THURBER ENGINEERING LTD.

June 14, 2019 File: 21452

Fine Peace Holdings (Canada) Ltd.
6945 Isleview Road
West Vancouver, BC
V7W 2L1

Attention: Yang Jin, General Manager

OVERVIEW GEOHAZARD ASSESSMENT - FURRY CREEK LANDS
FURRY CREEK, BC

Dear Yang Jin:

This letter report presents the results of an updated overview geohazard assessment of the Furry Creek lands at Furry Creek, BC, further to the previous assessments completed by Thurber between 1990 and 1992. This study was commissioned by CREUS Engineering Ltd. on behalf of Fine Peace Holdings Canada Ltd. (Fine Peace), and is intended to support Fine Peace's Comprehensive Development (CD) Zoning Application to the Squamish-Lillooet Regional District.

We understand that the CD Zoning application would accommodate up to 574 new residential units, up to 120 resort tourist accommodation units, commercial floor space, and private marina and community facilities. A variety of building forms, including single-family houses, townhouses, and mid-rise apartment buildings are proposed.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. INFORMATION REVIEWED

The following background information was reviewed by Thurber as part of this study:

- Thurber's project archives from the original Furry Creek development, including overview geotechnical/geohazard reports dated December 7, 1990 and February 27, 1992.
- Historical aerial photographs (obtained from UBC Geography) of the Furry Creek area for the years 1957, 1969, 1976, 1979, 1982, 1987, 1990, 1994, and 2004.
- CAD linework, orthoimagery and LiDAR data (flown in 2006 & 2019), provided by CREUS.
- Available 1:20,000 scale TRIM topography and watercourse mapping.
- BC Ministry of Forests Biogeoclimatic Ecosystem Classification Mapping.
- Environment Canada Climate Normals or Averages for the period 1981-2010.
- Published geological maps and papers for the Sea to Sky corridor, obtained from the Geological Survey of Canada and other information sources.

2. SITE DESCRIPTION

2.1 General

Furry Creek is located along the east side of Howe Sound, approximately 30 km north of Horseshoe Bay. Howe Sound is the southernmost fjord in British Columbia and is situated within a larger physiographic region known as the Georgia Lowland, which extends along much of the Salish Sea and mainland coast (Holland 1976). These lowlands rise eastward and merge with the Coast Mountain Range at an elevation of approximately 1300 m above sea level.

The Furry Creek lands (the subject property) comprises approximately 419 ha to the north and south of Furry Creek, including approximately 57 ha to the west of Highway 99 with a total of 3.3 km of ocean frontage. Historical land uses at the site, as described in detail in the CD Zoning Application, mainly relate to resource extraction and include mining, logging, and gravel quarrying.

The subject property ranges in elevation from sea level to about 400 m above sea level. The proposed development areas are located within the rain-dominated elevation band (< 300 m), with the exception of the Mountain Lands development area which is located in the transient elevation band where rain-on-snow events predominate (300 to 800 m).

2.2 Climate and Vegetation

The subject property is contained entirely within the "Coastal Western Hemlock - Dry Maritime" biogeoclimatic zone and experiences relatively warm, dry summers and mild, wet winters. Watercourses at the site typically experience their annual peak flow between October and February, coinciding with the autumn and winter rain and/or rain-on-snow storm events.

Environment Canada weather records from the nearest weather station at Squamish (period 1981 to 2010) indicate that mean annual precipitation is about 2000 mm. However, due to orographic uplift effects (the upward flow and cooling of air masses over mountains), precipitation amounts increase significantly with elevation. Climate statistics for various elevations at Furry Creek were estimated using the ClimateBC online tool (http://www.climatewna.com/ClimateBC_Map.aspx); the results are shown on Table 1.

TABLE 1 – CLIMATEBC[1] STATISTICS FOR FURRY CREEK (PERIOD 1981-2010)

Elevation (m asl)	Mean Annual Precipitation (mm)	Mean Winter Precipitation (mm)	Mean Annual Precipitation as Snow (mm water equivalent)	Mean Annual Number of Frost-Free Days
0	2030	1620	75	305
100	2180	1735	95	300
200	2315	1845	125	290
300	2420	1930	200	270
400	2525	2015	253	260
800	2940	2345	600	225
1200	3020	2410	1090	190

1. http://www.climatewna.com/ClimateBC_Map.aspx

THURBER

It can be seen from Table 1 that annual snowfall accumulations increase rapidly with elevation at Furry Creek. In the transient elevation band (300 to 800 m), winter precipitation is driven by both rainfall and rain-on-snow activity.

2.2.1 Climate Change Considerations

According to the Pacific Climate Impacts Consortium Plan2Adapt web-based mapping tool (https://pacificclimate.org/analysis-tools/plan2adapt), the Squamish-Lillooet Regional District is projected to experience an approximate 6% increase in winter precipitation, a -12% decrease in summer precipitation, and a +1.7^{o} C increase in annual mean temperature by the 2050s (compared to the 1961-1990 baseline period), although there is considerable uncertainty in these projections. Increases in winter precipitation, and precipitation intensities, are expected to increase the likelihood of shallow landslides in coastal BC (Jakob and Lambert 2009).

2.3 Bedrock Geology

According to British Columbia Geological Survey Open File 2017-8 (Cui et al. 2017), bedrock at Furry Creek comprises mid-Cretaceous granitic rocks of the Coast Plutonic Complex. The nearest mapped fault is located approximately 4.5 km north of Furry Creek, at the descent of Highway 99 into Britannia Beach. The rock has been deeply scoured by repeated glaciations over the Pleistocene time period (2.6 Million to 12 thousand years ago) to form a series of rounded knobs and depressions. The rock is generally massive except where cut by northwest-trending jointing and minor faults which have the potential to result in localized instabilities.

2.4 Surficial Geology

The current landscape of the site and the underlying soil stratigraphy were largely formed during the last (Fraser) glaciation, which ended approximately 12,000 years ago. Glacial ice flowed out of the Coast Mountains, then moved southwestward out of Howe Sound, depositing glacial sediments (till) over the scoured bedrock surface. At the time when the area was de-glaciated, relative sea levels were approximately 220 m above the present datum due to glacio-isostatic depression of the earth's crust by the weight of the ice sheet that covered most of British Columbia. At Furry Creek, a complex assemblage of glaciomarine, marine, ice-contact, and glaciofluvial outwash sediments were deposited into the high-level sea, forming an irregular surficial mantle over the till at present day elevations below about 220 m above sea level. These sediments have been subsequently reworked in post-glacial time by fluvial downcutting and mass-wasting processes (for example, in the form of modern stream channel deposits) as the earth's crust rebounded and sea levels fell to the current datum.

