REPORT

Class 2 Flood Hazard Assessment

Lots 75, 76, 77, DL 530 & Rem DL 530 & Lot 4, KDYD, Plan KAP79399 on Monck Road, near Merritt, BC

Submitted to:

Nicola Lakeshore Estates
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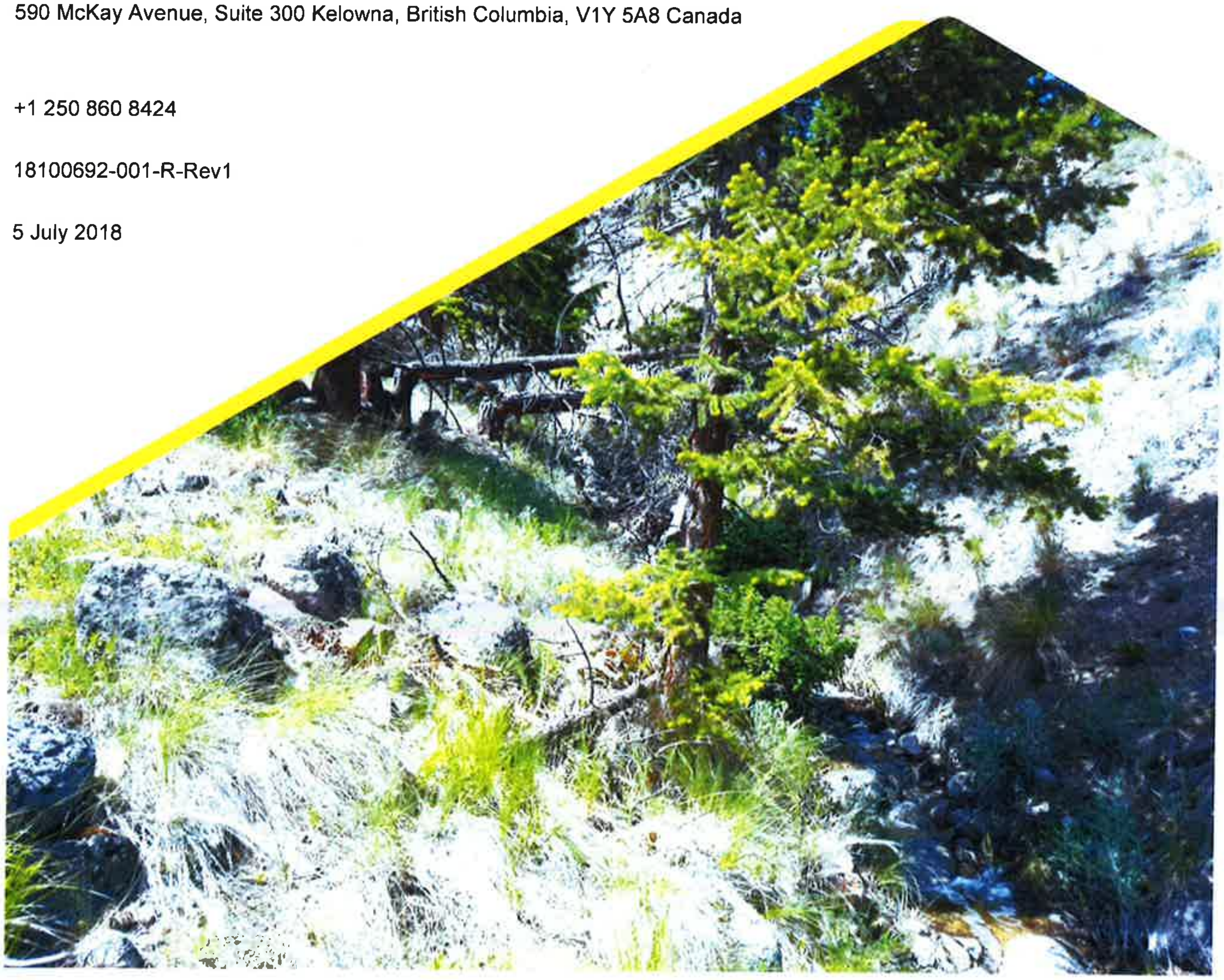

Distribution List

1 eCopy - Nicola Lakeshore Estates

1 eCopy - Watson Engineering Ltd.

