

**HEMLOCK VALLEY OFFICIAL COMMUNITY PLAN  
STAGE 1 STUDY  
OVERVIEW OF GEOTECHNICAL HAZARDS**

Report

to

**FRASER VALLEY REGIONAL DISTRICT**

Thurber Engineering Ltd.  
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A handwritten signature in black ink, appearing to read "R. F. Gerath", located below the professional seal.

## SUMMARY

This report is an overview (reconnaissance-level) assessment of geotechnical hazards in the Community of Hemlock Valley area in the Fraser Valley Regional District. Hazards in Hemlock Valley include snow avalanches, rock falls, debris landslides, debris flows and creek flooding and erosion.

The primary purpose of this report is to guide area citizens, District building inspectors, District planners and professional engineers and geoscientists in interpretations of 6 1:5,000-scale contour theme maps which are part of this report. The maps are on file with the Fraser Valley Regional District.

The map themes are:

1. Hazard Zonation
- 2A Avalanche Hazard Limits -- Residential Areas
- 2B Landslide Hazard Limits and Safeline Locations -- Residential Areas
3. Geologic Hazards
- 4, Surface and Near-Surface Earth Materials
5. Slope Classes (% and ° from horizontal)
6. Limits of Clear Cutting based on September 4, 1966 Aerial Photos

Hazard runout zones and horizontal setbacks (safelines) from tops of slopes are shown in subdivided residential areas. Limits of hazard areas mapped outside residential areas require definition in more detailed studies. We do not map snow avalanche hazards in Hemlock Valley's operational ski area.

District building inspectors will request site-specific hazard evaluations (permit reviews) for building permit applications in hazard areas and safeline zones defined by this study. The evaluations are mandated by Section 699 of the BC Municipal Act. Permit reviews will be conducted by professional engineers and geoscientists with required training or experience. Although the overview study provides professional guidance, it is expected that engineers and geoscientists will independently identify ground and hazard conditions to support of future permit reviews. Permit reviews will require work by geotechnical or hydraulic engineering professionals as well as professional geoscientists and engineers who specialize in snow avalanches.

All residential lots are subject to BC Ministry of Environment and Lands covenants which require a minimum 30 m building setback from and 3 m elevation above any water course.

A typical residential lot in Hemlock Valley is 20 m by 30 m in dimension. Many building sites are constrained by lot dimensions and proximity to steep, potentially unstable slopes. Safeline zones account for uncertainty over the long term stability of these slopes. Long return period snow avalanche hazards occur on each side of Edelweiss Drive. Snow avalanche hazards will decrease in this area as 30 year old trees grow to maturity uphill of Edelweiss Drive.

There are about 270 subdivided lots in the community of Hemlock Valley. Our overview hazard assessment finds about 47 % of the lots are exposed to snow avalanche, landslide or other hazards with estimated probabilities of occurrence greater than 10% in 50 years (roughly 1:500 annually).



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Figure 1 - Location Plan

GLOSSARY

STATEMENT OF GENERAL CONDITIONS

REFERENCES

APPENDIX A - Overview Avalanche Hazard Assessment by D&E McClung  
Enterprises Ltd.

APPENDIX B - Theme Map Legends

THURBER ENGINEERING DRAWINGS (submitted separately)

14-50-42-1 Hazard Zonation

14-50-42-2 Hazard Limits and Safeline Locations

14-50-42-3 Geologic Hazards

14-50-44-4 Surface and Near-Surface Earth Materials

14-50-44-5 Slope Classes

14-50-44-6 Limits of Clear Cutting on September 4, 1966



## 1. INTRODUCTION

Thurber Engineering Ltd. (TEL) has completed an overview (reconnaissance-level) study of geotechnical hazards in the Hemlock Valley Official Community Plan (OCP) area in accordance with our July 6, 1998 proposal to the Fraser Valley Regional District (FVRD).

Use of the TEL report is subject to the enclosed Statement of General Conditions.

## 2. PURPOSE OF STUDY

The purpose of this study is to define hazard areas to guide building permit evaluations required by Section 699 of the BC Municipal Act.

## 3. SCOPE OF WORK

TEL work involved office studies including aerial photo interpretation, review of available geotechnical engineering reports in the area and map preparation. We completed four days of field work in Hemlock Valley.

Hazard runout zones and horizontal setbacks (safelines) from tops of slopes are shown in subdivided residential areas. Limits of hazard areas mapped outside residential areas require definition in more detailed studies. We do not map snow avalanche hazards in Hemlock Valley's operational ski area.

Several OCP boundaries do not follow ridge drainage divides (Figure 1). For mapping purposes, if a ridge is higher than the adjacent OCP boundary, our mapping extends outside the boundary to the top of the ridge (e.g. Mount Klaudt area).

The mountain basin north of Mount Keenan is reserved for the community's water supply. No residential building is allowed in this area but it is included in our overview evaluation.

Technical terms are printed in bold where first used in the report. They are defined in alphabetic order in a glossary that follows text and legends which accompany 6 maps with different themes:

1. Hazard Zonation;
2. Hazard Limits and Safeline Locations;
3. Geologic Hazards;
4. Surface and Near-Surface Earth Materials;
5. Slope Classes (% and ° from horizontal)
6. Limits of Clear Cutting on September 4, 1966.



The overview of landslide and flood hazards is conducted by Thurber Engineering Ltd. Potential snow avalanche sites on the east slopes of Mount Keenan are evaluated by D&E McClung Enterprises Ltd. (DEM). DEM's report is Included in Appendix A and its snow avalanche hazard zonation is shown on Theme Map 2.

The theme map base shows Sakwi Creek originates in the bedrock canyon on the east side of OCP area. We understand others define Sakwi Creek as the one that flows just below west Sakwi Creek Road. We suggest area citizens name all creeks and branches for ease of future reference.

#### **4. LOCATION**

The OCP area is entirely contained in the Fraser River drainage basin. Most of the area contains headwaters of Sakwi Creek which drains south to the Harrison River (Figure 1). Mountain ridges to the north and west separate this basin from others which drain into the Chehalis River and Harrison Lake.

#### **5. FOREST HISTORY**

Hemlock Valley is located in the Coastal Cedar and Hemlock Biogeographic Zone characterized by prolonged wet and snowy winters and brief warm, dry summers (BC Ministry of Forests, 1988).

The earliest available aerial photos for Hemlock Valley were taken in 1952 (see References; the photos are on file at the Fraser Valley Regional District in Chilliwack). The valley was entirely forested then. Unfortunately, a significant portion of the east slopes of Mount Keenan is obscured by shadows so it is difficult to interpret the full extent of snow avalanche activity on the upper to middle slopes. The photos do show a multi-track snow avalanche path that runs out near the south end of what is now Edelweiss Drive. They also show snow avalanche run out limits above what is now Snowmist Place and the community's sewage disposal beds.