According to Geological Survey of Canada Open File 5322 (Blais-Stevens 2008), the proposed development areas occupy glaciomarine and ice-contact terraces and areas of exposed bedrock in the uplands, and the post-glacial (Holocene) alluvial fan of Furry Creek in the lowlands. Soil cover is generally thin on steeper slope areas, and at the margins of the subject property, but is highly variable in thickness and character within the proposed development areas. In the Uplands South area, for example, significant thicknesses of outwash sand and gravel remain in the area of the abandoned gravel pits.

3. GEOHAZARD ASSESSMENT

3.1 Background

The Furry Creek area is subject to high volumes of precipitation and runoff driven by winter storm activity, which in combination with the steep terrain gives rise to various geohazards that have the potential to affect the community. These include mass-wasting (landslide) hazards, fluvial (creek) hazards, and coastal hazards. As described below, landslide hazards, which are the focus of this report, may originate in bedrock or soil and exhibit various modes of movement including falls, slides and flows.

The Furry Creek area is also situated in a seismically active area. A seismic event may trigger rock falls, debris slides or other landslide processes; however, in general, the seismic hazard for a specific property must be considered on a site-specific basis. In the case of a proposed development, this is generally captured under the jurisdiction of the British Columbia Building Code (BCBC) 2018.

3.2 Hazard and Risk Acceptability Criteria

In British Columbia, geohazards have historically been managed using a hazard-based (rather than a risk-based) approach; for example, the 200-year return interval event adopted as the safety level for flooding hazards. At both the federal and provincial level, there is no legislated guidance for risk-based acceptability criteria to geohazards, and the term "safe" has not been defined.

We understand from CREUS that the BC Ministry of Transportation and Infrastructure (MoTI) is the approving authority for residential development at Furry Creek. MoTI's Guide for Rural Subdivision Approvals (https://www.th.gov.bc.ca/da/Subdivision_Home.asp), and the accompanying internal MoTI document entitled "Subdivision Preliminary Layout Review – Natural Hazard Risk" (2009; updated in 2013 and 2015) provide guidance on geohazard acceptability criteria for residential development, paraphrased as follows:

- "For a building site, unless otherwise specified, ~ 500-year return period [10% probability in a 50-year period] of a damaging event";
- "For a large-scale development, an annual hazard probability of a life-threatening or catastrophic landslide a 10,000-year return period [0.5% probability in a 50-year period] event"; and
- "Large-scale developments must also consider total risk and reference international standards".

The MoTI guidelines also state the method of geohazard assessment by a qualified engineer/geoscientist should "determine if there is a hazard", "determine extent of any hazard", and, "identify building sites free from hazard, or where risk could be rendered acceptable". These guidelines, however, remain unpublished, and the terms "damaging", "life-threatening", "free from hazard", and "where risk could be rendered acceptable" have not been fully defined.

THURBER

For the purposes of this overview study, our assessment has considered potentially damaging landslide hazards with an estimated probability of occurrence of 10% in 50 years (1:475 annual probability) as per the MoTI guidelines and previous development approvals at Furry Creek.

3.3 Terminology

3.3.1 Landslide Hazards

Generally accepted landslide hazard terminology as referenced in this report is presented in Table 2. Diagrams of typical landslide processes are also shown on Figure 1.

TABLE 2 – LANDSLIDE HAZARD TERMINOLOGY

<table>
<tr><th colspan="2" rowspan="3">Mode of Movement[1]</th><th colspan="3">Landslide Process and Material Type</th></tr>
<tr><th rowspan="2">Rock</th><th colspan="2">Soil</th></tr>
<tr><th>Predominantly Coarse-Grained (“Debris”)[2]</th><th>Predominantly Fine-Grained (“Earth”)[3]</th></tr>
<tr><td colspan="2">Falls</td><td>Rock Fall</td><td>Debris Fall</td><td>Earth Fall</td></tr>
<tr><td rowspan="2">Slides</td><td>Rotational</td><td>Rock Slump</td><td>Debris Slump</td><td>Earth Slump</td></tr>
<tr><td>Translational</td><td>Rock Slide</td><td>Debris Slide</td><td>Earth Slide</td></tr>
<tr><td colspan="2">Flows</td><td>Rock Flow</td><td>Debris Flow</td><td>Earth Flow</td></tr>
<tr><td colspan="2">Avalanches</td><td>Rock Avalanche</td><td>Debris Avalanche</td><td>Earth Flow</td></tr>
<tr><td colspan="2">Lateral Spreads</td><td>Rock Spread</td><td>Debris Spread</td><td>Earth Spread</td></tr>
<tr><td colspan="2">Topples</td><td>Rock Topple</td><td>Debris Topple</td><td>Earth Topple</td></tr>
<tr><td colspan="2">Creep</td><td>Rock Creep</td><td>Soil Creep</td><td>Soil Creep</td></tr>
<tr><td colspan="2">Complex / Compound</td><td colspan="3">Combinations in time and/or space of two or more modes of movement</td></tr>
</table>

1. Table modified from Varnes (1978), Cruden & Varnes (1996), with terminology per Hutchinson (1988) and Hungr et al. (2001).
2. Soils with at least 20% of particles greater than 2 mm in diameter are classified as “Debris”.
3. Soils with at least 80% of particles smaller than 2 mm in diameter are classified as “Earth”.

3.3.2 Fluvial Hazards

Rivers, creeks and streams can experience different water flow (fluvial) processes, ranging from floods to debris floods to debris flows. Debris flows are normally treated as a landslide process (Table 2); however, they are discussed here as a continuum of fluvial processes.

Distinction between fluvial hazard processes is important, as these processes differ in flow mechanics and potential consequences. Transitions between processes are common within space and time during an event; for example, dilution of a debris flow through partial sediment deposition and tributary injection of water can lead to a transition towards debris floods and eventually floods. Definitions of these processes are listed below:

- Flood: For the purposes of this study, floods are defined as water flows with sediment concentrations of up to 10% by volume, transported as suspended load and bed load.
- Debris Flood: Debris floods can be defined as “a very rapid, surging flow of water, heavily charged with debris in a steep channel” (Hungr et al. 2001). Debris floods typically occur

on creeks with channel gradients between 3% and 30%. The term "debris flood" is similar to the term "hyperconcentrated flow", defined by Pierson (2005) on the basis of sediment concentration as "a type of two-phase, non-Newtonian flow of sediment and water that operates between normal streamflow (water flow) and debris flow (or mudflow)".