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1.0 INTRODUCTION

At the request of Nicola Lakeshore Estates and Watson Engineering Ltd., Golder Associates Ltd. (Golder) completed a flood hazard assessment for the proposed subdivision of Lots 75, 76, 77 within DL 530, KDYD, Plan KAP 79399, on Monck Park Road, near Merritt, BC (herein referred to as the subject property). The subject property also includes those portions of the remainder of DL 530 and Lot 4 of DL 530 adjacent to Lots 75, 76, and 77 between Monck Park Road and Jagpal Way (Upper Access Road).

The flood hazard assessment was carried out for an unnamed drainage that crosses the proposed subdivision. For the purposes of this report, this unnamed drainage will be referred to as Unnamed Creek; the proposed subdivision will be referred to as the subject property. Refer to Figure 1 for a map showing the subject property and the watershed upslope of the subject property that is drained by Unnamed Creek.

It is understood by Golder that the owner proposes to subdivide the subject property into strata lots and has requested a hydrological assessment for clear flood hazard. Golder further understands that a geohazard assessment was completed by Westrek Geotechnical Services Ltd. (Westrek 2018). This assessment indicated that the subject property was identified as potentially being subject to flooding and debris flow hazards from Unnamed Creek.

This report should be read with Section 6 and the *Important Information and Limitations of This Report* included in Appendix A. This information is key for the proper use and interpretation of this report. This report does not consider potential flooding hazards associated with Nicola Lake.

1.1 Background

Westrek (2018) reported that from a geohazard perspective, safe development of the subject property was possible if surface water management upslope of the subject property was implemented. Westrek recommended that a surface water management plan account for site features, flooding potential, and debris flood potential from Unnamed Creek.

It was stated in an email from the Ministry of transportation and Infrastructure (MoTI) (Joan Brickwood, 2018) that prior to subdivision approval:

1) A runoff management plan should be developed and implemented for the subject property.
2) A hydrological assessment for clear flood hazard is required for the runoff management plan.

Golder submitted a proposal to Nicola Lakeshore Estates on 16 May 2018 to complete the hydrological assessment for the subject property that is required by the MoTI (second bullet above).

Nicola Lakeshore Estates indicated that all lakefront properties have a flood covenant registered for the properties within the proposed development.

