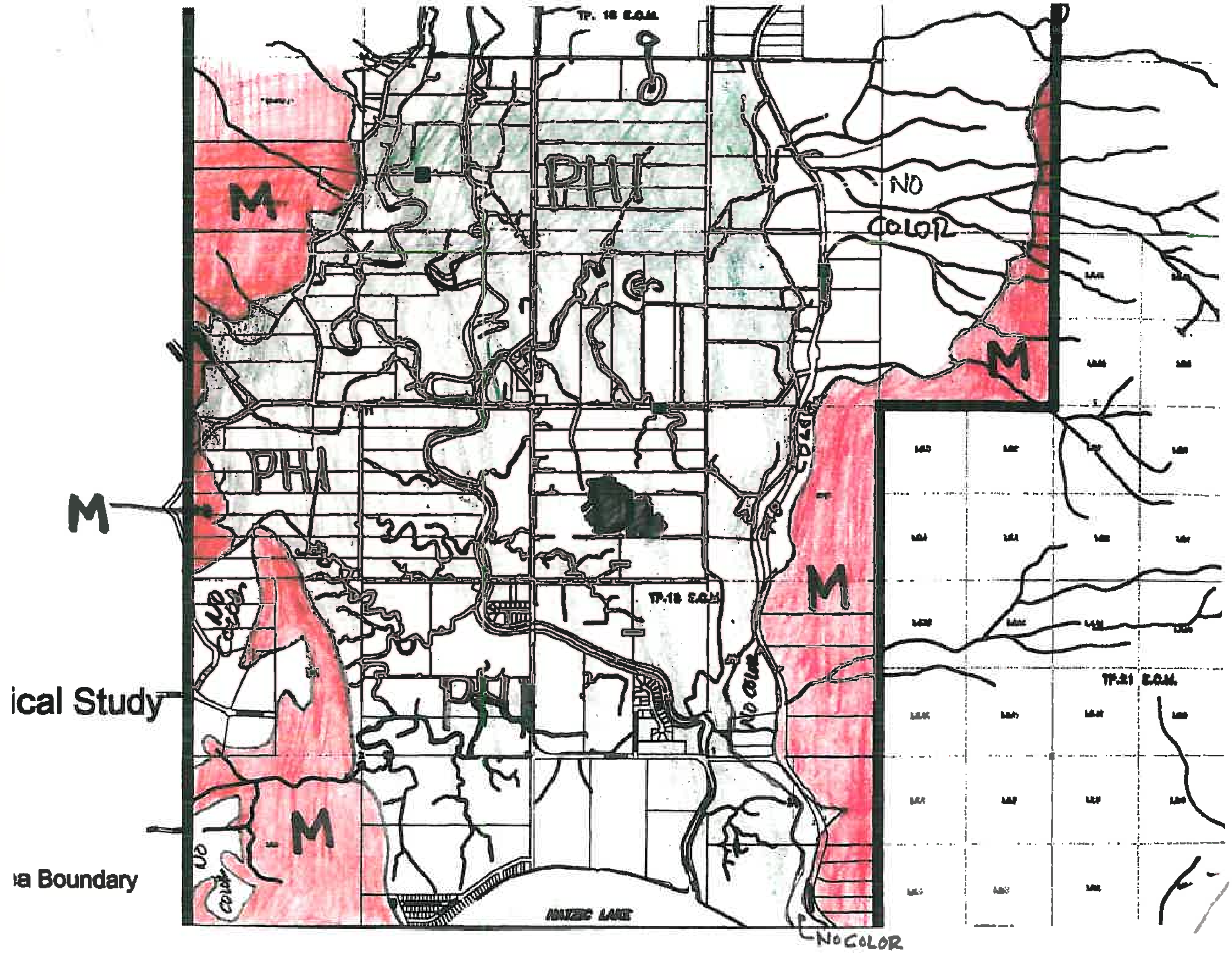

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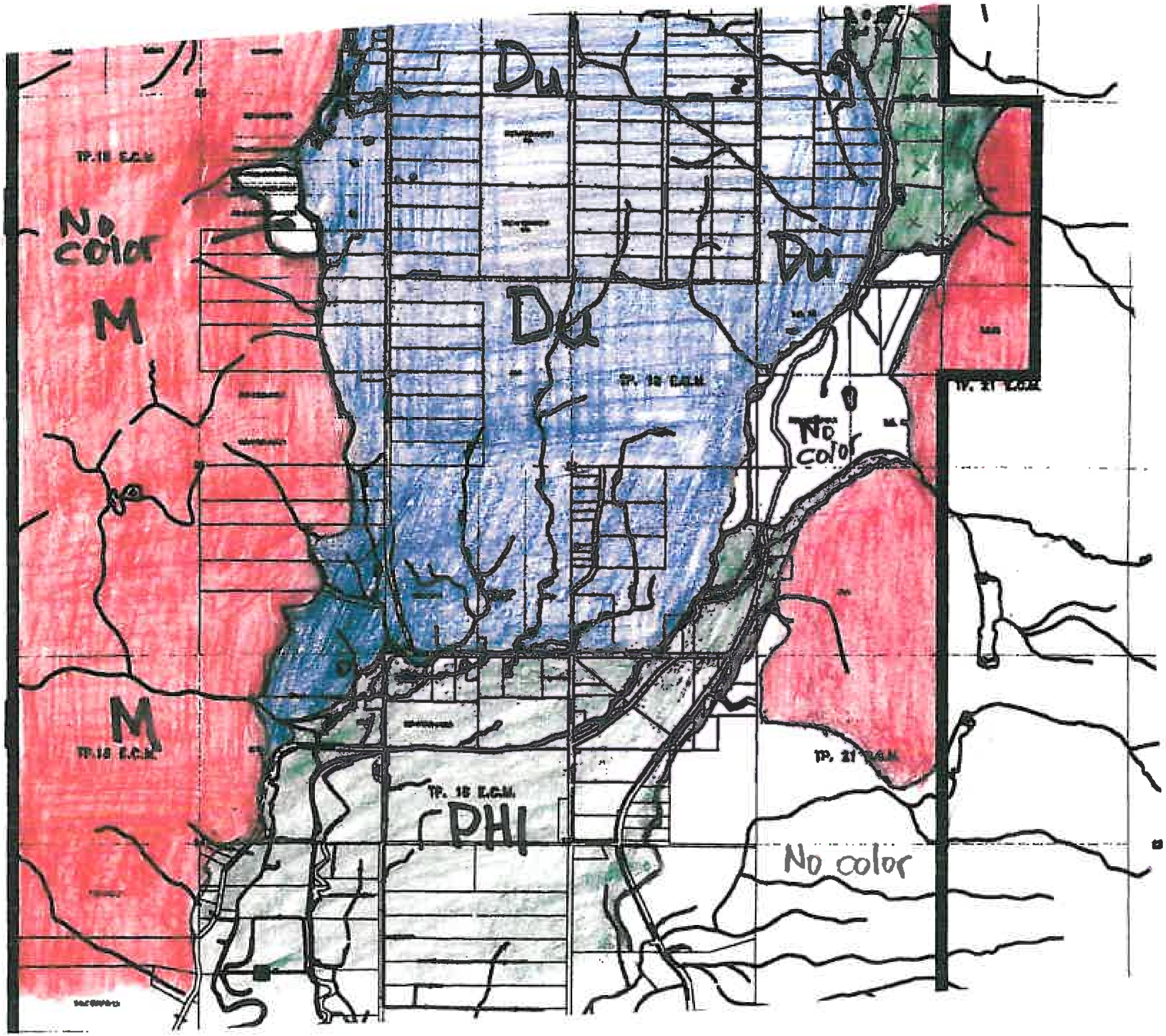
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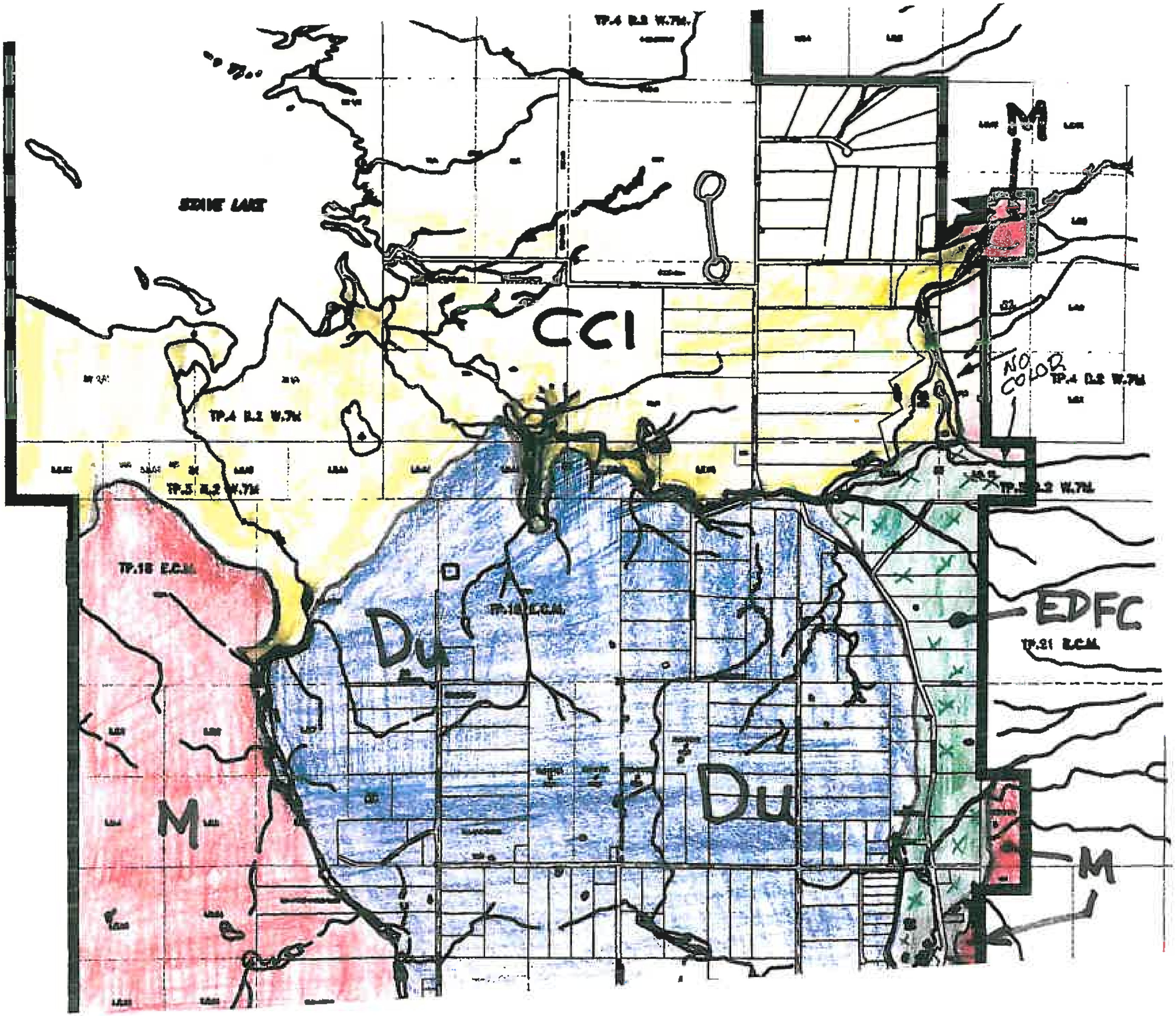
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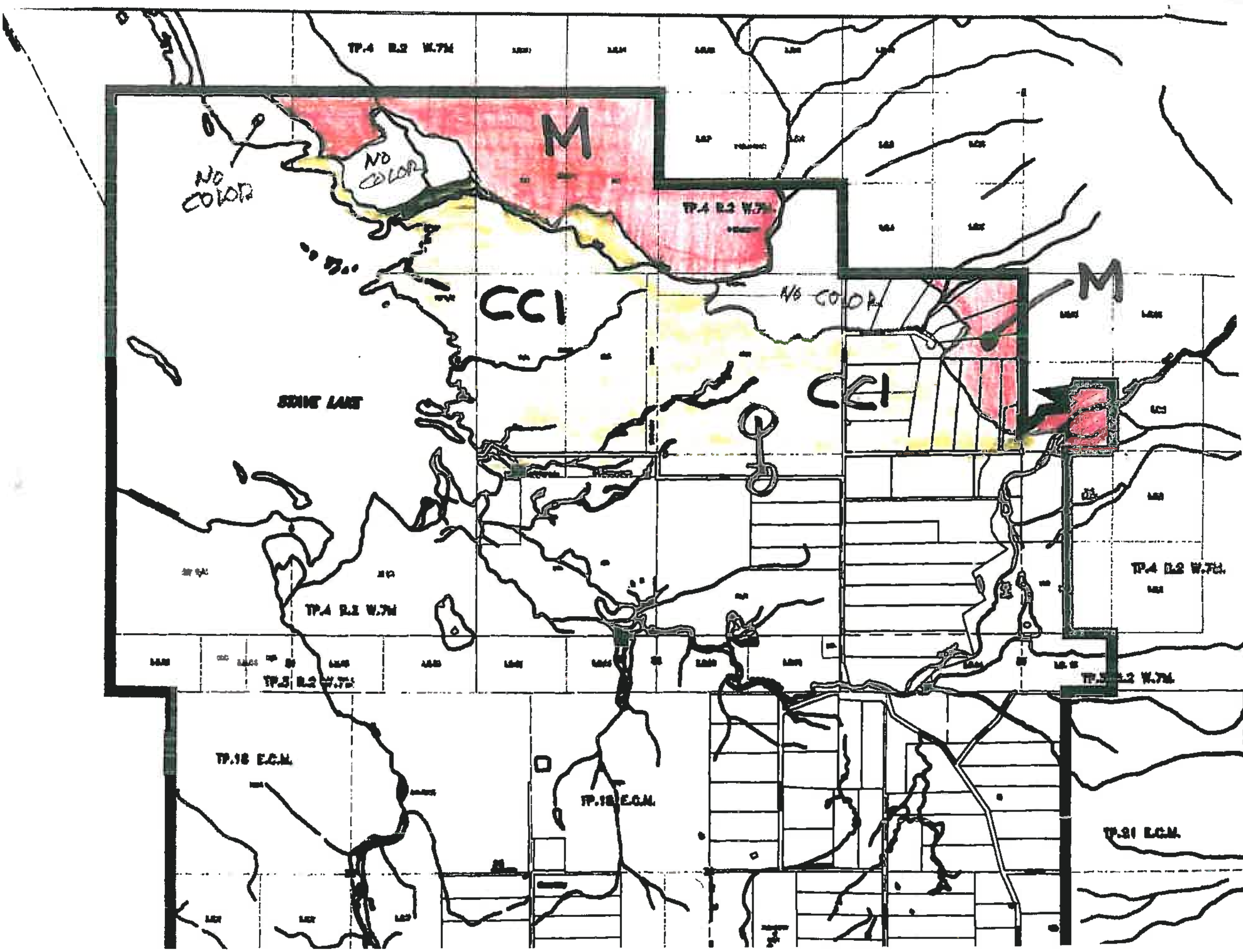
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Potential hazard areas are plotted the Geotechnical Hazard Map, (hereinafter the *Hazard Map*). Most are naturally occurring landslides, floods (including water inundation and deposition of alluvial debris) and seismic hazards. Known debris flow tracks and years of occurrence are shown on the Hazard Map. The best way to deal with geotechnical hazards is to avoid them. If required and practical, the design, construction and maintenance of protective works might be considered. Incautious development work can trigger unexpected slope hazards.