- Debris Flow: A debris flow can be defined as: "a very rapid to extremely rapid flow of saturated non-plastic debris in a steep channel" (Hungr et al. 2001). Debris-flow material is typically saturated; however, unlike debris floods, the movement is colluvial (gravity transported) rather than fluvial (water transported). Hungr et al. (2001) suggest the use of peak discharge as the most reliable criterion to distinguish between debris flows and debris floods. For debris floods, typical peak discharges are 2 to 5 times that of a hydrologic ("clear water") flood; by contrast, debris flows may have a peak discharge up to 40 times higher than a flood due to the surging behaviour of these events. Debris flows also typically require a channel gradient in excess of some 25% for transport over long distances and have sediment concentrations typically in excess of 50% to 60%.

3.4 Methods

3.4.1 Desktop Mapping

Digital Elevation Models (DEMs) and slope gradient maps of the study area were created using GIS software based on the LiDAR "bare earth" imagery and topographic contours provided by CREUS. These maps were augmented with the results of the air photo interpretation and desktop review of the previously listed information sources to assist in the interpretation of the terrain conditions and slope stability in the study area. An overlay of the DEM showing the historical landslide events and key terrain features is presented on Sketch A-1 in Appendix A.

3.4.2 Site Reconnaissance

A total of three days of ground reconnaissance fieldwork were completed in April / May 2019 to verify the terrain features and landslide processes identified from the desktop mapping. No aerial reconnaissance was carried out. The fieldwork consisted of short foot traverses at selected stopping points within the proposed development areas, including steep slope areas, rock bluffs, creek crossings, and other areas of interest. Conditions in the upper headwaters of the major creeks (North Creek, Middle Creek, South Creek) and along the mountain ridgelines high upslope of the Furry Creek lands were not assessed.

Information gathered included visual assessment of the general topography, slope gradients, landforms, soil and bedrock exposures, hydrologic conditions, and vegetation. Detailed field notes and photographs were collected on a georeferenced map of the study area using a tablet computer. The location of field observation waypoints is shown on Sketch A-1 in Appendix A; key findings are discussed below.

3.5 Hazards Identified

3.5.1 General

Figure 2 shows the approximate extent of potentially damaging geohazards, mapped at 1:5,000 scale from the available LiDAR imagery. Landslide hazards have been assessed based on an estimated probability of occurrence of 10% in 50 years (1:475 annual probability). Symbols within each hazard polygon denote the primary hazard types identified.

The observed terrain conditions, and hazards, are broadly consistent with the findings of Thurber's previous study completed in 1992. We have not identified any evidence of catastrophic landslide hazards from our study, nor are any such hazards documented at Furry Creek from published historical accounts of landslides and flooding events along the Sea to Sky corridor for the period 1855 to 2007 (Blais-Stevens and Septer 2008). However, localized hazards are present at a number of locations as discussed in the following sections.

3.5.2 Rock Fall

Rock falls are rapid, potentially destructive failures of fragmental rock masses with individual blocks deposited downslope through a combination of rolling and bouncing. Typical causal mechanisms include freeze-thaw activity, heavy rainfall, and seismic activity. Disturbance to rock masses from wildfires, incautious blasting, or other construction disturbances can greatly increase the occurrence of rock falls. Rock falls can damage surface structures through direct impact and also impart cratering damage to buried facilities.

Rock fall is the dominant landslide hazard process observed within the study area. Rock fall hazards were identified at the following locations (see Photos 1 to 8, attached):

- Within the Northwest and Collector areas, where semi-detached rock masses with open (dilated) joints were observed along the margins of steep bedrock bluffs up to 50 m in height. Rock fall activity from these areas appears relatively infrequent, given the relative scarcity of debris at the base of the bluffs; however, localized detachments weighing from a few kilograms to several tonnes are certainly possible and difficult to predict. The development layouts appear to be relatively favourably sited with respect to rock fall in that the proposed buildings and roads generally follow the ridgelines; however, there may be isolated adverse occurrences requiring protective measures and/or slope treatments (i.e. scaling, shotcrete, rock bolting, trim blasting, etc.) to mitigate the risk.
- Within the Northeast area, where the proposed development footprint verges on steep bedrock-controlled terrain at the base of the Mountain Lands area with the potential for localized rock fall hazards.
- Within the Uplands North area, where blocks of fallen rock up to 8 m in diameter were noted at scattered locations near the toe of the high mountain slopes at the eastern margin of the proposed development. These mountain slopes rise to a high alpine ridge at about the 1100 m elevation contour. The probable source area(s) and frequency of rock fall from these slopes is uncertain; however, as shown on Sketch A-1 in Appendix A, the distribution

of the observed blocks suggests that rock fall activity may be concentrated within chutes/gullies on these slopes. Avoidance of this area is judged to be the only practical mitigation strategy given the massive size of these blocks and the potential seriousness of the hazard.

- Within the Uplands South area, where construction disturbance on the steep slopes leading down to Furry Creek could potentially dislodge cobbles and boulders within the coarse glaciofluvial outwash soils that underlie this area.
- Within the Upper Benchlands area, which is situated on steep bedrock slopes which rise approximately 75 to 100 m to a glacially-scoured bedrock plateau located at about the 200 m elevation contour. Moderate to steep bedrock slopes continue upslope of this plateau to a ridgeline at about the 400 m elevation contour. The rock in this area of the site appears to be more heavily jointed, and, as can be seen from Sketch A-1 in Appendix A, exhibits a pronounced northeast-southwest trending structural “grain”. We interpret the latter to be the result of intense glacial scour along planes of weakness aligned with the pattern of bedrock jointing. Extensive rock fall deposits (talus) are present at the base of bedrock slopes within the southern half of the Upper Benchlands area, and in isolated pockets / patches within the northern half. Rock fall activity from these areas, however, appears relatively infrequent given the observed weathering of the exposed rock and the heavy moss cover blanketing the talus deposits. Nonetheless, localized detachments weighing from a few kilograms to several tonnes are certainly possible and difficult to predict.