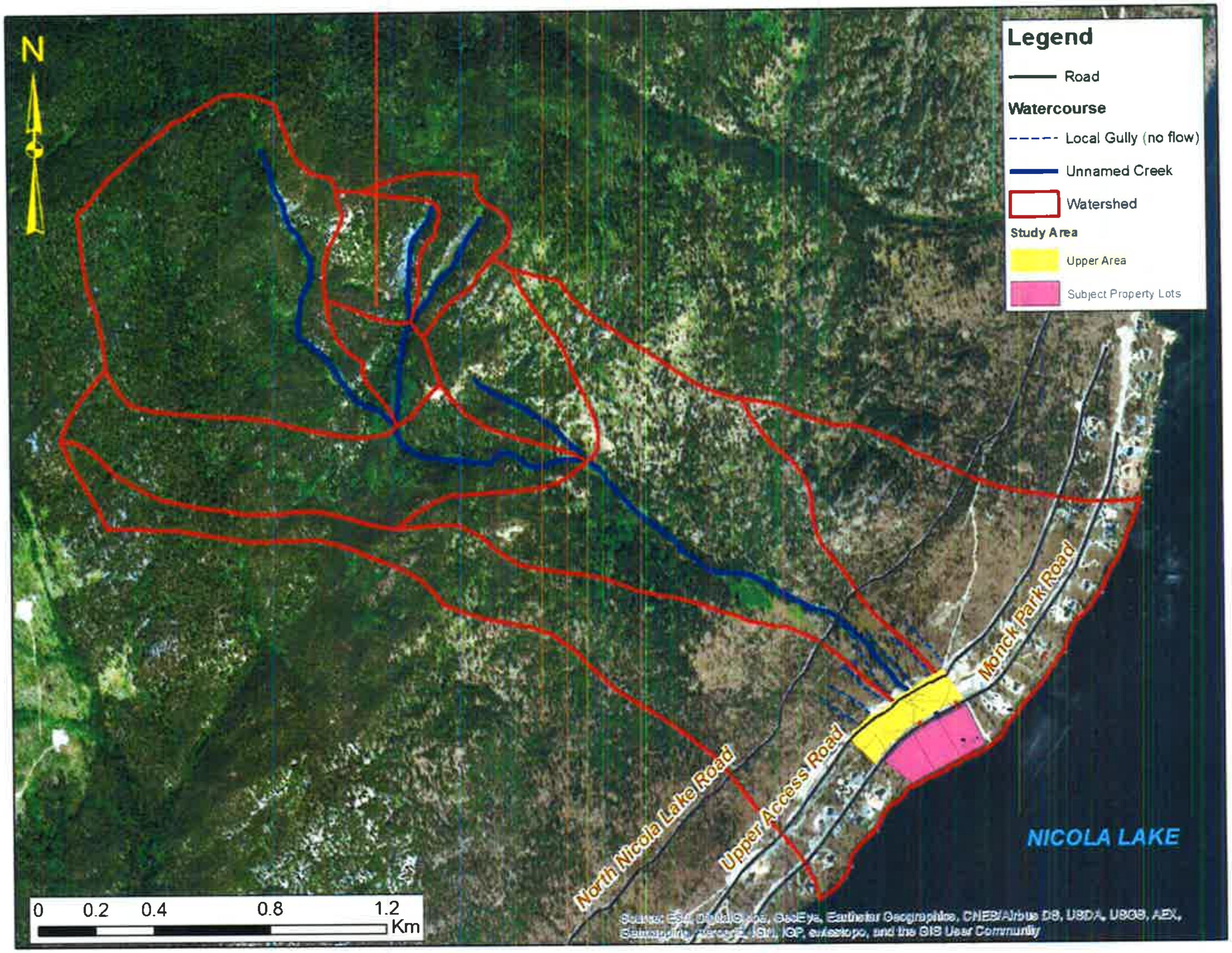

Figure 1: Map of Unnamed Creek and Subject Property

1.2 Professional Practice Guidelines

Engineers and Geoscientists BC (EGBC, formerly known as APEGBC) published *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC* in June 2012 (the Guidelines). Based on experience on similar projects the Guidelines are the practice standard for flood hazard assessment work in BC.

The MoTI typically requests that the Guidelines be followed when completing flood hazard assessments. The Guidelines present several broad categories of assessments depending on the application and characteristics of the study area and recommended assessment methods for each category. Based on this guidance and details of the proposed development provided by the owner, it was recommended that a Class 2 flood hazard assessment be completed for the subject property.

1.3 Scope of Work

The scope of work was outlined in Golder's 16 May 2018 proposal (Reference No. P18100692-001-P-Rev1). The scope of work generally included a site visit assessment of the subject property and Unnamed Creek where it drains towards the subject property, a geomorphology assessment including review of debris hazards, hydrological estimates of clear flow rates including consideration for climate change, and the preparation of a flood hazard assessment report for the subject property.

1.4 Methods

Golder completed a site visit to the subject property and portions of the watershed of Unnamed Creek on 24 May 2018. Visual observations made during this site visit were focussed on the following three areas:

- The channel of Unnamed Creek upslope of the subject property for a distance of approximately 1,000 m
- The subject property
- The typically gently sloping terrain areas adjacent to Nicola Lake

Indications of previous flooding or high-water levels, or the absence of these signs, were documented. The channel type, width, and slopes were documented, as well as the presence of adjoining side channels and estimates of flow rates at the time of the site visit. Wood, rock, and soil debris located near or within the channel reach were also documented. Geo-referenced photographs were taken of the observed areas. Geomorphological interpretations were based on the field observations and review of available historical air photos. The potential for geomorphological hazards like debris flows were assessed from the geomorphological interpretations.