1966 aerial photos show most of Hemlock Valley area was clear cut (Theme Map 6). Many of the existing roads follow logging roads evident on these photos. The lack of forest cover makes the 1966 images valuable for photo interpretation.

1996 colour aerial photos show the Hemlock Valley much as it is today with 30 year old trees established in some formerly logged areas.

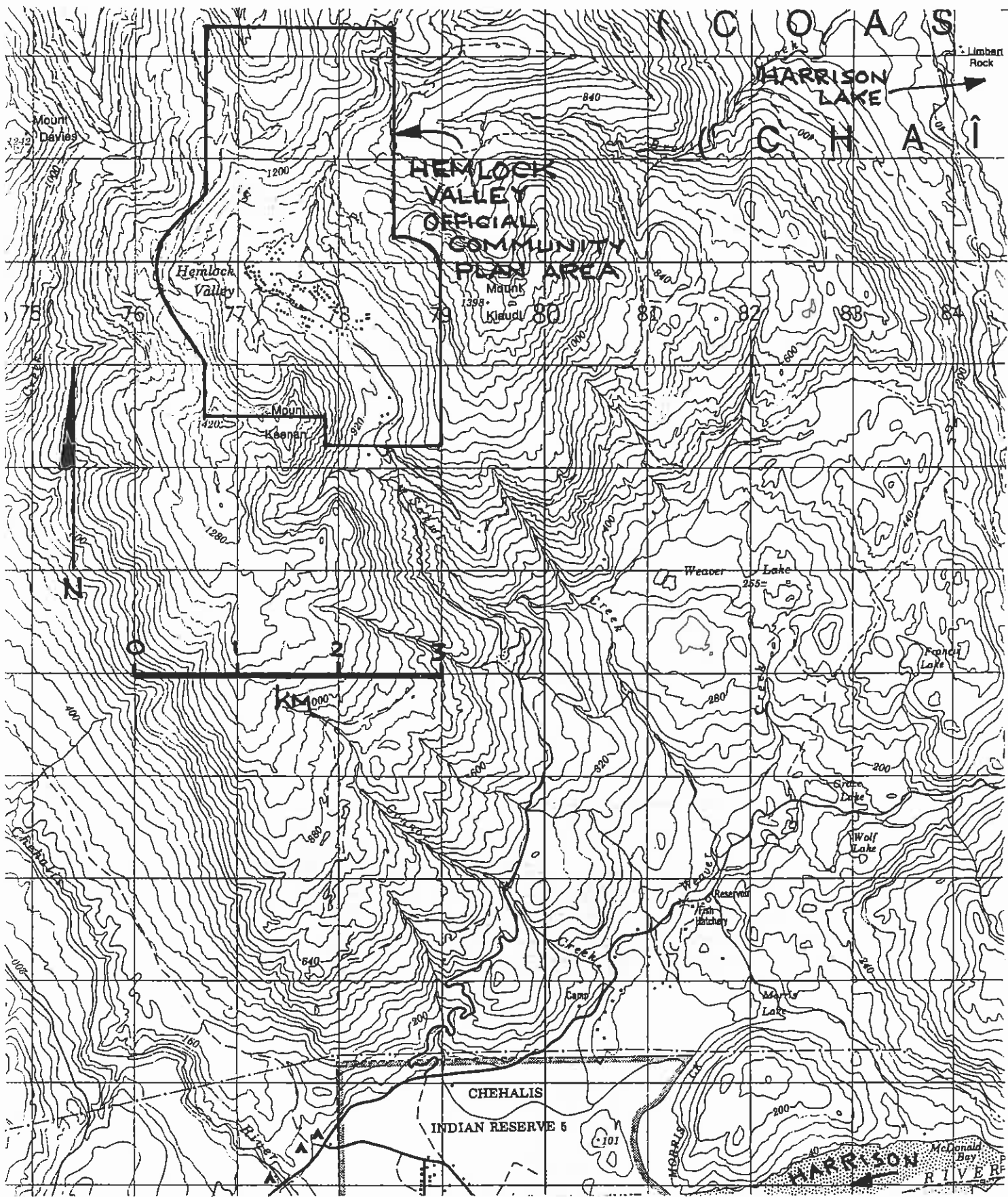


Figure 1: Location plan showing Hemlock Valley Official Community Plan area. Base map from west portion of NTS 92 H/5 - Harrison Lake

## 6. GEOLOGY AND GEOMORPHOLOGY

### 6.1 Bedrock Geology

Reconnaissance mapping published by the Geological Survey of Canada (Roddick et al., 1979) shows the Hemlock Valley area is underlain by metamorphosed volcanic and sedimentary rocks of the Harrison Formation. Small bodies of granitic rock are mapped near the summit of Mount Klautd. The shapes of many surface features are controlled by shallow bedrock.

The Harrison Formation has several types of bedrock. One characteristic rock is tough, light-coloured **felsite** quarried north of the community for various construction purposes. The Harrison Formation is also structurally complex and a variety of ancient fault and fracture systems are evident near the crest of Mount Keenan, along the steep upper canyon of Sakwi Creek, and from the south slope of Mt. Klautd to just west of Weaver Lake (beyond the map area).

### 6.2 Geomorphology

Scoured bedrock surfaces show Late-Pleistocene glacier ice flowed south through the Hemlock Valley prior to the great regional deglaciation 11,000 years ago. In general, ice flows reduced the valley floor and steepened the valley sides. The north-facing mountain basin that provides the community water supply is a **cirque** formed by vigorous ice erosion over several cycles of Pleistocene glaciation.

Currently hazardous geomorphic processes (geologic hazards) are shown on Theme Map 3. The hazards include **creek floods, creek erosion and deposition, gullying, snow avalanches, rock fall** and soil landslides such as **debris slides and debris flows**.

### 6.3 Surficial Geology

Surface and near-surface earth materials are shown on Theme Map 4. Ancient glacial ice and meltwater deposited soil on the valley floor and sides. The most significant of these deposits is dense **till** which appears to be 10 m deep or more in some residential areas. We also observed sandy to gravelly **glacial outwash** in a terrace-like feature north of the community maintenance yard.

Post glacial deposits include bouldery to soil-rich **colluvium** on steep slopes. Bouldery colluvium is derived from weathered bedrock and rock fall activity. Much soil-rich colluvium is derived from till. Another common surface material is **alluvium** transported and deposited by creeks.



Theme Map 4 also shows an abandoned glacial meltwater channels and a moraine-like feature near the bedrock canyon at the head of Sakwi Creek. These features and the canyon itself appear to have formed at the margins of Harrison Valley glacier ice whose surface must have been higher than remnant ice in the Hemlock Valley.