  The development layout generally follows the bedrock plateaus located at about the 120 m and 200 m elevation contours, and in general appears to be favourably sited with respect to road grading and building construction. Rock fall hazards originating from the moderate to steep slopes between and upslope of the bedrock plateaus, however, pose a potential risk to the proposed development and its inhabitants. Construction disturbance (blasting, rock excavation, etc.) could also trigger localized rock fall which could potentially threaten the existing Benchlands development at the toe of the talus slope. Bearing in mind these issues, development of the Upper Benchlands will likely require protective measures and slope treatments, detailed construction practices, and, very careful siting of the building lots to mitigate these risks in some areas. Such provisions may lead to a significant increase in construction costs and place constraints on the architectural design of the houses. Further geotechnical assessment of this area will be required to map the rock fall hazards in greater detail and the scope and extent of these required provisions.

3.5.3 Debris Slides and Slumps

Debris slides are rapid, channelized or open-slope failures that involve the detachment of a thin sheet of mineral and organic soil from steep slopes, and are perhaps the most common landslide type in British Columbia. Typical causal mechanisms include freeze-thaw activity, heavy rainfall, seismic activity, or changes to natural drainage patterns due to logging, road construction, or other disturbances. Areas underlain by thicker sediments can experience deeper rotational failures (slumps) rather than shallow translational failures (slides).

Debris slide / debris slump hazards were identified at the following locations (see Sketch A-1 in Appendix A and Photos 9 and 10, attached):

- Within the Mountain Lands area, where an inferred slide track was observed on the eastern flank of the mountain from the 1957 air photos, extending from the top of slope to about the present location of the Forest Service Road (FSR).
- Within the Uplands North area, where an inferred slide track was observed upslope (east) of the proposed developments on the 1994 air photos, extending to about the present location of the FSR.
- Within the Uplands South area, where several inferred slide tracks were observed from the 1957 and 1994 air photos on the steep slopes leading down to Furry Creek. There is also evidence from the LiDAR imagery of larger slump failures along the north (right) bank of Furry Creek, possibly caused by undercutting of the toe of the slope or changes to natural drainage patterns due to road construction and gravel pit development.
- Within the Uplands South area, along the steep soil slopes bordering the north and west perimeter of the abandoned gravel pit and adjacent slopes leading down to Middle Creek.
- Within the Collector area, where a large inferred slump failure in glacial sediments was observed from the LiDAR imagery on the steep slopes leading down to Middle Creek.
- Within the Upper Benchlands area, where the steep bedrock slopes are locally mantled by veneers of organic and mineral soil with observed seepage at the soil/rock interface.

3.5.4 Excavated Bedrock and Foundation Setback Hazards

Figure 2 shows a number of areas across the subject property with possible geotechnical hazards where proposed developments are located on or adjacent to steep bedrock slopes (also see Photos 5 to 8, attached). Within these areas, further, site-specific geotechnical assessments will be required to confirm the siting of individual buildings and associated foundation design and construction requirements. Where the buildings cannot be adequately set back from the crest of these slopes, it will be necessary to construct the buildings with specially designed foundations, using carefully excavated platforms and rock anchors. These buildings will need to be very carefully sited and the building, its access and landscaping designed with input from both geotechnical and structural engineering disciplines. Protective measures may also be required at these locations to mitigate risks from rock fall.

The Northwest area is bisected by the CN Rail tunnel as shown on Sketch A-1 in Appendix A. We understand from CREUS that there will be restrictions on building development immediately above the tunnel alignment, per CN Rail requirements. Further discussion on this area is provided in Section 3.6.

3.5.5 Seismic Liquefaction Hazards

The alluvial sediments forming the fan of Furry Creek are potentially liquefiable under strong earthquake shaking. The potential consequences of liquefaction include differential vertical settlement, horizontal displacement (lateral spreading), and associated damage to buildings and buried facilities. Previous seismic analyses completed by Thurber indicate that liquefaction hazards on the Furry Creek fan are localized, rather than widespread; however, these hazards will need to be assessed on a site-specific basis in accordance with BCBC 2018.

3.5.6 Fluvial (Creek) Hazards

Furry Creek and the other named creeks (North Creek, Middle Creek, South Creek) draining the subject property are subject to fluvial hazards including flooding and bank erosion. Previous studies by others have also identified that Furry Creek is subject to debris flood hazards. The assessment of, and mitigation from, fluvial hazards is beyond the scope of this study but should be undertaken by a qualified hydrotechnical engineer / flood control engineer in accordance with EGBC's Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC (v 2.1, 2018).

The upper headwaters of North Creek and South Creek drain the steep mountain slopes to the east of the subject property. The morphology of these creek basins indicates the potential for debris flood (South Creek) and debris flow (North Creek) hazards; however, no evidence of such hazards was identified in the field or from the desktop review. We attribute this discrepancy to the small drainage area of these creek basins and the relative absence of debris in the channels due to the generally massive nature of the exposed bedrock and the thin soil cover. Further geotechnical assessment of the upper elevations of these creek basins should, however, be undertaken during preliminary/detailed design to confirm debris volumes in the channels and potential fluvial hazards.

3.5.7 Coastal Hazards

Coastal hazards include flooding resulting from extreme tides, wave action, storm surge, global sea level rise (and combinations thereof), and the associated erosion of shoreline areas. Landslide or earthquake-induced tsunamis are another potential coastal hazard.

The alluvial fan of Furry Creek is potentially subject to coastal flooding and shoreline erosion hazards, in view of the local topography and erodibility of the fan deposits and imported fill materials on the fan. The assessment of, and mitigation from, coastal hazards is beyond the scope of this study but should be undertaken by a qualified hydrotechnical engineer / flood control engineer in accordance with EGBC's Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC (v 2.1, 2018).

With regard to tsunami hazards, previous studies by Clague and Orwin (2005) and others conclude that tsunamis triggered by a megathrust earthquake off the BC coast would attenuate to less than 2 m before reaching North and West Vancouver; they also conclude that there is no evidence for tsunamis induced by landslides or delta foreslope slumps (submarine failures) in Howe Sound within the past several thousand years. Nonetheless, the potential for a landslide-triggered tsunami in Howe Sound, although very low, cannot be ruled out. The height of such a tsunami at Furry Creek would depend on the location, size and character of the triggering landslide and the distance from the landslide source.