A historical air photo review was completed for the Unnamed Creed watershed and surrounding area, which included review of photos from 1968 to 2015 (Table 1). The air photos were provided on loan from the UBC Department of Geography. The purpose of the air photo review, in support of the flood hazard assessment, was to gather historical evidence of:

- Debris flow/flood events
- Changes in channel morphology such as aggradation, erosion, or avulsion
- Other connected indicators (slope instability such as landslides and rockfall)

Table 1: Historical Air Photos Reviewed

Year	Flight Line Number	Air Photo Frame Numbers
1968	BC7102	251 to 253
1986	BC86055	193 to 195
2004	BCC04017	155,156
2015	BCD15202	62 to 64

Readily available data from Environment and Climate Change Canada (ECCC) were obtained to support the statistical hydrology analysis. Short duration rainfall data are available for point locations at selected ECCC climate stations and at other locations using the online IDF_CC Tool from the University of Western Ontario. This web-based application was applied for this study. Hydrology software (HEC-HMS) from the US Army Corps of Engineers was used to analyze precipitation-based runoff in the Unnamed Creek (US ACE 2017).

LiDAR survey data was obtained from Nicola Lake up to approximately 1,100 metres above sea level (masl). This data was used to support the hydrology and geomorphology assessments.

Hydraulic analysis of the channel and mitigation options were completed using standard calculations for open channels (Manning's formula), pipe inlet (weir equations), and pipe flow.

2.0 SITE INFORMATION

2.1 Location and Legal Description

The subject property is located at Lots 75, 76, 77 within DL 530, KYD, Plan KAP 79399, on Monck Park Road, near Merritt, BC. The subject property also includes those portions of the remainder of DL 530 and Lot 4 of DL 530 adjacent to Lots 75, 76, and 77 between Monck Park Road and Jagpal Way (Upper Access Road). The dimensions of the subject property are approximately 300 m by 300 m. The subject property is located on a natural bench on the western shore of Nicola Lake. A borrow pit operation is located upslope of Monck Park Road. The proposed lots are located between the Jagpal Way (Upper Access Road) and Nicola Lake.

2.2 Proposed Development

It is understood that Nicola Lakeshore Estates is proposing to subdivide Lots 75, 76, and 77 into 40 individual building lots. This is a proposed strata development. According to Nicola Lakeshore Estates, this is the 'Phase 3' development. It is further understood that a future 'Phase 4' development would subdivide the remainder of DL 530 and Lot 4 to build additional strata lots, but a layout for these lots has not been created at this time. There will be less than 100 total building lots in the proposed development.

Based on preliminary 'Phase 3' drawings provided by Watson Engineering Ltd., there will be one access road off Monck Park Road that will generally bisect the subject property. This proposed road will be parallel to Monck Park Road. There will be 20 lakefront lots below the proposed road and 20 upper lots above the proposed road.

2.3 Existing Conditions and Physical Attributes

The subject property is located on the northwest shore of Nicola Lake. It is crossed by an Unnamed Creek that drains a small watershed on the Nicola Lake valley hillside. A description of the existing conditions and physical attributes of the subject property are below.

2.3.1 Geology

Nicola Lake and the subject property are located in the Thompson Plateau, which is a sub-region of the Interior Plateau of British Columbia (Church and Ryder 2010). The Thompson Plateau generally includes bedrock geology consisting of (Valentine et al. 1986):

- Flat or gently dipping lavas
- Sedimentary and volcanic rocks
- Granitic stocks
- Batholiths

According to geodatabase information online (iMapBC) the area of the Unnamed Creek watershed contains granodioritic intrusive rocks from the Paleogene. Westrek (2018) provides additional description of the setting and bedrock geology of the subject property.