The Hazards Map utilizes a contour base map with 2 and 10-m contour intervals. It and this report form one document to be read and interpreted together.

The FVRD requires qualified professionals to estimate quantitative (numeric) hazard probabilities in support of residential and other types of development permit applications. Although these estimates are usually subjective to some degree, they require documentation and explicit reasoning. Professionals can also use engineering analyses (*e.g.* factor-of-safety approaches) to support their findings, particularly in seismic risk assessments.

QPs must be familiar with the nomenclature and logic of hazard and risk assessment procedures including the definition of partial risk[1]. Use of the latter emphasizes needs for hazard avoidance and is a fundamental basis for FVRD probability-based permitting thresholds (Cave, 1993). QPs must follow FVRD reporting guidelines and fully understand Association of Professional Engineers and Geoscientists of BC (APEGBC) professional practice guidelines for legislated landslide hazard assessments (APEGBC, 2008). Adjunct literature and reports are listed in Appendix B of this report. The FVRD library may contain other reports that should be reviewed for information.

1.2 Bases of Findings

Qcd relies on the relative accuracy of 2 and 10-m base map contours to define valley-floor terrain features on the Hazards Map. Terrain features are poorly resolved on steep, forested mountain slopes. Limited field measurements suggest that valley contours reasonably approximate actual slope gradients – primary factors in assessing slope stability. Photo interpretation work is

[1] Partial risk is defined as the product of the probability of occurrence of a specific hazardous landslide and the probability of that landslide reaching and adversely affecting a specific element at risk, typically a proposed or existing building (See Wise M, G Moore and D VanDine 2004).

supplemented by about 35 hours of road and foot traverses, observations of scattered soil exposures and discussions with six land owners. Qcd is familiar with 2003 debris flows on the east side of the valley having conducted some 20 hr of emergency response work there (Thurber Engineering Ltd., 2003). The present study is conducted at an overview (reconnaissance) level of effort. Therefore, actual hazard and terrain conditions may vary from what are shown on the Hazard Map and described herein.

1.3 Report Structure

The area's geology is summarized in Section 2 then discussed in somewhat more detail in following sections. Area F Terrain Complexes are described in Section 3. Section 4 contains expanded discussions of hazards. Section 5 is a brief review of seismic hazards. The Hazard Map Legend, References, and a list of Aerial Photos Used are contained in Appendices A through C.

Hazard Map units are color coded to provide first-approximations of hazard probabilities and intensities. The hazard mapping is intentionally precautionary and conservative in outlook. Detailed work is required to confirm or revise Hazard Map information.

2. GEOLOGY

The bedrock geology is mapped in general detail by (Monger and Journeay, 1994). Granitic rock (quartz diorite) is only exposed on mountain slopes. Bedrock structural discontinuities are evident in the field but unmapped by Monger and Journeay. Glacial till and slope debris form discontinuous soil covers on the bedrock-controlled slopes.

Alluvial and glacial deposits on the south valley floor are mapped in general detail by Armstrong, 1978. A plateau of glacial drift that dominates the central valley is formed of dense, till-like surface deposits.