3.6 Preliminary Geotechnical Recommendations for Subdivision Design

We offer the following comments to support the preliminary layout and design of the proposed roads, lots, and building footprints:

- Permanent, unsupported soil cuts in overburden should be cut no steeper than 1.5H:1V and preferably 2H:1V or flatter. Some ravelling and maintenance of slopes cut steeper than 2H:1V should be anticipated. Finer-gained soils, and areas where groundwater seepage is encountered, may require cutting at shallower slope angles to control sloughing. These slopes should be vegetated or provisioned with other durable erosion protection such as rock blanketing as soon as possible following completion of excavation. In this regard, the glaciofluvial soils exposed in the former gravel pits at the Uplands South area are more highly susceptible to surface erosion, particularly where concentrated surface runoff can discharge down the slope face. The relatively high erodibility of these soils should be carefully considered in the layout of road and lot grades and the design of the stormwater collection system.
- All steep, natural rock slopes above proposed building areas will require precautionary hand scaling. Removal of loose rock blocks, soil and trees on and at the crests of rock slopes will be required for safety purposes. Additional details on this can be provided once lot/road layout and grading is completed.
- Design of temporary and permanent rock cuts should be undertaken per MoTI Technical Circular T-04/17 entitled "Geotechnical Design Criteria". Preliminary design of bedrock cut slopes may assume a slope of 1H:4V (76 degrees) with no rock support. However, actual requirements for slope support can only be determined after excavation. Comprehensive machine and hand scaling will be required to remove loose rock blocks from crest of slope areas and final rock faces. All final cut slopes should be blasted using controlled blasting techniques. Specifically, a backline pre-shear and buffer row should be used to avoid damage to the face and minimize back-break. Blasting operations should be undertaken in accordance with MoTI Standard Specifications.

  Depending on the actual rock conditions encountered, and the effectiveness of the controlled blasting, rock slope stabilization including rock bolting, shotcrete, dental concrete and slope mesh may be required. All rock slopes should be inspected by a qualified geotechnical engineer during and on completion of blasting to identify zones of loose rock and/or unstable blocks and determine the requirement for scaling and rock bolting. All scaling and bolting should be carried out on an on-going basis while the blasting/rock slope stabilization contractor is on site and has access to the working face.

  We recommend a minimum 3 m wide zone of cleaned bedrock (i.e. remove all soil, loose rock vegetation, etc.) above all rock cuts and at the soil/rock interface in mixed overburden and rock cuts.
- As the development of the Northwest area is expected to require a significant volume of blasting and rock excavation, it may be necessary to conduct pre-construction geotechnical surveys of the inside of the CN Rail tunnel, possibly including terrestrial LiDAR scans, to document the existing conditions. Controlled blasting techniques,

supplemented by ground displacement and vibration monitoring above or inside the tunnel, may also be required to satisfy CN Rail requirements.

- Fill slopes in coarse granular material or blasted rock fill should be tentatively planned at 1.5H:1V to 2H:1V, depending on the height of the slope, with careful attention to site preparation, fill placement and compaction. Additional details on this can be provided once lot/road layout and grading is completed. Geosynthetic reinforcement of higher fill slopes and embankments may be required to satisfy the minimum factors of safety for global stability per current MoTI standards. Given the relatively shallow depth to bedrock at the site, and the high volumes of winter precipitation and runoff, it may be necessary to incorporate robust drainage measures (e.g. French drains, drainage blankets, secondary culverts, etc.) into the base of fills and embankments across ephemeral creek channels and other naturally wet areas.

- The talus deposits, in addition to their obvious susceptibility to rock fall hazards, exhibit visible signs of creep (a common hillslope process involving the slow, downward movement of soil and rock particles due to gravity), and could be marginally stable in some areas. Construction of roads, buildings and other infrastructure on talus deposits is not recommended.

3.7 Conditional Nature of Geotechnical Hazards

The mapped hazards on Figure 2 are conditional which means they are subject to change pending further geotechnical assessment and once the layout of the proposed roads, lots and building footprints has been finalized. Unexpected determination of hazard may affect lots now judged to be hazard free.

4. CONCLUSIONS

Based on the findings of the overview geohazard assessment, we conclude:

1. The proposed developments should, where possible, avoid the geotechnical hazard areas shown on Figure 2. However, based on the referenced geohazard acceptability criteria, we expect that many of the proposed lots within the hazard areas can be rendered feasible for development with further, site-specific geotechnical assessment to verify lot siting and recommended provisions for protective works, slope and foundation treatments, and construction practices.

2. In certain areas of the subject property, a potential reduction in building lots may also be necessary to avoid locations of serious hazard. We are least confident of the proposed lots within the Uplands North area for the reasons described in Section 3.5.2.

3. The observed rock fall hazards in the Upper Benchlands area require further, detailed geotechnical assessment. In the interim, we suggest that this area be given lower priority for development for the reasons described in Section 3.5.2.

5. CLOSURE

We trust the above provides the information you require at this time. If you have any questions regarding this letter, please contact either of the undersigned.

Yours truly,
Thurber Engineering Ltd.
David Regehr, M.Eng., P.Eng.
Review Principal

Jason Pellett, M.Eng., P.Eng./P.Geo.
Geotechnical Engineer

Attachments:

- Statement of Limitations and Conditions
- Figure 1 – Examples of Landslide Processes
- Figure 2 – Geotechnical Hazard Areas
- Photos 1 to 10
- Appendix A – Landslide Inventory Mapping

THURBER

REFERENCES

Blais-Stevens, A. 2008. Surficial geology and landslide inventory of the lower Sea to Sky corridor, British Columbia; Geological Survey of Canada, Open File 5322, scale 1:50,000.

Blais-Stevens, A., and Septer, D. 2008. Historical accounts of landslides and flooding events along the Sea to Sky Corridor, British Columbia, from 1855-2007. Geological Survey of Canada, Open File 5741, 117 pp.

Clague, J.J., and Orwin, J. 2005. Tsunami Hazard to North and West Vancouver, British Columbia. Centre for Natural Hazard Research Simon Fraser University. Prepared for North Shore Emergency Planning Office.

Cornforth, D.H. 2005. Landslides in Practice: Investigation, Analysis and Remedial / Preventative Options in Soils. John Wiley & Sons Inc., Hoboken, NJ, USA.

Cruden D.M., Varnes D. J. 1996. Landslide types and processes. In: Turner A.K.; Schuster R.L. (eds) Landslides: Investigation and Mitigation. Transp Res Board, Spec Rep 247, pp. 36–75.