2.3.2 Geomorphology

Unnamed Creek is a 2nd order channel and is a tributary to Nicola Lake. The channel is considered steep and confined. Unnamed Creek discharges onto gently sloping terrain along the margin of Nicola Lake at the subject property. A distinct and currently active alluvial fan feature was not observed in the historical air photos but geomorphic evidence of channel discharge and sediment accumulation were observed.

Observations from the historical air photo review indicate that:

- The watershed of Unnamed Creek has not been harvested over the period of the photo record.
- Access roads into the upper watershed areas were not observed.
- The watershed is contained within steep slopes that are situated downslope of more gently sloping areas. This situation of flat slopes over steep slopes is common in the BC Interior.
- No evidence of wildfire burns affecting the timber stands within the watershed were identified in the available imagery.
- Large landslides and similar exposed sediment sources delivering sediment into the channel of Unnamed Creek were not observed in the available imagery.
- Significant debris flood/flow deposits between the gully of Unnamed Creek and Nicola Lake were not observed in the earliest imagery reviewed indicating that several centuries (e.g., 500 years or more) have passed without such an event occurring.

2.3.3 Field Reconnaissance

A field reconnaissance of Unnamed Creek was completed on 24 May 2018. The field reconnaissance included a foot traverse of Unnamed Creek starting from near the Nicola Lake shoreline (most downstream end of the stream and gently sloped terrain along the lake) and continuing upstream towards the upper boundary of the subject property (upstream the borrow pit), and upstream along Unnamed Creek for a total distance of approximately 1,000 m (survey area) upstream of the lake and 700 m upstream of the subject property. The terrain slopes observed within the survey area indicated that the profile of the stream channel can be separated in three main reaches (from upstream to downstream, Figure 1):

- **The upper reach**. Extends above the above upper boundary of the subject property (above borrow pit, at approximately 670 masl elevation). Upper Access Road crosses the area on the upstream side of the borrow pit. Golder survey extended upstream for approximately 700 m, to approximately 850 masl elevation. Typical terrain slopes were estimated at approximately 25%. North Nicola Lake Road crosses the area at mid-elevation – approximately 780 masl.
- **The middle reach.** Overlaps the approximate boundaries of the borrow pit, located immediately above the proposed development perimeter (between Monck Park Road and Upper Access Road), with terrain slopes of approximately 20%.
- **The lower reach**. Located between Monck Park Road and Lake Nicola Shoreline, covering the proposed development perimeter, and with typical terrain slopes of approximately 15%.

A summary of the field observations for each reach is provided in the following sections in the order from upstream to downstream.

2.3.3.1 Upper Reach

This reach occupies the most upstream part of the Unnamed Creek watershed. The average longitudinal gradient (upstream to downstream) was estimated from LiDAR data at approximately 25%. The stream channel is confined within an incised valley that has a V shape and a typical top width of up to 20 m. The valley walls are steep with slopes estimated between 40% and 60%, for the majority of its length, with the exception of the most upstream end of the reach where the valley walls are shallower, with slopes estimated at 20%. The valley walls vary in length from 3 to 6 m in general therefore the stream has been identified as flowing in a gully.

The plan view of the stream channel shows a few small meanders and a relatively straight course along the gully. Multiple narrow sections were observed where the stream channel is incised into the gully floor with no discernible floodplain. The typical bankfull width was measured to be 1 m, with an average depth of approximately 0.2 m. The stream channel has a step-pool morphology with cobble and boulders as the main channel materials. Small isolated pockets with finer materials (small gravel and sand) were observed in the pool sections of the stream channel. At the time of visit the stream flow was observed and the discharge estimated at approximately 5 l/s.

The terrain adjacent to the stream channel in this reach are covered by a mature light pine forest. Windfall trees were frequently observed on the gully walls and some over or in the stream channel. Large deposits of debris materials (sediments) were not observed. Woody debris from the windfall areas (mostly tree trunks from the gully walls and the stream channel banks) was observed in the channel and was interpreted to be sourced from the upslope areas of the gully walls rather than carried downstream by the creek flows. The floodplain within this reach is either poorly developed or non-existent.