## 7. THEME MAPS AND THEIR USE

Each of the 5 theme maps uses the same topographic base but map unit boundaries may not be common. Ideally, the maps can be studied in numeric order:

- *Theme Map 1* shows where a property might be located relative to 3 hazard zones - No Apparent Hazard (NAH), Potential Hazard (PH) and Significant Hazard (SH). This map is somewhat general and more specific reference is needed in residential areas (Theme Maps 2A and 2B).
- *Theme Maps 2A and 2B* show hazard limits and safeline setback distances in residential areas. Where subdivided lots lie wholly or partially within hazard zones or setback areas, the District building inspector will request geotechnical hazard assessments in support of building permit applications.
- *Theme Map 3* shows anticipated geologic hazards. Many steep slope areas include multiple possible hazards only a few of which may need to be dealt with in more detailed professional evaluations.
- *Theme Map 4* shows dominant surface and near-surface materials. Mapped materials will help other professionals anticipate material properties and their relevance to hazard processes.
- *Theme Map 5* shows slope classes. Slope steepness is a major (but not exclusive) determinant of slope stability. Steeper slopes will be of interest to hazard professionals who will want to measure field slopes.
- *Theme Map 6* shows the limits of clear cutting on 1966 aerial photos. Significant ground disturbance may have occurred during the old harvesting operations. Field workers may find evidence of for such disturbance. As second-growth trees mature, down slope hazard limits (especially snow avalanches) defined by this study are likely to change to more favourable locations.

Each map has a legend. The legends are reproduced in Appendix B to facilitate copying onto 8.5 x 11 inch paper.



We expect future, more detailed hazard assessments and recommendations for safe building construction will be based on independent professional documentation of ground conditions and judgments about hazard probabilities.

## 8. HAZARDS AND CONSIDERATIONS OF PROBABILITY

Hazard and risk assessment work demands professional judgment over estimated probabilities of hazard occurrence. In general, BC building permit and subdivision approvals require a maximum probability standard of 10% in 50 years (1:475 annually, usually rounded to 1:500 annually) for landslide occurrences. Report users can refer to Hazard Acceptability Thresholds established by the Fraser Valley Regional District. Landslide hazard and risk assessments are conducted by a geotechnical engineer or a geotechnics geoscientist with required training or experience.

The accepted standard for river and creek hazards generally requires flood proofing to a water level equivalent to a 200-year flood return period. The 200-year return period flood levels have not been surveyed and calculated along Hemlock Valley creeks. This is compensated for by BC Ministry of Environment and Lands setback and elevation covenants on all residential lots: No building can be placed within 30 m distant and 3 m in elevation above the boundary of the nearest water course. Flood hazard and risk assessment work is conducted by a hydraulic engineer or a hydrologist geoscientist with required training or experience.

The <sup>DME</sup> report discusses hazard acceptability thresholds for snow avalanches. Snow avalanche hazard and risk assessments are conducted by a professional engineer or professional geoscientist with required training or experience.

## 9. CONDITIONS WHICH PROMOTE GEOLOGIC HAZARDS

### 9.1 Natural Processes

Natural processes which promote geologic hazards include:

- Extreme precipitation such as prolonged, intense rain, rapid snow melt and rain-on-snow. This activity promotes local creek flooding and debris flows and debris floods.
- Loading by new snowfall will promote dry avalanches if significant weak layers are present. Rain or melt may generate wet snow avalanches. Snow pack creep is common on most slopes.



- Strong earthquakes may trigger rock falls and landslides. Seismic design of buildings is controlled by requirements of the BC Building Code.
- Ground water discharges on steep slopes. Discharge or seepage areas may be fed by perched soil aquifers, particularly on soil slopes. Ground water discharge is a geotechnical condition and not a hazard by itself. However, wet ground complicates hazard considerations and must be evaluated in more detailed permitting studies. There is much wet ground in the Edelweiss Drive area.

## 9.2 Human Activity

A variety of human activity can promote or trigger erosion and landslide hazards. The most common activities are dumping of soil, rock or waste fill and placement of drain pipe outlets at and just below the crests of erodible or unstable slopes. Dumping of yard and other waste on steep slopes is a common occurrence. Land owners must avoid such activity to preserve steep slope stability.

Hemlock Valley roads have gravel surfaces which require maintenance with a road grader. Excess scraped material should not be pushed into locations vulnerable to erosion such as the one observed on Lot 1 near the junction of Snowflake Crescent and Sakwi Creek Road.

## 9.3 Human Exposure

Human exposure to hazards is best limited by simple avoidance. Skiers should be warned that snow avalanches, even small ones in forest areas, can injure or kill. We understand there is uncontrolled skiing in the community watershed north of Mount Keenan. We strongly suggest that Hemlock Valley residents and visitors avoid winter use of this area when snow avalanche areas are present.

We recommend that cross country ski trails below the east slopes of Mount Keenan be posted with warning signs about potential for snow avalanches, and that snow avalanche conditions in the area be monitored and controlled by the ski area's operational staff. We assume snow avalanche hazard mitigation in the operational ski area is limited to control work or avoidance.

# 10. HIGHLIGHTED HAZARD AREAS

## 10.1 Edelweiss Drive Area

Subdivided lots along Edelweiss Drive are exposed to long term probabilities of debris flows and snow avalanches. Some lots east of



Edelweiss Drive are located on wet slopes with low, creek-eroded or machine excavated slopes at their base. Comparatively steep slopes below Edelweiss Drive complicate driveway access and building placement. A combination of hazards and slope conditions will complicate permit reviews in the Edelweiss Drive area.

### **10.2 Snow Mist Drive and Snowmist Place**

Portions of this area are exposed to long-term snow avalanche hazards.

### **10.3 Sewage Disposal Beds**

The sewage disposal beds are exposed to long-term snow avalanche hazards. However, risk to the disposal beds is probably acceptable. Buildings near the beds should not be occupied.

### **10.4 Creek-Eroded Slopes, west Sakwi Creek Drive Area**

A number of lots along Sakwi Drive and its extensions such as Snow Flake Place, include the tops of steep and comparatively high, creek-eroded slopes. The slopes are generally forested with 30-year old trees. A recent debris slide was found north of Snowflake Crescent. Vegetation patterns indicate older slides have occurred on the slopes. At one site, the creek is eroding till at the base of the slope. As a result, the slope is undercut and its thin colluvial cover is sliding toward the creek. There is a house directly above. Other steep slope areas will be destabilized as the creek shifts its course in the future.

Area slopes are comparatively high, typically 6 to 12 m. The tops of some slopes show dumped fill, including branches, yard waste and other materials. Our considerations of slope angles, slope heights, potential slope undercutting by the creek and potential regression at the top of the slopes, lead us to recommended horizontal setback (safeline) from slope crests. These distances are roughly based on slope heights with variations for local conditions.