Cui, Y., Miller, D., Schiarizza, P., and Diakow, L.J. 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-8, 9p. Data version 2018-04-05.

Holland, S.S. 1976. Landforms of British Columbia, a physiographic outline; B.C. Ministry of Energy, Mines and Petroleum Resources, Bulletin 48.

Hungr O., Evans S.G., Bovis M., and Hutchinson J.N. 2001. Review of the classification of landslides of the flow type. Environmental and Engineering Geoscience, VII, pp. 221-238.

Hutchinson J. N. 1988. Mass Movement. In: The Encyclopedia of Geomorphology (Fairbridge, R.W., ed.), Reinhold Book Corp., New York, pp. 688–696.

Jakob, M. and Lambert, S. 2009. Climate change effects on landslides along the southwest coast of British Columbia. Geomorphology, 107: 275-284.

Pierson, T.C. 2005. Hyperconcentrated flow – transitional process between water flow and debris flow. In Jakob, M. and Hungr, O. (eds.), Debris-flow Hazards and Related Phenomena, Springer, Berlin, 2005.

Varnes, D.J. 1978. Slope Movement Types and Processes. In: Landslides Analysis and Control. National Academy of Sciences, Special Report 176, Washington, D.C.: pp. 11-33.

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or 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 Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together 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. THURBER IS NOT 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 purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is 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 THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

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 judgmental in nature. 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 the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to 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 the conditions at the sampled points at the time of sampling. If 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.

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 Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not 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 Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any 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.

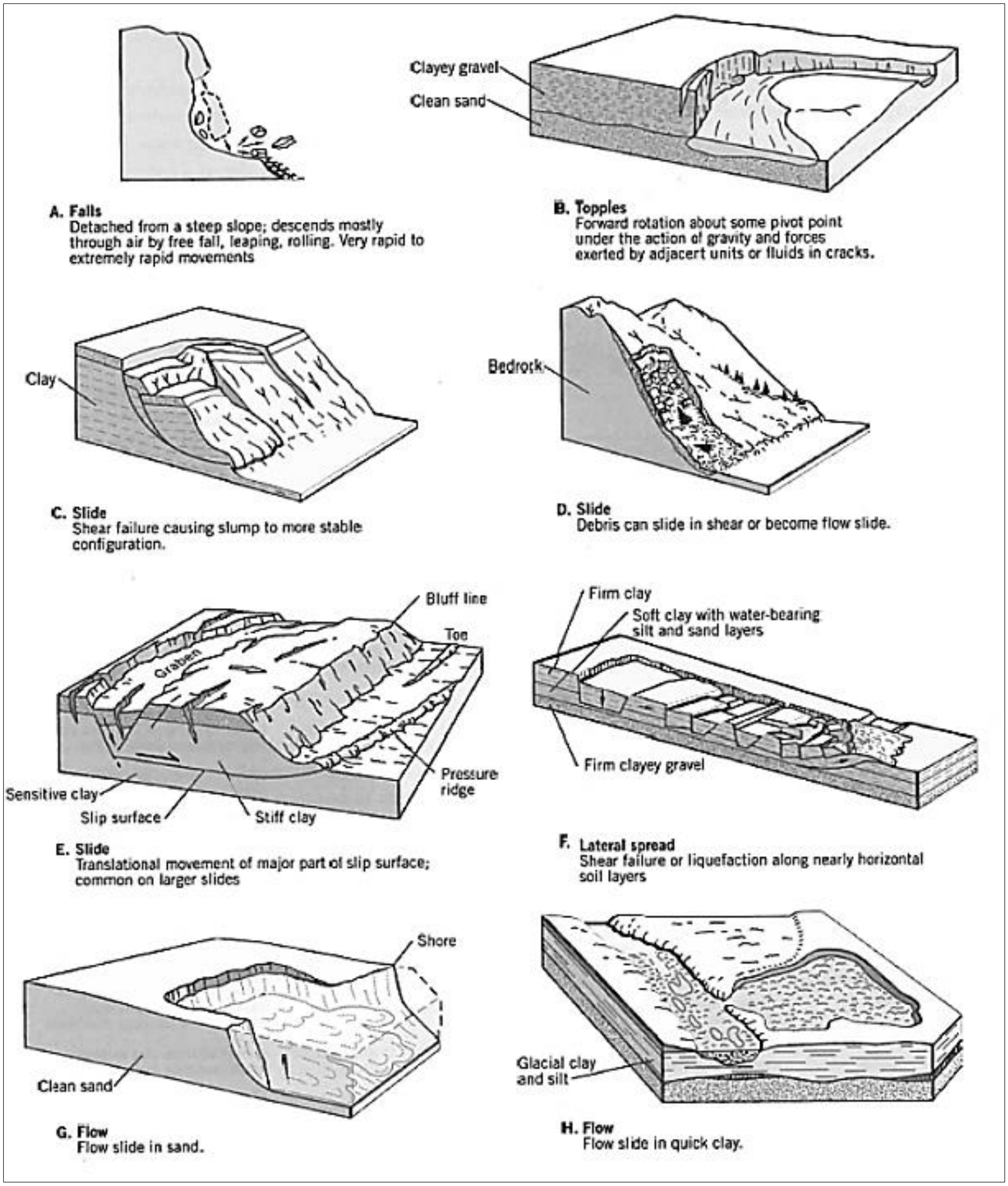
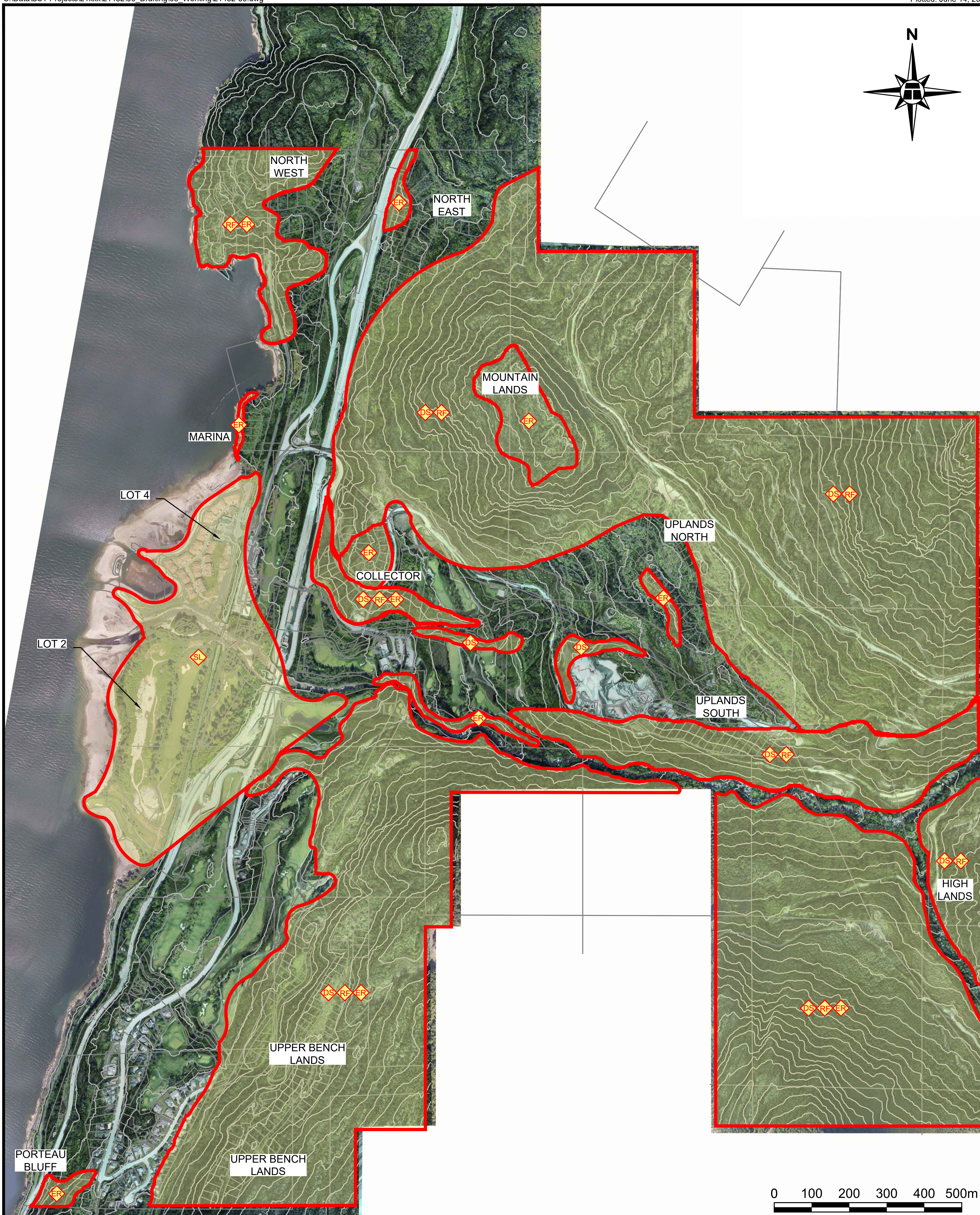