On both sides of the main gully occupied by Unnamed Creek, two secondary gullies were observed aligned parallel with the main gully. They are situated approximately 100 m downstream of North Nicola Lake Road and extend downslope to the upper margins of the subject property. No channel or active flow was observed in these features. While they may collect surface runoff and serve as a temporary drainage features during the snow melt period and during more intense rain events, they appear to be geomorphically old features and possibly associated with the post-glacial formation of the current Unnamed Creek gully.

2.3.3.2 Middle Reach

This reach extends from the downstream boundary of the Upper Reach to Monck Park Road, and overlaps almost entirely the borrow pit area. As a result, the majority of the original natural terrain is now disturbed by the aggregate extraction activities. The area is now mostly covered by aggregate storage piles and associated access roads. A gravel road (Unnamed Access Road) runs above the borrow pit. The material onsite appears to be primarily colluvial material derived from slope erosion. Some alluvial material was observed but not in large enough quantities to validate referring to the more gently sloped terrain towards the lake as an alluvial fan.

The initial (natural) terrain gradient was estimated at approximately 20% from nearby terrain. In this reach the main channel of Unnamed Creek was diverted northwest, away for the borrow pit area, flowing in the Unnamed Access Road side ditch. The channel runs along the northwest limit of the borrow pit for a short distance after which returns towards the borrow pit area. Near the centre of the borrow pit a HDPE culvert redirects the flow towards the downstream section of the borrow pit after which the flow is again diverted northwest, away from borrow pit, along a local access road.

2.3.3.3 Lower Reach

This reach extends downstream of Monck Park Road to the Lake Nicola shoreline, and overlaps almost the entire Subject Property. The terrain is slightly irregular with an average gradient of approximately 15%. No active channel with runoff was observed. Discontinuous draws (swales shape) were observed with a typical top width of 4 m to 5 m, and up to 1.5 m deep. Large sub-angular to rounded boulders were observed throughout the area in a random pattern, which suggests they were transported and placed by past glaciers.

The upper half of the reach was cleared off and the large boulders removed for the construction of an effluent infiltration system (Westrek 2018). Several alignments of stand-pipes were also observed in the field by Golder during the field reconnaissance. The lower half is covered by a light tree (mostly pine) coverage with no visible signs of debris flows (no tree scars, no tree buttress buried). The trees were estimated to be between 100 and 200 years old based on height and diameter.

2.3.4 Watershed and Site Drainage

The Unnamed Creek drains a watershed area of approximately 2.7 km^2. The watershed has a southeast-facing aspect. It is a forested watershed and there are bedrock outcroppings. According to geodatabase information online (iMapBC) the biogeoclimatic zones in the watershed range from (lowest elevation to highest elevation):

- Bunchgrass, Very Dry Warm, Nicola variant (BG xw 1) (lowest elevation at Nicola Lake)
- Ponderosa Pine, Very Dry Hot, Thompson variant (PP xh 2)
- Interior Douglas-fir, Very Dry Hot, Thompson variant (IDF xh 2)
- Interior Douglas-fir, Dry Cool, Thompson variant (IDF dk 1) (highest elevation in watershed)

The elevation of Nicola Lake is approximately 626 masl. The elevation of the subject property ranges from Nicola Lake up to 660 masl. The highest point in the watershed is approximately 1,330 masl.

The drainage direction follows the watershed aspect. All drainage on the subject property flows southeast. A key feature near the subject property is the presence of the borrow pit in the upper area above Monck Park Road. Construction of this borrow pit has altered the land surface and drainage. Unnamed Creek does not have a natural channel through the borrow pit, which is approximately 120 m in length. At the time of the site visit surficial drainage was being diverted along the roadside ditches above the subject property.