### **10.5 Other Creek Eroded Slopes**

Some residential lots south of Sakwi Creek Road (between Mt. Downing and Mt. Klautt Road) contain steep, but comparatively low (2 to 5 m high), creek eroded slopes. Except for lots opposite Mt. Downing and Mt. Keenan Roads, most of these slopes are located well north of the nearest creek. Several residential lots east of Klautt Road include slopes eroded by Sakwi Creek whose flood plain lies at the base. These low slopes are vulnerable to erosion and top of slope regression if Sakwi Creek erodes their base.



Our considerations of slope angles, slope heights, potential creek undercutting and potential regression at the top of the slopes, lead us to recommend an 7 m horizontal setback (safeline) from slope crests.

Several lots in the area will be affected by the 30 m horizontal setback and 3 m above the nearest creek covenant established by the BC Ministry of Environment and Lands.

### **10.6 Quarry Area**

The quarry area at the north end of Enzian Drive contains a rock cliff composed of highly fractured felsite (Section 6.1). It appears that most rock fragments are removed from rock fall debris that accumulates at the foot of the cliff. This is a rockfall hazard area. Engineering analyses are required to assess the stability of the cliff face and slopes above. In the interest of public and workplace health and safety, we recommend the quarry area should be fenced to restrict public access and that hiker or skier access to the top of the cliff also be limited by fencing. No heavy equipment should operate in the area, especially to scale loose cliff rock, until a favourable stability evaluation and possibly a quarry reclamation plan are available.

### **10.7 Bedrock Canyon**

Bedrock canyon walls on upper Sakwi Creek are extremely steep. We suspect canyon wall vegetation was destroyed in a post 1966 forest fire or by shallow soil landsliding. We recommend that skier or hiker access to the top of the canyon be restricted with fencing and warning signs.

### **10.8 Flood Hazard Areas**

We cannot be certain that all residential buildings or undeveloped lots meet MoLP flood setback criteria (Section 8) but most subdivided lots appear to avoid flood plain areas. The maintenance yard area and nearby buildings (including the community fire hall) are built on the floor of a gravel pit. Ponded water in the maintenance yard indicates ground water rises to the gravel surfaced pit floor. In addition, the maintenance yard might be flooded by a branch of Sakwi Creek that flows across Laurel Road. We recommend buildings in this area be flood proofed by raising concrete foundation walls a minimum of 1.0 m above adjacent ground.

## GLOSSARY OF TECHNICAL TERMS HEMLOCK VALLEY STUDY

(In alphabetic order. Words in italics are defined elsewhere in the Glossary. Definitions are taken or adapted from Bates and Jackson, 1987. See Theme Map legends for supplemental information).

### Alluvium

A general term for clay, silt, sand, gravel, cobbles and boulders carried and deposited by rivers and creeks in recent (post-glacial) time. The term is synonymous with "fluvial deposits".

### Cirque

A deep, steep-walled half bowl-like valley situated high on a mountain and commonly at the head of a valley. Cirques are produced by the erosive activity of a mountain.

### Colluvium

A general term for any soil or rock material deposited by slope processes including soil creep, rock fall, landsliding or related gravitational processes including sediment-laden water flows (*debris floods*).

### Creek Erosion and Deposition

Scouring and removal of soil material by flowing water and subsequent deposition of some of this material at a downstream location. Creek erosion often undercuts or steepens already steep slopes and may promote soil steep slope instability.

### Creek Flood

Submersion by flood water with attendant *creek erosion and deposition*.

### Debris Flow

Rapid, destructive flow of rock debris, sand, gravel, cobbles, boulders, mud, damaged trees and fine organic material. Debris flows typically travel down steep creek channels and deposit in lower gradient channels or on fan surfaces. In this study, *debris floods* can occur in areas mapped as Debris Flow.

### Debris Flood

A water flood that carries and deposits large amounts of coarse debris that may include sand, gravel, cobbles, boulders and organic debris. The term emphasizes debris transport rather than water flow and inundation. Debris floods are often transitional from *debris flows*.



## Debris Slide

A slow to rapid , potentially destructive, down slope movement of predominantly wet surface soil and weathered rock debris. In BC, debris slides sometimes often originate in forest clear cuts and along the outside edge of old logging roads. Debris slides may run out as debris flows.

## Estimated Probability of Hazard Occurrence

A probability statement used to define the limits of a *geologic hazard*. Acceptable probabilities vary with intended building uses, possibilities of community growth, physical settings and destructive potential of events.

A hazard probability guideline for BC subdivision and building permit approvals is 10% in 50 years or 1/475 annually (*usually rounded to 1/500*). In the absence of historic landslide records or <sup>14</sup>C dating, probabilities are estimated by expert judgement.

Technically, the hazard probability guideline is an encounter probability: the probability of occurrence at least once for a given return period and specified time. The encounter probability (E) for a *Poisson* distribution where  $E = 50\text{yr} / 500 \text{ yr} = 0.1$ ) and  $L = 50 \text{ yr}$ ;  $T = 500 \text{ yr}$  is calculated as:

$$\begin{aligned} E &= 1 - e^{-LT} \\ &= 1 - (0.9048) \\ &= 0.0952 \\ &\approx 0.1 \end{aligned}$$

This is functionally the same as a calculation for a *Binomial* distribution where the probability of a landslide hazard in a 50 year period (given an annual probability of hazard occurrence of 1/475) is :

$$\begin{aligned} P_{50} &= 1 (1 - (1 / 475))^{50} \\ &= 0.1 \end{aligned}$$

## Felsite

A general term for any light coloured, intrusive volcanic rock, chiefly composed of microcrystalline grained quartz and feldspar.

## Flood Return Period

A probabilistic statement that gives the average period of time (in years) in which a given flood level or discharge will be equalled or exceeded. Return period estimates are based on stream gauge records, statistical analyses and field surveys.

### **Flow Slide**

Down slope movement of liquified mud which may carry cobbles, boulders and damaged trees. In Hemlock Valley, flow slides might originate in *till*.

### **Geologic Hazard**

A naturally occurring or man-made geologic condition or phenomenon that presents risk or is a potential danger to life and property. In formal hazard and risk assessment work, the estimated magnitude and annual probability of occurrence are defined. Synonymous with 'geotechnical hazard'.

### **Glacial Meltwater Channel**

A channel carved in rock or soil by water derived from the melting of glacial ice and snow.

### **Glacial Outwash**

Sand, gravel, cobbles and boulders derived from glacial ice and carried and sorted by glacial meltwater.

### **Hazard and Risk Assessment**

Various formalized and detailed assessments which consider the probability and magnitude (e.g. landslide volume and impact force) of geologic hazard occurrence and consequences (property damage, human injury and death, environmental damage and exposure in space and time).

### **Moraine**

A mound, ridge or other distinctive landform deposited by and in direct contact with glacier ice.

### **Organic Soil**

Fibrous to amorphous organic material typically found in poorly drained depressions or bogs.