3. HAZARD INTERPRETATION FRAMEWORK: TERRAIN COMPLEXES

Five terrain complexes are defined on Figure 1[2] to facilitate Section 4 discussions. Each is formed by distinctive landform assemblages:

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[2] Terrain complexes on Figure 1 should not be confused with terrain units and potential slope hazards shown on the Hazard Map and described in Appendix A.

3.1 Bedrock-controlled Mountain Slopes (M on Figure 1)[3]

These slopes were scoured by Pleistocene-Age glacial ice. They are now forested and laced with ravines and cliffs. The highest slopes are situated above the northeast valley where Durieu Ridge rises 1,200 m above the valley floor. Western slopes rise 500 to 600 m to broad, glacially eroded crests. Very steep slopes and cliffs line the southwest valley side.

Many landslides occurred in abandoned clear cuts and forest roads on Durieu Ridge during heavy rains in October 2003. Several descended into steep valleys and generated debris flows on Carratt, Eng and McNab Creeks. The same storms triggered debris flows on nearby Field and Saporano Creeks as well as Dale Creek further south. Rock is quarried for industrial aggregate on two slopes, one on the west and one on the east valley sides.

3.2 Cascade Creek-Carratt Creek lowland (CCl)

This broad lowland is located at the north end of the study area. Stave Lake extends north from its west end and the lowland itself is formed of alluvium deposited Cascade and Carratt Creeks, both of which have histories of water and debris floods.

3.3 Durieu Upland (Du)

Widely scattered soil exposures show that surface materials are dense, moist to dry, till-like soil. Most exposures show gravel and cobbles encased in the finer grained material - sandy silt with a trace to some clay (ML fines in the Unified Soil Classification). Water-well logs compiled by Armstrong, 1978, 1994 and Magwood, 2004 show this soil overlies sandy to gravely aquifers on the central upland.

The upland is a moraine-like feature but Armstrong (1978) identifies its glacial marine affinities. It may have formed at the front of a northward advancing glacier ice lobe (or between two fronts including one to the north) when late Ice-Age marine water extended well into the Fraser lowland. If the surface material is actual till, it may have formed as glacier ice advanced down the Fraser Valley some 12,000 years ago (Sumas Re-advance) and overran and buried marine deposits.

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[3] The Hazard Map shows lower to middle portions of north, east and western mountain slopes. The highest slopes are shown on other topographic maps (TRIM base) available from the provincial government.

Three creeks flow along the Duryea upland margins. Lag ace Creek flows south from Allan Lake on the east margin. Two (hereinafter Belcherton Creek *North* and Belcherton Creek *South*) flow in opposite directions from a low drainage divide at the foot of mountain slopes on the west margin. The latter creeks occupy a continuous valley confined by bedrock slopes to the west and upland glacial deposits on the east. These observations suggest the through valley was first incised by late Ice-Age melt water discharging (perhaps sub-glacially in part) from the north or south along the mountain slopes. The valley will intercept most western slope hazards and thereby protects most residential land higher on the east side.

Three creeks flow down the south slopes and have eroded ravines along their courses. From east to west, they are, Sue Brook, Oru Creek and Durieu Creek. They reach the southern lowland where they are deflected westward in ditches and by deposits from Pattison Creek's dominant fan deposits. The Seux and Oru Creek interfluve narrows to an erosional ridge along upper Seux Road. It may define the headward margin of an old landslide tentatively identified along Oru Creek's ravine (see Hazard Map).

Seepages occur on the ravine slopes. Upland water wells draw groundwater from a productive aquifer tens of metres below the upland surface (Magwood, 2004). Conceivably, it is sustained by Stave Lake (Pacific Hydrology Consultants Ltd. *in* Terra Engineering Ltd., 1991). The three ravines may be affected by seepage from this aquifer but aerial photos and old trees on the ravine slopes indicate they were eroded long before Stave Lake dam was built and raised the natural lake level by some 20 m.

Topographic depressions occur at the head of some upland ravines. They might indicate that subsurface erosion occurs along near-surface aquifers so the depressions may be preliminary indicators of headward ravine erosion. These features, area seepages and the fine-grained matrix of upland soils suggest that concern is warranted over soil sloughs and slumps and possibly over seismically induced slides on the moderate to steep soil slopes. Larger slides may occur where creeks erode ravine foot slopes; soil slides were observed where Lagace Creek undermines thin soils on such slopes.

3.4 East Debris Fan Complex (EDFC)

This complex is formed by coalescing debris flow fans including that of Field Creek at the north end, Carratt Creek, Eng Creek, McNab Creek and Saporano Creek at the south end[4]. The lower creek channels fill with alluvial sediment continuously remobilised from older debris flow material. This sediment requires continuous removal to maintain culvert flows beneath Sylvester Road.

Sandy to gravely sediment from Eng and McNab Creeks is deposited in Allan Lake. It is drained southward by Lagace Creek which is also included in this complex. Portions of the creek channel are congested with gravely sediment confined between by Sylvester Road and the upland slopes.

A farmer was killed in his barn by a debris flow that probably occurred in March or April of 1962 near east Hartley Road. Muddy debris probably reached lower Eng Creek and ran out to Sylvester Road. The post-event clean-up area and the ravine debris-flow track are shown on 1962 aerial photos (Appendix C).

3.5 The Pattison Creek-Hatzic Prairie lowland (PHl)

This lowland is formed of fine to coarse-grained alluvial sediment deposited by Lagace Creek, Pattison Creek, creeks issuing from the Durieu Upland, alluvial fans on the west side of the valley (Kenworthy and Currie Creeks) and Hartford, Dale and Scorey Creeks on the east side. The southern area lies within the Fraser floodplain. Pattison Creek's debris fan and its sediment-charged but largely embanked channel dominate the north half of the area. Pattison Creek's steep drainage basin contains several landslide areas which shed much debris into this very active creek. The upper south basin contains a distinctive bedrock slide.

4. GEOTECHNICAL HAZARDS

4.1 Mountain Slopes

General

A variety of hazards originate on steep mountain slopes; many of them can be triggered by intense rain and rain-on-snow. (The fatal debris flow was reportedly triggered by rain-on-snow). Debris flows can be initiated by comparatively small soil slides which descend to ravine channels. Descent channels and banks are then scoured as flowing debris accumulates volume and momentum. Flow

[4] The drainage divide between Cascade Creek-Carratt Creek and Pattison Creek-Hatzic Prairie Lowlands is located between Carratt and Eng Creeks.

debris usually contains significant volumes of bouldery and organic debris.