Unnamed Creek flows in a natural channel above the Upper Access Road (Figure 2). At the Upper Access Road the channel is diverted along the following path:

- Northwest along the road, flowing along the roadside ditch for approximately 140 m. The geometry of the ditch averages a bottom width of 0.2 m, top width of 3 m, and depth of 0.3 m.
- The ditch crosses the Upper Access Road through an approximately 10 m long, 400 mm diameter HDPE culvert that drains to the borrow pit area.
- Drainage then flows southwest through the borrow pit for approximately 70 m.

- After this the drainage flows northwest through another similar culvert and flows for approximately 100 m into an area with standing water.
- An outlet from the area of standing water was not identified in the field. It is assumed that some of the water infiltrates into the ground in this area.
- Across the Upper Access Road, downstream (below) from the creek first diversion, standing water was also observed, suggesting that some water from the channel may be infiltrating under the road.
    - Nicola Lakeshore Estates provided additional information about existing drainage infrastructure near the subject property. Nicola Lakeshore Estates indicated that the existing drainage at the operations building (approximately 100 m northeast of the subject property) is collected via two catchment basin manholes then down to an easement that discharges to Nicola Lake via a 450 mm HDPE pipe. This information was not verified in the field by Golder, but it is assumed that the standing water that was observed can drain to this infrastructure.