### **Perched Soil Aquifers**

Relatively thin, water-bearing layers of silt, sand or gravel interbedded in less permeable material (e.g. *till*) on a steep slope. A perched aquifer is a geologic condition that is often associated with geologic hazards on steep soil slopes.

## **Rock Fall**

Free fall of rock fragments from a cliff face. Sustained rock fall activity may build *talus* at the base of the slope.

## **Snow Avalanche**

A rapid, destructive down slope movement of relatively pure snow. Snow avalanches may also carry soil, rocks and damaged trees.

## **Soil Creep**

Gradual, steady down slope movement of seasonally saturated soil and loose rock, usually on a steep slope. Technically, *colluvium* is creeping soil but motion may not be perceptible except by evidence of bowed or thrown trees or stretched tree roots.

## **Talus**

*Rockfall* material at the foot of steeper terrain such as a cliff.

## **Till**

Earth material deposited directly by glacial ice. Typical till has a dense to very dense matrix of sand, silt and clay that encloses gravel, cobbles and boulders.

## REFERENCES

- Bates, R. L. and J. A. Jackson, 1987. Glossary of Geology. Third ed., published by American Geological Institute. 788 p.
- BC Ministry of Forests, 1988. Biogeoclimatic Zones of British Columbia
- Monger, J. W. H., 1989. Geology, Hope, British Columbia; Geological Survey of Canada Map 41-1989. Sheet 1.

## MAPS USED

- BC Ministry of Crown Lands. 92H.031.3.2 *and* 3.4. 1988, 1:5,000 scale with 2 and 10 m contours.
- Energy Mines and Resources Canada 1:50,000 scale 92 H/5. Harrison Lake
- BC Ministry of Crown Lands. Terrestrial Resource Inventory Mapping (TRIM) 1:20,000 scale, 20 m contours. 92 H.031

## AERIAL PHOTOS USED

- **1952** North to South Line, B&W, 152 mm cfl, Nom. Scale: 1:31:680  
Shows valley prior to logging  
BC 1622 059-064
- **1966.** North to South Line, B&W, 152 mm cfl, Nom. Scale: 1:31:680  
Shows valley cleared of trees  
BC 5217 183-188
- **1996, East-West Lines, Colour, 305 mm cfl, Nominal Scale: 1:20,000**  
30 BCC96079 182-187, 30 BCC96080 040-045, 182-187

also

BCC 451 194 - 200  
BC 79193 096 - 101, 181-186  
BC 81126 214 - 218, 229-233  
BC 93031 194-200

## **Overview Avalanche Hazard Assessment: Hemlock Valley, British Columbia**

submitted to Fraser Valley Regional District (FVRD)

David M. McClung, Ph.D., P.Geo.

January 10, 1999

### **Introduction:**

This report contains information in relation to assessment for snow avalanche hazards at Hemlock Valley, B.C. The purpose of the study was to estimate an Avalanche Hazard line which is equivalent to approximate return interval for avalanches on the order of 10% chance in 50 years (equivalent to a return period of about 500 years). The assessment was made by two days of field observations (October 20 and November 3, 1998) study of air photos from 1952, 1966, 1979, 1985, 1996. In addition, previous reports on avalanche hazard assessments were reviewed: Stethem (1980; 1981), Freer (1981) and Mears (1982). Further, Mr Brad Buck of the Hemlock Valley Ski area was interviewed with respect to local conditions and avalanche occurrences.

This study contains snow avalanche hazard assessments in residential areas of Hemlock Valley. Other avalanche areas are identified by Thurber Engineering Ltd. on Theme Maps 2 and 3. (Safeline Locations and Geologic Hazards). Snow avalanche hazards are not evaluated in the recreational ski area. The resulting Avalanche Hazard line drawn has been estimated from field observations combined with the information listed above combined with judgemental analysis and experience.

### **Hemlock Valley : Snow Climate and Relation to Avalanche Frequency**

Hemlock Valley is contained within a maritime snow climate (proximity to Pacific moisture source) characterized by relatively warm winter temperatures, moderate to heavy snowfalls - approximately 3 m average maximum depth) and the possibility of rainfall during any month of the winter. The elevation band for slopes adjacent to the study area (900 - 1200 m.a.s.l.) is also a consideration as a determiner of avalanche frequency.

Normally when return intervals of 300-500 years are used in avalanche zoning applications, short term snow climate data are not very useful for estimations: for such long return intervals it is a safe assumption that the proper sequence of conditions will develop for the release of large dry avalanches which are normally used as the prototype for the design avalanche. The prevailing conditions at Hemlock Valley (relatively warm winter temperatures and relatively low elevation band) do combine to reduce the frequency of large destructive avalanches in the short term which helps to explain why there are no reports of avalanche occurrences within and above the areas for which the Avalanche Hazard Line is drawn for this report. In short, the fact that the terrain above the Avalanche Hazard Line does constitute potential avalanche terrain and, that such terrain is in a location for which heavy snow accumulations are possible, presents the combination of factors necessary and sufficient for potential avalanche activity with return intervals on the order of several hundred years.

## Specified Return Interval

The approximate return interval used to estimate the Safe or Avalanche Hazard Line for this study is about 500 years. The Subdivision Policy and Procedures Manual (1996) issued a standard for natural hazards of 10% chance in 50 years which is equivalent to a return period of 475 years if hazards are viewed as a Poisson process. The Subdivision and Policy Procedures Manual (1996) recommends the above prescription "except for snow avalanches where the consultant should base the work on how far avalanches are expected to run in 300 years." The work done in this study is consistent with either of these of these recommendations (300-500 years) since the level of precision of the study is only approximate. The term that should be applied to the present study for return period is several hundred years.

Normally, when a return period is specified (for example 500 years) it is implied that the annual probability (0.2%) is constant every year regardless of past history. However, this concept does not apply to the study area at Hemlock Valley; most of the avalanche threat is due to logging activity in 1963. As protective forest cover returns both in potential start zones and runout zones the annual probability will decrease. If destructive avalanches should occur to remove forest cover, the annual probability will increase. The airphoto sequence shows that protective forest cover is returning in some parts of the study area and in other parts it is not. Inspection of the airphoto sequence at Hemlock Valley shows that the forest cover is returning most effectively at the bottom of the slopes (runout areas) rather than the start areas (see TEL clear cut theme map) which is discouraging from the perspective of potential decrease of the avalanche hazard.

## Study Area Description

The avalanche threatened areas found in this study are all to be found on the lower slopes of Mt Keenan in a general direction from north west to south east starting at the beginning of Edelweiss Drive until it meets the Hemlock Valley Road near Sakwi Creek with continuation until to the Hemlock Valley Sewage Treatment Site. Avalanche activity is possible on slopes all along Edelweiss Drive. However, within this area, 7 potentially hazardous areas were identified as particularly noteworthy and these will be referred to sequentially by number proceeding from north west (beginning of Edelweiss Drive) to the last site at the Sewage Treatment Plant (see Avalanche Hazard Map with numbers from 1 to 7). These sites are noteworthy because they contain well either well defined avalanche paths above or terrain which would spawn potentially destructive avalanches given the correct combination of factors.