It is reiterated that forested mountain slope details are ill-defined by Hazard Map contours and even less so by 20-m contours on TRIM mapping that extends beyond Hazard Map limits to the mountain crests. QPs *must* study stereoscopic aerial photo images to assist field evaluations of mountain slope hazards[5].

A large landslide occurred above Eng Creek during the October 2003 storms. It added to debris that ran down the creek from the abandoned clear cuts and forest roads on the highest slopes (Thurber Engineering Ltd., 2003 and BGC Engineering Ltd, 2004a).

Soil and rock slides can originate on more-or-less planar 'open' slopes which must also be investigated with difficult work. Very steep open slopes are poised above the alluvial valley floor north and south of Currie Creek. Complex open and gullied slopes between Kenworthy Creek and the Durieu Road area are discussed in Section 4.6.

Forest Operational Areas

Mountain slope clear-cut logging and forest road work can significantly affect slope stability. Considerable attention has been paid to possibilities of adverse forest operational effects over the last decade (Wise, Moore and VanDine, 2004). The fatal 1962 slide appears to have initiated just below an old clear cut or wildfire limit. In 2003, large debris flows originated in abandoned forest operational areas on Durieu Ridge. They severely impacted rural residential land at the foot of Carratt, Eng and McNab Creeks. The FVRD library contains reconnaissance-level forest operational hazard mapping of the southeast study area by Denny Maynard and Associates Ltd. (1995).

Detailed Hazard and Risk Assessments

Mountain slopes are difficult to reconnoitre and evaluate because they may resist even the most energetic and expensive foot access and because hazards are subject to contingencies of topography, forest cover, intense rainfall, snow cover and accidents of nature.

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[5] Appendix C is not a complete list of available provincial or private aerial photos. Photo research is required to investigate specific areas. Historic but not necessarily complete, serial coverage can be borrowed at cost from UBC's Geographic Data Center.

It is anticipated that moderate to high hazard probabilities and hazard magnitudes prevail on most steep mountain slopes and where known debris flow paths are shown on the Hazard Map. In some cases, QPs and permit review officials may have to invoke the Precautionary Principle. It states: cautious decisions are warranted if risks of serious or irreversible harm involve significant scientific uncertainties (UN, 1994).

Application of this principle is not new; it is a form of cautious judgment. However, the significance of conflicting or uncertain evidence is relatively new considering demands of now widely applied formal hazard and risk assessment procedures.

4.2 Cascade Creek-Carratt Creek Lowland

This broad valley floor is exposed to varying degrees of debris flow, debris flood and inundation hazards from Cascade Creek, Carratt Creek and, to a lesser degree from North Belcherton Creek. Two alluvial fans and an apparent glacial terrace are identified included at the north end of the lowland. Draw downs of lake water may adversely affect lake-margin slope stability.

Alluvial Fans

FVRD Bylaw 681 2005 designates a floodplain building control elevation at 83.8 m geodetic around the margin of Stave Lake. Its fluctuating water levels are controlled by the hydroelectric dam at Stave Falls, west of the study area. Aerial photo interpretation indicates that soft, wet organic soils are widespread where ground water breaks out on the fan west of Sylvester Road.

Schedule A of the Bylaw defines Cascade Creek and Carratt Creek alluvial fan areas. It should be noted that Bylaw's area boundaries do not exactly conform to those defined herein. Further consultation is required to reconcile any important differences.

Cascade Creek is contained by a 1.7-km long dyke system ('Non-Standard Dykes' in the Bylaw) from its valley outlet in Cascade Falls Regional Park to north Sylvester Road. FVRD is responsible for maintaining the dykes as part of a local service area but maintenance is constrained by lack of legal access. Channel maintenance last occurred in 2006. A 60-m water course building setback applies along the creek as far west as Stave Lake.

Carratt Creek is contained by gravel embankments composed of flood debris removed from the channel between the mountain slopes and Sylvester Road. The Bylaw also identifies these embankments as 'Non-Standard Dykes' and 30 m water course building setback applies along the creek to its confluence with Cascade Creek. It is assumed that the embankment system was not built and is not maintained to provide flood protection for adjacent lowlands.

Section 5 of Bylaw states, "All developments on properties on alluvial fans are subject to Section 56 of the (BC) Community Charter and/or Section 920 of the Local Government Act." This means that qualified professionals may have to refer to or acquire creek hydrologic and survey data for flood hazard assessments. Qcd recommends these assessments should be conducted by qualified professionals with training and experience in creek hydrology and creek hydraulic engineering.

4.3 Durieu Upland

Potential hazard zones are defined along the boundaries of the three ravines on the south slope of the Durieu Upland, along the nearly continuous slope crest on the east side of Belcherton Creek (North and South) and along ravines and crests above Legace Creek. A few small and isolated hazard areas are defined on the upland surface.

As noted in Section 3.3, scattered exposures indicate upland soils are formed of dense mixtures of sand, silt and a trace of clay. The material contains a variety of particle sizes including sand and gravel, cobbles and boulders. Recently excavated or eroded soil exposures stand very steeply, a reflection of soil density and some cohesion. Some upland water wells draw on a granular aquifer defined by Magwood, 2004 in a subsurface soil profile along Hartley Road. Perched aquifers seep along the ravine slopes. It is conceivable that the queried landslide above Oru Creek was conditioned by hydrostatic pressures along a within a formerly buried aquifer.

Identification of upland hazard areas is largely based on conservative judgment over unknown soil and ground water conditions. Exploratory test pits or drill holes may be needed to support slope hazard evaluations.

Fine-grained components of the upland soil cause it to lose strength when it is excavated and handled by heavy machinery. If dumped on slopes and wetted, this material will be prone to slope movements which might range from soil creep to sloughs and slumps. Most of the ravine slopes have adjusted their inclinations over thousands of years to moderate angles ranging from 18^0 to 27^0 (33% to 50%) from the horizontal. Lesser slope angles are found along small creeks and steeper slopes occur along portions of some ravines.