Figure 1. Examples of Landslide Processes (after Varnes 1978 and Cornforth 2005).



NOTES:

1. THIS FIGURE IS TO BE USED IN CONJUNCTION WITH THURBER'S ACCOMPANYING GEOTECHNICAL REPORT (PROJECT #21452) DATED JUNE 14, 2019.
2. HAZARD LINES DENOTE THE EXTENT OF POTENTIALLY DAMAGING GEOTECHNICAL HAZARDS BASED ON AN ESTIMATED PROBABILITY OF OCCURRENCE OF 10% IN 50 YEARS (1:475 ANNUAL PROBABILITY), MAPPED AT 1:5,000 SCALE. THESE LINES ARE CONDITIONAL AND ARE SUBJECT TO CHANGE PENDING FURTHER GEOTECHNICAL ASSESSMENT AS PART OF PRELIMINARY/DETAILED DESIGN.
3. THE BOUNDARIES OF THE GEOHAZARD MAPPING CORRESPOND TO LEGAL LOT LINES AND THE EXTENT OF THE AVAILABLE LIDAR DATA.
4. FLUVIAL AND COASTAL HAZARD LINES (FLOODING, BANK EROSION, ETC.) ARE NOT SHOWN.
5. CAD LINEWORK, LIDAR DATA AND ORTHOIMAGERY PROVIDED BY CREUS ENGINEERING LTD.
6. TOPOGRAPHIC CONTOUR INTERVAL 20 M.

LEGEND:

- RF — POSSIBLE ROCK FALL HAZARDS (REPORT SECTION 3.5.2)
- DS — POSSIBLE DEBRIS LANDSLIDE HAZARDS (REPORT SECTION 3.5.3)
- ER — POSSIBLE EXCAVATED ROCK AND FOUNDATION SET BACK HAZARDS (REPORT SECTION 3.5.4)
- SL — POSSIBLE SEISMIC LIQUEFACTION HAZARDS (REPORT SECTION 3.5.5)

THURBER ENGINEERING LTD.

CLIENT: FINE PEACE FURRY CREEK DEVELOPMENTS LTD.

GEOTECHNICAL HAZARD AREAS

OVERVIEW GEOHAZARDS STUDY
FURRY CREEK DEVELOPMENT
FURRY CREEK, B.C.

DESIGNED	DRAWN	APPROVED
JDP	MOM	DNR

DATE	SCALE	
14/06/19	1:10,000	
PROJECT No.	**FIG. No.**	**REV.**
21452-30	2	0

CANCEL PRINTS BEARING EARLIER NUMBER

PHOTO 1: View of talus deposits (rock fall debris) in the Upper Benchlands area.

PHOTO 2: View of rock bluffs high upslope (east) of the Uplands North area. Light-colored areas on the bluffs indicate where relatively recent rock fall has occurred.

PHOTO 3: View of rock fall debris along the east side of Uplands North area, near the toe of the steep mountain slopes. Note the field notebook in centre of photo for scale.

PHOTO 4: View of scatted rock fall debris (talus) at the north end of the Uplands North area, near the base of the Mountain lands.

THURBER

PHOTO 5: View of steep rock bluffs upslope of the existing gravel road in the Collector area.

PHOTO 6: View of steep bedrock bluffs in the Collector area, upslope of Clubhouse Road.

THURBER

PHOTO 7: View of steep bedrock bluffs within the Northwest area. Yellow polygon shows partially detached rock mass.

PHOTO 8: View of steep bedrock bluffs within the Northwest area. Yellow arrow indicates unfavourably oriented fracture plane dipping out of the slope.

THURBER

PHOTO 9: View of steep slopes in the Upper Benchlands area with evidence of shallow sloughing in the thin veneer of soil overlying bedrock.