### Site #1

This site consists of a long potential avalanche path created by logging activity in 1963. I walked the entire path on October 20, 1998 and measured the slope profile. The starting zone consists of a slope distance of almost 100 m long (north aspect) with average slope angle of  $41^{\circ}$  about 75 m wide almost completely free of forest cover as a result of the 1963 logging. The next section is about 100 m long with average slope angle of  $34^{\circ}$  and the third section is about 125 m long with average slope angle  $9^{\circ}$ . Most small avalanches would stop somewhere in this section. The next section increases in steepness to  $21^{\circ}$  on average to the road. If large avalanches reach this section they will most likely reach the road and beyond. There is significant forest

cover above the houses at where the potential avalanche path intersects them. However, a large avalanche could remove this forest cover. Large avalanche occurrences would be very rare here but possible due the combination of steep smooth starting zone and steep terrain just above the houses.

#### Site #2

This site is approximately 60 m in a north west direction from the log home at the intersection of Edelweiss Drive and Larkspur Road. The average slope angle from the road to the top of the potential start area is  $28^{\circ}$  with steeper terrain at the top of the slope. The slope is long enough such that avalanches could cross Edelweiss Drive and have significant destructive potential. The potential avalanche path has two possible lobes. Forest cover is not significant at this site either in the starting area or runout area.

#### Site #3

This site is directly above the large condominium complex along Edelweiss Drive with a potential start zone on the talus slope directly above the condominium complex. The path is about 250 m long from the top of the slope to the back porch of the condominium with an average slope angle of  $31^{\circ}$  (steeper at the top of the slope). The slope is long enough and steep enough such that significant destructive effects can be expected at the condominium complex. Safety of people on the back porch or backyard of the condominium is an issue that should be addressed.

#### Site # 4

This site is approximately 250 m southeast along Edelweiss Road from where it intersects Larkspur Road. Potential avalanche path terrain exists almost all along this section of road from Site # 3 to the end of Edelweiss Road where it intersects Hemlock Valley Road at the southeast end of Edelweiss Road. At a point 250 m from Larkspur Road, the slope angle to the top of the likely start area is  $32^{\circ}$  and the slope angle from Hemlock Valley Road to the top of the start zone is  $25^{\circ}$ . The terrain between Edelweiss Road and Hemlock Valley Road has an incline between  $7^{\circ}$  and  $8^{\circ}$ ; easily steep enough to keep large avalanches running all the way to the creek. This area was identified in reports by Freer (1981) and Mears (1982) as having potential for avalanche runout and destructive effects (denoted as Subdivision 4 in their reports). The potential for large avalanches in this section is visible on the airphotos from 1952 possibly indicating that this site was subject to avalanches before the 1963 logging activity.

#### Site # 5

This site is directly above where Edelweiss Drive intersects Hemlock Valley Road. It was identified by both Freer (1981) and Mears (1982). Several possible starting areas are evident, including steep cliff bands, with distances along the incline from Edelweiss Road to the top of the start zones on the order of 250 m. and average angles  $22^{\circ}$  to  $25^{\circ}$ .

### Section between Site #5 and Site #6

This section has considerable protective forest cover without well defined potential avalanche paths or gullies. Forest cover removal either by humans or avalanches would increase the risk considerably in this section.

### Site # 6

This site is almost directly above the cul de sac at Snowmist Place with a large avalanche path which is in nearly direct line with the road leading to the cul de sac. This avalanche path and the area adjacent to it was noted by Mears (1982) and Freer (1981) designated the area above the southwest corner of Subdivision 6 as High hazard.

### Site # 7

This site contains the access road, a small building and the Hemlock Valley Sewage Plant (sewage lagoons). The small building sits directly in a well defined avalanche path. Stethem (1980) reported on the destructive potential of avalanches at this site: the Hemlock Valley Sewage Treatment Site. The potential for avalanches at this site has existed prior to 1963 when the area was logged.

### Relationship to Other Studies

Stethem (1981), Freer (1981) and Mears (1982) specified avalanche hazard assessments for portions of Hemlock Valley. Stethem and Freer used an effective return period of 300 years as a guideline whereas Mears used an effective return period of 100 years as a guideline. All previous reports were stated to be done with the use of avalanche dynamics to determine runout. In modern practice, the use of avalanche dynamics models for specifying runout is not recommended due to the highly speculative nature of the input friction coefficients and the near impossibility of relating such friction coefficients to return period (return period is related to terrain and avalanche occurrences at sites in question). Forest cover present at a site (as present at Hemlock Valley) also has a retarding effect on avalanches and this should be an important aspect of the problem but there is no method yet to quantify the effect in avalanche dynamics models.

The substantial lack of agreement between Potential and High Hazard zones between the Freer (1981) and Mears (1982) reports for the same sites shows the speculative nature of avalanche dynamics calculations. Since none of the reports above list friction coefficients used or give an explanation of how the calculations were performed or how the friction coefficients were determined, it is impossible to compare the methods used. Freer (1981) states that lots 49-59 of Subdivision 4 are in the High Hazard Zone (using 300 year max return period) whereas Mears (1982) states that none of these lots are in the High Hazard Zone (100 year max return period). The differences in the Potential Hazard Zone and High Hazard Zone for Subdivision 4 from Freer's report are less than 10 meters in some places which implies precision in avalanche dynamics friction coefficients which is beyond the frontier of human knowledge even in 1999.

The Avalanche Hazard Line for this study was determined from the perspective of return periods of the order of 300-500 years based on terrain analysis, the full sequence of air photos, two days of field checking melded with judgemental experience. The Avalanche Hazard Line is somewhat more conservative, but comparable, to the analyses of Freer and Mears in the areas for which the studies overlap (Subdivisions 4 and 6). More detailed studies during permit reviews should include modern methods of return period determination through use of terrain variables and the historical record of avalanche runout from the BC Coast Mountains as the spatial input to return period determination (McClung, 1999).

Further, the Avalanche Hazard Line in this study was drawn without consideration of small possible "islands of safety" for individual lots. One example is the log house at the intersection (uphill) of Larkspur Road and Edelweiss Road. This house is protected from avalanche hazards by a small rock bluff above it. More detailed studies may identify similar locations.

### Mitigation Methods for Hemlock Valley

Return of the forest cover to the level evident in the 1952 airphotos would have substantial effects on the Avalanche Hazard Line at Hemlock Valley. Reforestation might be an option worth considering particularly at some of the sites described above: the start zone of Site #1, Site #2 and Site #3.