One landowner observes that ravine slopes have tended to steepen in historic time where organic debris was dumped from land clearing operations. This is probably because impaired slope drainage can result in dumped and intact soil movements on the susceptible, fine-grained soil slopes. Most moderate to steep ravine slopes are identified as potentially hazardous and modest hazard setback zones are defined along ravine crests. Spoon-shaped ravine-head depressions are included in precautionary hazard zones.

4.4 East Debris Fan Complex

This hazard area contains well documented debris-flow and debris-flood paths (see Hazard Map, Thurber Engineering Ltd., 2003 and BGC Engineering Ltd, 2004a). October 2003 activity on Carratt, Eng and McNab Creeks originated in abandoned forest operation areas. This was not the case for 2003 debris flows on Field, Saporano and Dale Creeks. Each creek has a perceptible debris-flow fan.

SRK-Robinson 1993 maps a 1992 debris flow path on lower McNab Creek. It turned southwest and ran out on and along the south side of Kussman Road. Channel embankments built with material taken from the lower channel held 2003 debris in its path to Allan Lake.

There are no engineered debris containment or deflection works on any of the five creeks. Soil embankments along the south side of Kussman Road and at the foot of Saporano Creek provide unknown levels residential protection.

4.5 Pattison Creek - Hatzic Prairie Lowland

This area is exposed to varying degrees of debris-flow, debris-flood and inundation hazards from the Pattison-Lagace Creek systems, Belcherton Creek South and the Fraser River. Portions of the Pattison Creek area are subject to flooding associated with sediment aggradation in Hatzic Slough.

Alluvial fans are mapped on lower Currie and Kenworthy Creeks on the west side of the valley and Hartford Creeks (east of Seux Road at Sylvester Road), Dale Creek (informally named and situated directly above Dale Road) and Scorey Creek on the east side. Moderately sloping and gullied bedrock controlled terrain is observed above the Hartford Creek fan systems and the Dale and Scorey Creek fans are partly controlled by bedrock.

FVRD Bylaw 681 2005 designates a Fraser River flood control elevation of 9.3 m geodetic from the south lowland northward to Belcherton Creek near Durieu Road. The floodplain area meets Pattison Creek's alluvial fan area which is also defined in the Bylaw.

Pattison Creek Fan System

Pattison Creek floodway hazards are relatively well detailed by Associated Engineering Ltd., 1992; BC Ministry of Environment, 1980; BC Ministry of Forests, 1997; Golder Associates Ltd., 2003; northwest hydraulic consultants, 2005 and Thurber Engineering Ltd., 1990. The creek is contained by earth embankments along much, but not all, of its course. The embankments provide an undefined but minimal degree of flood protection for adjacent lowlands. Flood debris is periodically recovered from sediment basins along its channel (BC Ministry of Environment, 1984) and used for general construction purposes. The Bylaw defines 60 m watercourse building setbacks on the upper creek and 30 m setbacks on the lower creek (also identified as Lagace Creek) from just west of the Sylvester Road bridge to Hatzic Slough at Dale Road.

As noted in Section 3.1, Bylaw 681 2005 states, "All development on properties on alluvial fans are subject to Section 56 of the (BC) Community Charter and/or Section 920 of the Local Government Act." Thus, qualified professionals may have to refer to or acquire creek hydraulic and survey data to conduct flood hazard assessments. I recommend that these be conducted by qualified professionals with training and experience in creek hydrology or creek hydraulic engineering.

Alluvial-Colluvial Fans

Currie, Kenworthy, Hartford and portions of the Dale and the Scorey Creek fans, appear to have lesser hazard magnitudes than the East Debris Fan Complex. Lower portions of several fans lie within the Fraser floodplain.

4.6 Southwest Hazard Area

There are small debris fan complexes on the west side of the valley along Stave Lake Road between the Kenworthy Creek alluvial fan and Durieu Road. Steep mountain gullies and a nearly continuous line of cliffed and forested slopes with several bedrock promontories are poised above the lowland (see Hazard Map).

A 1980 Boxing Day debris flow severely damaged a house east of Stave Lake Road (#11445) but there were no fatalities (Skermer, 1981 and BC Ministry of Environment, 1983). A potentially destructive debris flow occurred nearby on November 24, 2004. It was triggered by a logging road fill failure and ran out across Stave Lake Road onto a residential property at #11428 (BGC Engineering Ltd, 2004b). A more recent flow appears to have begun in a mountain-slope forest operation area more than 1 km NW of the intersection of Durieu and Stave Lake Roads (Hazard Map)[6].

The historic debris flows and associated steep ravines raise concerns. The line of very steep, bedrock controlled, forest and cliff slopes as well as resident reports of an audible and apparently large rock fall northwest of Durieu Road also raise concern. Aerial photos suggest the south bedrock promontory (Hazard Map) may have tension features on its upslope side. These features are located above rural residential areas extending from Kenworthy Creek to about 800 m north of Durieu Road. It is recommended that the Southwest Hazard Area be inspected for due-diligence reasons with a helicopter reconnaissance. This should be done as soon as possible after seasonal snow disappears from the slopes.

5. EARTHQUAKE-INDUCED SOIL LIQUEFACTION AND LANDSLIDE HAZARDS

Provincial Government Regulation M268 was proclaimed on December 15, 2006. It states that a 10% in 50 yr (475-yr return) seismic acceleration can be applied in slope stability analyses for residential and other buildings defined under the 2005 Building Code[7]. This acceleration is lower than the 2% in 50 yr (2,475-yr return) acceleration used in structural engineering design work. (also see APEGBC, 2008).

[6] March 1969 aerial photos (BC flight line 5321 – Appendix C) offer exceptionally good views of slope features west of Belcherton Creek.

[7] It is important to note that a lower probability (2% in 50 year or 2,475-year return) but greater seismic acceleration is to be applied in structural engineering design work under the 2005 Building Code.

The lower mainland region of BC has not experienced a strong earthquake in many years but it will. It is essentially impossible to decipher evidence for ancient earthquake-induced landslides. Recent discoveries of some 13 surface fault ruptures extending from the Olympia and Seattle areas north to the Canadian border prove there have been strong, shallow earthquakes since the end of the Ice Age 11,000 years ago. The 4-km long Boulder Creek fault rupture in Kendall, Washington, 25 km southeast of Hatzic Valley, provides geologic evidence of two earthquakes in the last 10,000 years. Fault slip measurements imply events of M 6.8 to 7.2 (Siedlecki, 2007).