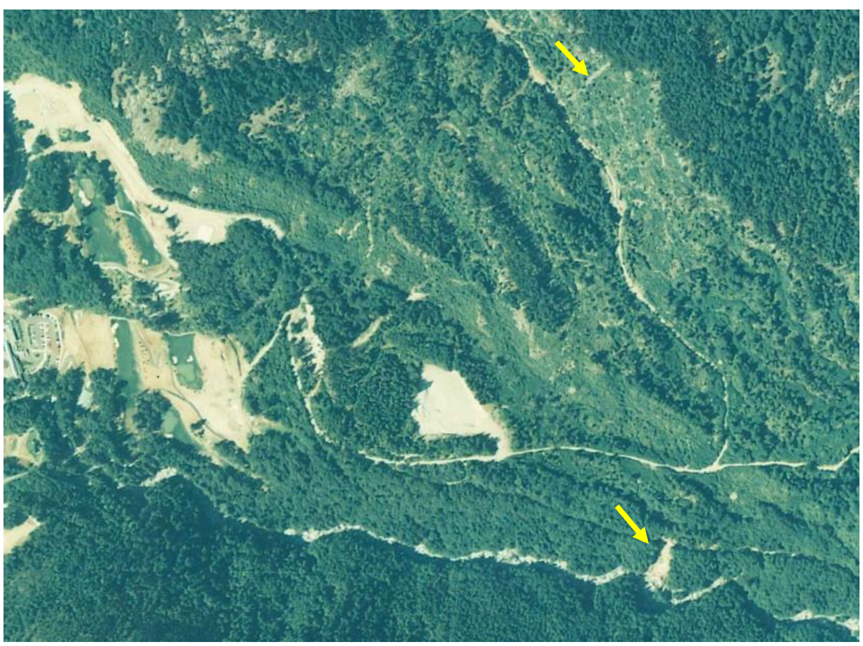
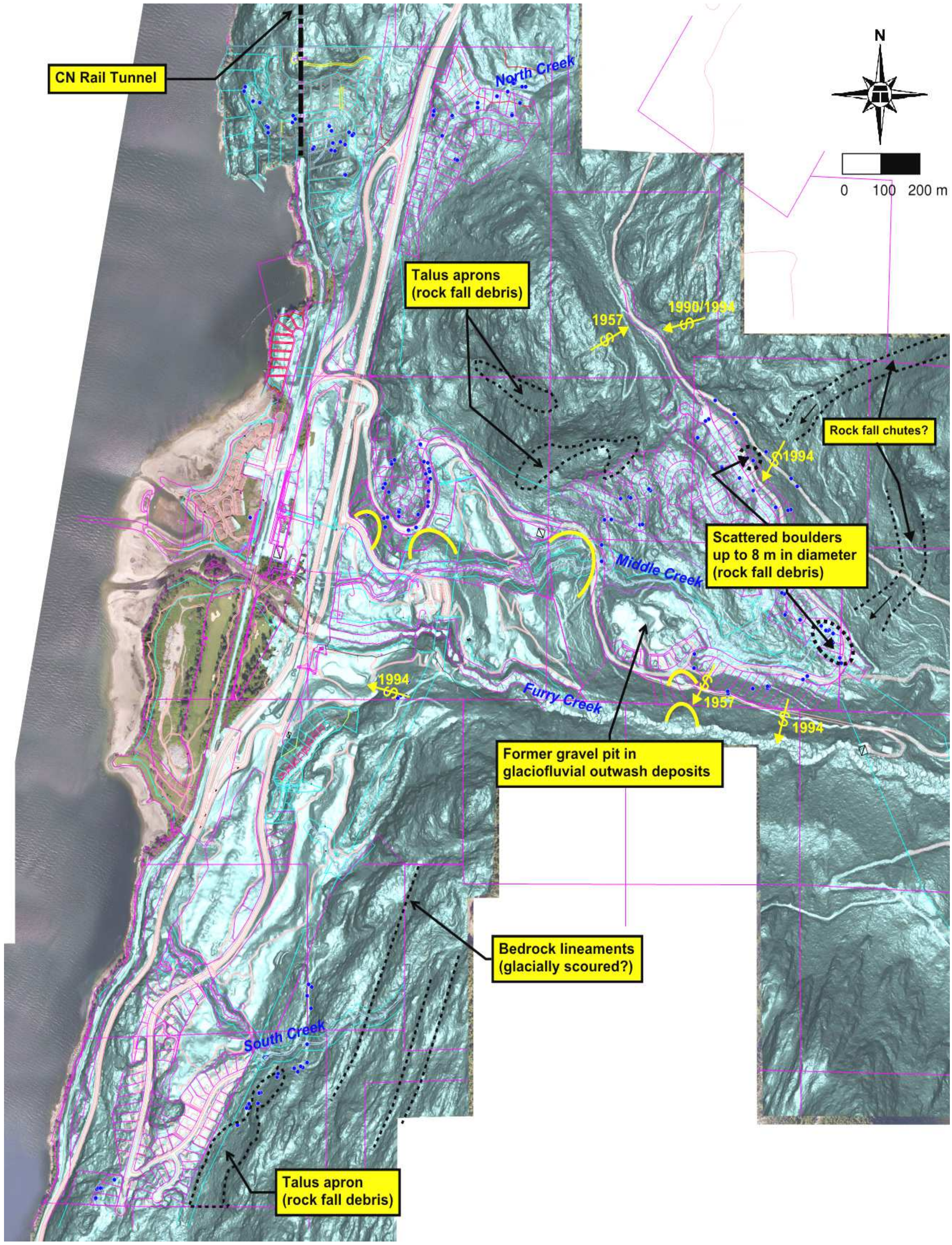


PHOTO 10: View of inferred landslide tracks (indicated by yellow arrows) from a 1994 air photo of the Uplands area.

APPENDIX A



LEGEND:

- GPS Field Observation Waypoint (2019)
- Headwall (scarp)
- Historical Landslide / Erosion Track
- Area or Feature of Interest

NOTES:

1. Identified terrain features are based on desktop review of the available LiDAR imagery and limited field checking.
2. The years noted on the figure correspond to the year of the historical air photo where this feature was first observed.
3. CAD linework, LiDAR data, and orthophotos provided by CREUS Engineering.

THURBER ENGINEERING LTD.

SKETCH A-1
LANDSLIDE INVENTORY MAPPING