### References

- Freer, G. 1981. Snow avalanche hazard - Hemlock Valley, B.C. Ministry of Trans. and Highways, 5pp.
- McClung, D.M. 1999. Extreme avalanche runout in space and time, accepted for Canadian Geotechnical Journal.
- Mears, A. I. 1982. Avalanche hazard analysis and land-use recommendations at selected portions of Hemlock Bowl British Columbia, 10 pp.
- Province of British Columbia. Ministry of Transportation and Highways 1996. Subdivision policy and procedures manual, p. APP-61.
- Stethem, C. 1980. A report on the destructive potential of avalanches at the Hemlock Valley sewage treatment plant, 8 pp.
- Stethem, C. 1981. A report on the snow avalanche hazard in potential development areas in Hemlock Bowl at Hemlock Valley, 7 pp.

Legend  
**Hazard Zonation (Thurber Drawing 14-50-44-1) \***

Hazard Zone	Description. Avalanche hazard zones in the Edelweiss Drive area are not shown on this map - See Drawing 2A.
<p style="text-align: center;"><b>NAH</b></p>	<p><b>No Apparent Hazard</b> - Estimated relative probability of hazard occurrence is judged to be less than 1:500 annually.</p> <p>NAH areas do not require hazard assessment by a professional engineer as otherwise stipulated by Section 699 of the BC Municipal Act except at the discretion of the Building Inspector. Limits of no apparent hazard areas require professional verification during permit reviews.</p>
<p style="text-align: center;"><b>PH</b></p>	<p><b>Potential Hazard</b> - Estimated relative probability of hazard occurrences are judged to be moderate to low (e.g. 1:200 to 1:500 annually).</p> <p>PH areas require hazard assessment by a professional engineer (geotechnical engineer for slope hazards and hydraulic engineer for creek hazards) as stipulated by Section 699 of the BC Municipal Act.</p>
<p style="text-align: center;"><b>SH</b></p>	<p><b>Significant Hazards</b> - Estimated relative probability of hazard occurrences are judged to be high (e.g. 1:1 to 1:200 annually). Includes all areas of active and inactive creek processes shown on Drawing 3.</p> <p>SH areas require hazard assessment by a professional engineer (geotechnical engineer for slope hazards and hydraulic engineer for creek hazards) as stipulated by Section 699 of the BC Municipal Act.</p>

\* Hazard zone information is provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently identify hazard zones and hazard magnitudes based on field evidence.

## Legend

### **Avalanche Hazard Limits -- Residential Areas (Thurber Drawing 14-50-44-2A)\***

Drawing 2A shows the estimated extent of long-term *snow avalanche* runouts in the Edelweiss Drive area. Numbered sites refer to locations described in *Overview Avalanche Hazard Assessment, Hemlock Valley, British Columbia* by D&E McClung Enterprises Ltd., 1999.

Avalanche tracks are interpreted from aerial photographs. Not all possible tracks are shown.

Refer to Drawing 2B to see how avalanche other hazards and safeline zones overlap in the Edelweiss Drive area.

Where Theme Maps 1 and 3 identify hazards in non-residential areas, hazard limits must be defined by more detailed geotechnical investigations.

- \* Avalanche hazard information is provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently estimate hazard probabilities and hazard magnitudes based on pertinent field evidence.

## Legend

### Landslide Hazard Limits and Safeline Locations (Drawing 14-50-44-2B) \*

Drawing 2B shows the estimated extent of long-term *landslide hazards and safelines*. Safeline zones (including steep slopes) are approximated on this map. Field measurements are required to locate a safeline on a specific property. Distances are to be field measured from the top of the nearest steep slope.

Refer to Drawing 2A to see how avalanche hazards overlap with landslide hazards and safeline zones in the Edelweiss Drive area. Where Theme Maps 1 and 3 identify hazards in non-residential areas, hazard limits must be defined by more detailed geotechnical investigations.

Long-term debris flow hazard limit east of Mount Keenan also includes rockfall hazard area as noted on map.

#### Safeline Cluster Details

- A 8 m back from steep slope. Include all of wedge-shaped lot. 8 m back from top of steep slope just south of this lot.
- B 6 m back from top of cut slope.
- C 8 m back from top of creek-eroded slope.
- D 10 m back from tops of steep slopes.
- E 8 m back from top of steep slope.
- F 10 m back from top of steep slope above possible slide bowl. These lots are also in long-term avalanche hazard zone.
- G 8 m back from top of steep slope on Lot 13, southwest to 18/19 boundary. 6 m back from Lot 19 to 23.
- H Road fill below road complicates access to these lots. Ground below is locally wet and there are debris slide hazards. These lots also in long-term avalanche hazard zone.

\* Landslide hazard and safeline information is provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently estimate hazard probabilities and hazard magnitudes based on pertinent field evidence.

Continued...

**Safeline Cluster Details continued...**

- I 6 m back from top of steep slope each side of creek. These lots also in long-term avalanche hazard zone.
- J Steep slope and road above these lots. Safeline extends 6 m beyond *foot* of slope. Area below slope is wet. These lots also in long-term avalanche hazard zone.
- K 6 m back from top of low, steep slope to east. Consider adverse erosion potential if creek to the west changes course to erode the toe.
- L All of Lot 10 - note non-engineered fill. 8 m back from top of steep slope on Lots 11 and 12. 6 m back from top of steep slope on Lots 13, 13A through 16.
- M 8 m back from top of slope below, which is in part, a road cut. Area above and below is wet and there are debris slide hazards. These lots also in long-term avalanche hazard zone.
- N 8 m back from top of slope below. Area above and below is wet and there are debris slide hazards. These lots also in long-term avalanche zone.