APEGBC (2008) provides geotechnical analytical techniques for evaluating the seismic stability of soil slopes. BC specialist task force design guidelines are available for buildings on liquefiable sites in accordance with the 2005 National Building Code (Task Force Report, 2007).

In ideal circumstances, government agencies commission geotechnical investigations to produce data or maps showing ground susceptibilities to seismic shaking and soil liquefaction. No information is available for Hatzic Valley. Specialized and expensive geotechnical drilling, groundwater investigations and geotechnical analyses will be required to evaluate soil liquefaction potentials for valley floor building sites and where necessary, for seismically induced landslide risks.

This study suggests that portions of the Cascade Creek-Carratt Creek and the Pattison Creek-Hatzic Prairie Lowands may be susceptible to seismic liquefaction. Durieu Upland ravine crests, ravine slopes and ravine foot slopes may be susceptible to seismic slope instability.

Thank you for the opportunity to conduct the Area F study. Please do not hesitate to contact me if you have any questions.

Yours truly,
Qcd Geotechnics

R. F. Gerath, P.Geo.
Engineering Geologist

PROFESSIONAL PROVINCE OF R. F. GERATH BRITISH COLUMBIA GEOSCIENTIST

Oct. 22, 2008

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APPENDIX A

AREA F TERRAIN AND TERRAIN HAZARD CLASSIFICATION LEGEND

Note: Potential hazard classifications *precede* bracketed terrain feature identifications on the FVRD Hazard Maps.

HAZARD PROCESSES

1 Potential hazard processes. Combination of capitalized and lower case letters. Most terms defined by Qcd; others defined in the Terrain Classification System for BC (Howes and Kenk, 1998).	**2** Qualifiers Subscripts defined by Qcd
Example: **Ls_R** Potential Landslide involving bedrock **1**	**2**

Erosion Hazards

P Soil piping and caving
V Gully or ravine erosion

Fluvial (Alluvial) Hazards

Fl Flood (inundation)
Dfl Sediment-laden water flow (see * below)

Landslide Hazards

Df Debris Flows
Dfl Debris Flood *
Dff Debris flows and debris floods
Ds Debris slides
Dss Debris sloughs and slumps

Ls_R Rock slide
Ls_S Soil Slide

Rf Rock fall

Ush Collective term for *any or all* of the above. Undifferentiated slope hazards
Uh_M Undifferentiated hazards along outside margins of terrain polygon

TERRAIN FEATURES

Note: Bracketed terrain feature classifications *follow* potential hazard classifications on the FVRD Hazard Maps.

1 Surficial Materials. Capitalized. Based on Terrain Classification System for BC but adapted by Qcd for this study. More than one forms a terrain complex with the first one dominant	**2** Surface Expressions Lower case. Based on Terrain Classification System for BC but adapted by Qcd for this study. May be more than one with no significance given to order.	**3** Qualifiers Subscripts defined by Qcd
Example **Rss_x** Bedrock-controlled steep slopes. Terrain complex (mountain slopes) **1 2 2 3**		

Fluvial (Alluvial) Materials (F) and Surface Expressions

F^Af Alluvial fan
F^Af_x Alluvial fan complex (several fans in lateral contact)
F^Ap Alluvial floodplain

Colluvial Materials (C)

Cf Colluvial (debris flow) fan .

Fluvial-Colluvial Materials and Surface Expressions

FCf Alluvial-Colluvial-fan (Alluvial processes dominant)
FCf_x Alluvial-Colluvial fan complex (several fans in lateral contact)
FCf_R Alluvial-Colluvial fan, bedrock controlled in part

Colluvial-Alluvial Materials and Surface Expressions

CFf Colluvial-Alluvial fan (Colluvial processes dominant)
CFf_x Colluvial-Alluvial fan complex (several fans in lateral contact)

Till or Till-Like Surface Materials and Surface Expressions

Mb Thick till (depths > 2 m)
Mbv Variably thick till depths > 2 m to < 1 m. Bedrock controlled terrain and bedrock exposures implied
Ms Steep till-like soil slopes (may be bedrock at shallow depths)
Mms Moderate to steep till-like soil slopes
Mhd Ravine headwater depression in till-like soils

Fluvioglacial (Ice-Age meltwater) Materials and Surface Expressions

$F^{G}b$ Thick fluvioglacial materials (>2 m)
$F^{G}t$ Fluvioglacial terrace (kame terrace)
$F^{G}h$ Fluvioglacial hill (kame)
$F^{G}u$ Fluvioglacial undulating (kame deposits)

Bedrock and Bedrock-Controlled Slopes

Rms Bedrock-controlled, moderate to steep slopes
Rr Bedrock ridges
Rs Bedrock–controlled slopes. Steep but relatively uniform.
Rss_x Bedrock- controlled steep slopes. Complex mountain slopes.

Organic and Wetland Materials

Obv Variably thick organic or wetland soils depths > 2 m to < 1 m
<u>Obv</u> Organic deposits overlying active alluvial fan materials
$F^{A}f$

NAH No apparent (slope) hazards

Appendix B

List of References

(* Contains drill hole or test pit information)

*Armstrong, JE, 1984. Geological Survey of Canada Paper 83-23, Environmental and engineering applications of the surficial geology of the Fraser Lowland, BC. 54 p.

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Appendix C
Aerial Photos Used

(Vertical aerial photos are used for stereographic viewing in terrain hazard work. All aerial photos owned by Fraser Valley Regional District)

Date (d/m/y)	Line No.	Image No.	Comments
10/01/52	BC 1691	007-008	E-W line centered on Durieu Rd. Small scale, B&W, laminated.
1953	BC 1621	043-044	N-S line shows unstable areas in Eng-McNab and other creek basins prior to logging on Durieu Ridge.
1962	BC 4067	152-153	E-W line shows debris flow track and clean-up area just north of Hartley Road east. This debris flow killed a farmer in his barn.
04/28/63	BC 5062	115-118 194-197	E-W lines, Hartley Road south to south to Dale Road area. Medium scale, B&W, laminated.
05/10/68	BC 7058	031-036 095-100	E-W lines. Lower numbers roughly centered on McNab Ck; higher numbers on Carratt Ck. Medium scale, B&W.
03/12/69	BC 5321	010-115 161-166	E-W line centered on Dale Rd. area. Medium scale, B&W. E-W line centered on Durieu Rd. Medium scale, B&W
03/19/71	BC 5406	162-163	E-W line centered on Dale Rd. area. Small scale, B&W, laminated.
03/19/71	BC 5407	031-033	E-W line centered on Allan Lk. area. Small scale, B&W.
05/31/74	BC 5580	047-049	E-W line centered on Pattison Ck., south of Durieu Rd. Medium scale, B&W, laminated.