Legend  
Geologic Hazard Map (Thurber Drawing 14-50-44-3) \*

Map Symbol	Geologic Hazard Descriptions. <i>Brackets indicate areas estimated to have moderate to low probabilities of hazardous processes. (e.g. about 1:200 to about 1:500 annually, except for creek processes). Snow avalanche runout areas west of Hemlock Valley Road and the Edelweiss Drive area are shown on Drawing 2A.</i>
A A <sub>s</sub>	<i>Snow Avalanche (Tracks definable - A; small, usually undifferentiated- A<sub>s</sub>). Forest clear cutting may increase avalanche magnitude and frequency. Snow avalanche hazards are not identified in Hemlock Valley's operational ski area.</i>
F <sup>A</sup> , F	<i>Active - F<sup>A</sup> and occasionally active - F creek processes. Creek channels and adjacent lowlands subject to creek erosion, deposition and flooding. Occasionally active areas are often drained by ditches and culverts. All creek processes are estimated to have probabilities of occurrence greater than 1:200 annually.</i>
Df	<i>Debris Flow. Rapid, destructive flow of rock debris, sand, gravel, cobbles, boulders and organic debris. Debris flows may translate into debris floods (water flood that carries sand, gravel, cobbles, boulders and organic debris.). Potential debris flows may involve 1,000 to 2,500 m<sup>3</sup> of earth material. Field example - see debris flood material north of Sakwi Creek culvert on Hemlock Valley Road.</i>
Ds	<i>Debris Slide. Destructive landslide involving predominantly wet surface soil and weathered rock debris. Potential debris slides may involve 50 to roughly 1,000 m<sup>3</sup> of earth material. Field example - see slide scar opposite crest of Enzian Way or steep slope pr recent slide north of Snowflake place.</i>
Ec	<i>Continued Erosion Processes on Creek Eroded Slopes. Steep slopes cut by creek erosion and subject to Debris Slides (above) and other colluvial processes, especially soil and snow creep. Most are interpreted to be formed of thick till with a thin cover of colluvium. Portions of these slopes are extremely steep..</i>
Fs ?	<i>Flow Slide? Possible slide debris derived from till. Field example - see slide area just beyond north end of Edelweiss Drive. Further study needed to confirm identity of this feature.</i>
Ls?	<i>Landslide? Possible soil slide area mapped about 250 m north of Hemlock Ski Area main lodge. This is interpreted to be an ancient feature but it warrants more detailed study if significant commercial or residential development occurs in the area.</i>
NSP	<i>No Significant Geomorphic Processes.</i>
Rf	<i>Rock Fall. Rock fall on and below steep cliffs.</i>
V V <sub>L</sub>	<i>Gullying. V - Multiple gullies eroded in till, colluvium and local bedrock. Gullies may act as debris flow paths. V<sub>L</sub> - Comparatively large gullies apparently eroded in till - one map unit in west study area.</i>

\* Geologic Hazard information is provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently identify geologic hazards based on field evidence.



## Legend

### Surface and Near-Surface Materials Map (Thurber Drawing 14-50-44-4) \*

Map Symbol	Material Description. Includes typical engineering (Unified) soil classification in brackets
DG	<i>Disturbed ground.</i> Excavations and fills. Earth materials vary. Only larger areas mapped.
O	<i>Organic soil.</i> Soft wet, dark brown to black, fibrous to amorphous organics and organic silt (Pt, OL).
F <sup>A</sup>	<i>Fluvial (Creek) Deposits - Active.</i> Loose to compact, wet, typically subangular gravel cobbles and boulders with some sand (GP, GW with SP and SW fines)..
F	<i>Fluvial (Creek) Deposits - Occasionally Active.</i> Creel terrace or fan deposits subject to ground water saturation and occasional creek flooding and erosion. Usually mixed with organic material (including peat, roots and decaying wood) as well as silt-sand fines. Compact to dense, moist to wet, subangular gravel mixed with silt, sand and organics (GM, SM with OL fines).
C (Cr)	<i>Colluvium.</i> Active slope material affected by soil creep, snow creep, landslide, rock fall, snow avalanche and freeze-thaw activity on moderate to steep slopes. Although there are comparatively few landslide areas, surface soil creep is very common. C is usually sand to silt-rich colluvium derived from till and usually contains mixed, fine-grained organic material as well as subangular to rounded gravel and cobbles. This colluvium may be loose, compact or soft. Unified Soil Classification varies greatly.  Cr maps areas of angular rock fall debris - talus. Angular colluvium is derived from bedrock.
F <sup>G</sup>	<i>Glacial Outwash.</i> Pleistocene-Age, materials deposited by ancient glacial meltwater. Dense, sand, moist, rounded to subrounded gravel, cobbles and boulders. (GP, GW with SP fines).
T	<i>Till.</i> Pleistocene-Age, inactive material deposited directly by ancient glacier ice. Dense to very dense, grey to brown, moist. matrix of sand, silt, and a trace of clay containing gravel, cobbles and boulders. Exposed till is often fissile with partings parallel to the ground surface. Excavated or eroded faces weather to loose sand, gravel, cobbles and boulders. Till thickness vary from about 1.5 m on valley sides to greater than 8 m on valley floor.
R	<i>Bedrock.</i> Jurassic-Age, undifferentiated metamorphosed volcanics including felsite, volcanic breccia and argillite (Harrison Formation). Possible small areas of granitic rock..

Map units based on aerial photo interpretation and reconnaissance field study. All map unit boundaries are approximate.

- \* Surface material information is provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently identify surface and near-surface materials based on field evidence.

## Notes

### Surface and Near-Surface Materials Map (Thurber Drawing 14-50-44-4)

1. Plus (+) indicates several types of surface material are interpreted to occur in discrete areas within a map unit. Material symbols are given in alphabetic order with no implication as to which material covers a larger area. For example, C + R means areas of surface colluvium and exposed bedrock .
2. If materials are separated by a horizontal bar, the upper material is interpreted to be the dominant surface material and the lower material is assumed to lie beneath it.
3. In areas of colluvium and till (C + T), colluvium is assumed to be derived from till.
4. Glacial landform are shown in bedrock-controlled terrain each side of the drainage divide between Brett Creek (Harrison Lake drainage) and Sakwi Creek. They include:



Abandoned Glacial Meltwater Channel.



Moraine-like ridge

(Color coding is for drafting guidance only)



Legend  
Slope Classification Map (Thurber Drawing 14-50-44-5) \*

Number Code	Slope Percent * (%)	Slope Angle * (°)
1	0 to 15	0 to 9
2	16 to 30	9 to 17
3	31 to 50	17 to 27
4	>50	>27

Slope angles are approximated from BC Ministry of Crown Lands Maps (92H.031, 3.2 and 3.4) at 1:5,000 scale with 2 m and 10 m contours, 1988.

- \* Slope class information is provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently measure slope angles in the field.



**Legend**  
**1966 Clear Cut Limits (Thurber Drawing 14-50-44-6) \***

This map shows the approximate limit of clear-cut timber harvesting shown on aerial photos (BC 5217 183-188) taken on September 4, 1966. The toothed side of the line is the area cleared of trees. These aerial photos are on file with the Fraser Valley Regional District.

- \* Clear cut limits are provided for professional engineering or professional geoscience guidance in permit reviews. Professional hazard investigations are expected to independently assess old clear cut limits based on field evidence.



# STATEMENT OF GENERAL CONDITIONS

## **1. STANDARD OF CARE**

This study and Report have been prepared in accordance with generally accepted engineering or 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 us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us 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. WE CANNOT BE RESPONSIBLE FOR USE 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 site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

## **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 OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorize only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make the Report, or any portion thereof, available to any party without our written permission. Any use which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. We accept no responsibility for damages suffered by any third party resulting from unauthorized use of the Report.

## **5. INTERPRETATION OF THE REPORT**

- a) Nature and Exactness of Soil and Contaminant Description: 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 judgemental in nature and even comprehensive sampling and testing programs, 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 the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. 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 the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(see over...)