07/14/76	BC 5725	106-110	E-W line centered on Allan Lk. Small scale, B&W.
06/27/79	BC79044	175-179	E-W line covers to northern limit of study area. Medium scale, B&W.
06/25/79	BC79055	082-086	E-W line covers south portion of study area. Large scale, B&W. Good resolution.
06/25/79	BC79055	141-151	E-W line centered on Pattison Ck., south of Durieu Rd. Large scale, B&W. Good resolution of clear-cut portions of upper Pattison Ck.
09/20/83	BC83057	149-154	E-W line roughly centered on Kussman Rd. Medium scale, B&W. Shows extent of clear-cut logging and forest road activity in upper basins of Carratt, Eng and McNab Cks.
?/?/1993	BCB93029	210-215	E-W line roughly centered on Allan Lk. Medium scale, B&W. Shows clear cut areas Pattison Ck. north to Carratt Ck.
?/?/1993	BCB93030	063-067	E-W line roughly centered on Lundgren Rd. Medium scale, B&W. Shows most of upper basin of Pattison Ck.
04/20/04	SRS 6928	057-059	E-W line roughly centered between Kussman and Lundgren Rds. Medium scale, color, laminated except for No. 057 light paper copy.

Appendix D
Qcd GEOTECHNICS STATEMENT OF GENERAL CONDITIONS

1. STANDARD OF CARE

This study and Report are prepared in accordance with generally accepted applied geoscience or geo-environmental consulting practices in this area. No other warranty, expressed or implied, is made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to me, Robert F. Gerath, P.Geo., doing business as Qcd Geotechnics (hereinafter Qcd), by the Client, communications between Qcd and the Client, and to any other reports, writings proposals or documents prepared for the Client relative to the specific site described herein, all of which constitute the Report.

In order to properly understand the suggestions, recommendations and opinions expressed herein, reference must be made to the whole of the report. Qcd cannot be responsible for us by any party of portions of the report without reference to the whole report.

3. BASIS OF REPORT

The Report has been prepared for the specific planning and permitting objectives and purposes that were described to Qcd by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document, subject to the limitations provided herein, are only valid to the extent that this Report expressly addresses proposed objectives and purposes, and then only to the extent there has been no material alteration to or variation from any of the said descriptions provided to Qcd unless specifically requested by the Client to review and revise the Report in light of such alteration or variation or to consider such representations, information and instructions.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT Qcd's WRITTEN CONSENT TO ITS CLIENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS Qcd EXPRESSLY APPROVES. The contents of the Report remain Qcd's copyright property. The client may not give, lend, or sell the Report, or otherwise make the Report, or any portion thereof, available to any person without Qcd's prior written permission. Any use which a third party makes of the Report is the sole responsibility of such third parties. Unless expressly permitted by Qcd, no person other than the Client is entitled to rely on this Report. Qcd accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Hazards, Terrain Units and Soil Descriptions, Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Observational or sampling work implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between actual points inspected or sampled.

b) Actual conditions may vary significantly between the points observed, interpreted or sampled and the Client and all other persons making use of such documents or records with my express written consent should be aware of this risk and this report is delivered on the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents conditions at locations observed, interpreted or sampled at the time of the work. Where special concerns exist, or the client has special considerations or requirements, the client should disclose them so that additional or studies or investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to me. Qcd has relied in good faith upon representations, information and instructions provided by the Client and others concerning the study area. Accordingly, Qcd cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by me. Qcd is entitled to rely on such representations, information and instructions and not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

6. RISK LIMITATION

Applied geoscience and geo-environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause an accidental release of those substances. In consideration of the provision of the services by Qcd, which are for the Client's benefit, the Client agrees to hold harmless and to indemnify and defend Qcd from and against any and all claims, losses, damages, demands, disputes, liability and legal investigative costs of defense, whether for personal injury including death, or any other loss whatsoever, regardless of any action or omission on the part of the Company, that result from an accidental release of pollutants or hazardous substances occurring as a result of carrying out this Project. This indemnification shall extend to all Claims brought or threatened against the

Company under any federal or provincial statute as a result of conducting work on this Project. In addition to the above indemnification, the Client further agrees not to bring any claims against the Qcd in connection with any of the aforementioned causes.

7. SERVICES OF SUBCONSULTANTS AND CONTRACTORS

The conduct of applied geoscience and geo-environmental studies frequently requires hiring the services of individuals and companies with special expertise and/or services which Qcd does not provide. Qcd may arrange the hiring of these services as a convenience to Clients. As these services are for the Client's benefit, the client agrees to hold Qcd harmless and to indemnify and defend Qcd from and against all claims arising through such hirings to the extent that the Client would incur had he hired those services directly. This includes responsibility for payment for services rendered and pursuit of damages for errors, omissions or negligence by those parties in carrying out their work. In particular, these conditions apply to the use of drilling, excavation and laboratory testing services.

8. CONTROL OF WORK AND JOB SITE SAFETY

Qcd is responsible only for the activities of myself on the job site. The Client acknowledges that he, his representatives, contractors or others retain control of the site and that I never occupy a position of control of the site. The Client undertakes to inform Qcd of all hazardous conditions, or other relevant conditions of which the client is aware. The Client also recognizes that Qcd activities may uncover previously unknown hazardous conditions or materials and that such a discovery may result in the necessity to undertake emergency procedures to protect Qcd as well as the public at large and the environment in general. These procedures may well involve additional costs outside of any budgets previously agreed to. The Client agrees to pay Qcd for any expenses incurred as a result of such discoveries and to compensate through payment of additional fees and expenses for time spent by Qcd to deal with the consequences of such discoveries. The client also acknowledges that in some case the discovery of hazardous conditions and materials will require that certain regulatory bodies be informed and the Client agrees that notification to such bodies by Qcd will not be a cause of action or dispute.

9. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Qcd cannot accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or in part thereof, which may be based on information contained in the report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.