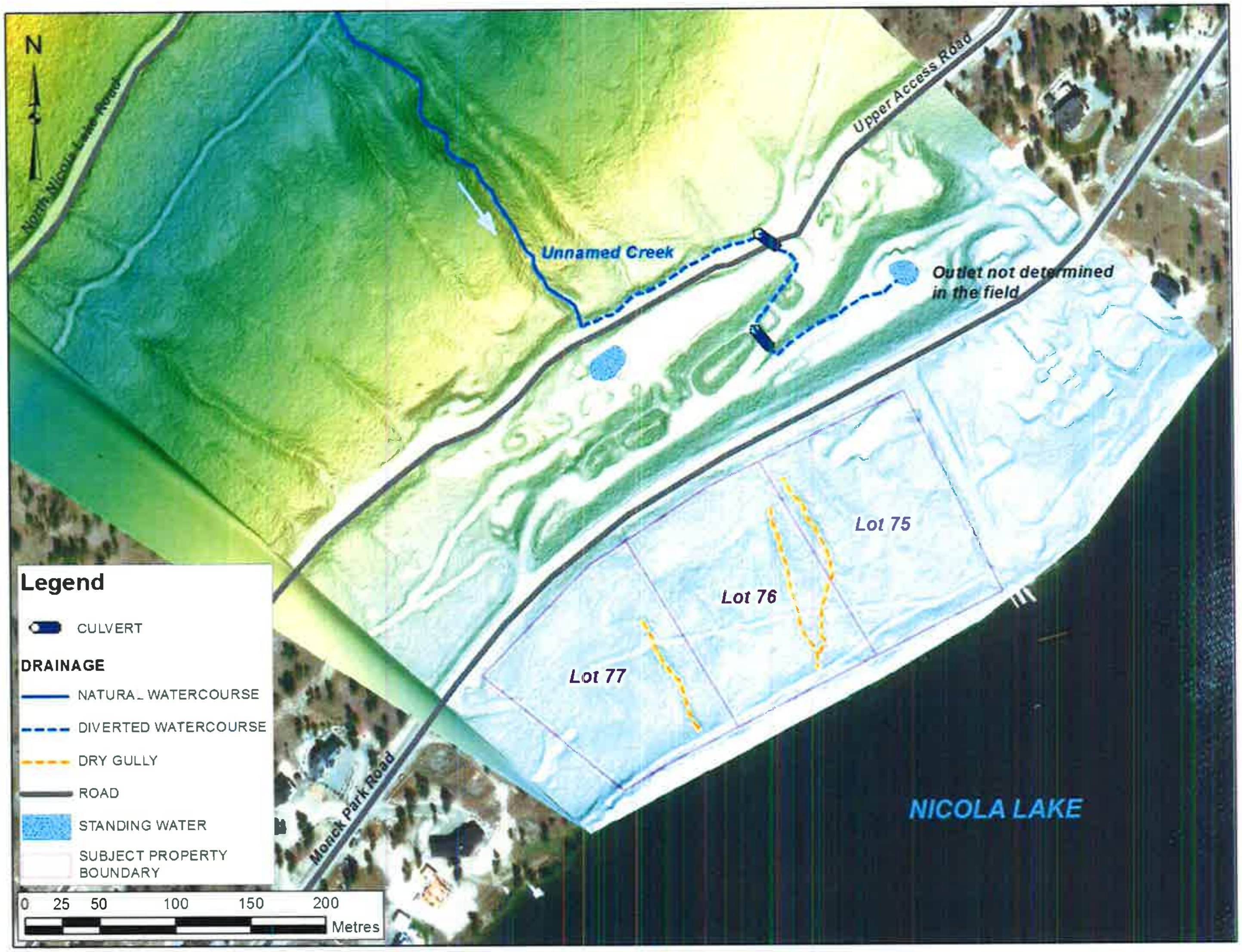

Figure 2: Drainage features above and at the subject property (hillside elevation shading is from the LiDAR data)

Under the design flow conditions, the roadside ditch will not have sufficient capacity to safely convey the flow. The Upper Access Road will be overtopped which will lead to overland flow in the borrow pit area. It is anticipated that after flow passes the borrow pit area, Monck Park Road will be overtopped and there will be overland flow on the subject property and concentrated flow in the existing gullies on the subject property. This creates a potential overland flood hazard for the entire subject property.

2.4 Floodplain Regulations

The Thompson Nicola Regional District (TNRD) has floodplain regulations in the Zoning Bylaw No. 2400. Based on this bylaw, the Unnamed Creek requires a flood construction level of 1.5 m above the natural boundary. It also requires a floodplain setback of 15 m.

As noted in Section 1.1, Nicola Lakeshore Estates indicated that all lakefront properties within the development currently have a registered flood covenant.

3.0 HAZARD ASSESSMENTS

The following sections provide assessment of the flood-related hazards at the subject property. For historical context, an air photo review was also completed.

3.1 Fluvial Geomorphology and Debris Flow/Flood Hazards

A review of fluvial geomorphology in Unnamed Creek was completed in Sections 2.3.2 and 2.3.3. Observations in the upper reach channel and the gully from the air photo analysis and the field reconnaissance indicates that a debris flood/flow event has not occurred in the channel over the historical past (the last 100-200 years) and has not occurred over at least 500 years. The current forest cover on the lower reach indicates that significant debris flood/flow events are unlikely to have occurred over the last 500 or more years. An assessment of watershed-scale changes and debris flood/flow hazard is provided below.

3.1.1 Assessment of Watershed-Scale Changes

Watershed-scale environmental changes have the potential to affect the entire watershed, which could affect the hydrology and flood hazards of the watershed. A desktop review of the Unnamed Creek watershed was carried out using readily available imagery and historical air photos. Environmental changes that have the largest potential to affect the hydrology of the watershed and the flood levels (peak flows) were considered to be related to the forest cover, and they include:

- ***Timber Harvesting:*** Timber harvesting tends to have the potential to affect the hydrology of the watershed by changing the surface runoff over the affected areas. Without the full tree coverage both winter snow accumulation and spring melt rates increase and therefore increasing the runoff downstream. In addition, sediment load and other erosion related processes can increase the potential for debris flows. Harvesting at higher elevations (the upper part of the watershed), would have the greatest impact and is, therefore, of most concern. No evidence of historical harvesting was observed in the upper part of the watershed.
- ***Forest Wildfires:*** Forest wildfires within the watershed can be considered common. Based on the ecology of this forested watershed, these forests can experience frequent fire events that maintain their health. Many wildfires are caused by lightning but some can be human caused. Large scale wildfires may have a similar effect on the watershed hydrology as described above for timber harvesting. However, there is hydrological research on post-wildfire conditions that indicates the effects on peak flows are inconclusive (Bladon and Redding 2009; Winkler et al. 2010). Physical changes across the watershed can result in the normal regime of the watershed becoming out of sync. No evidence of historical wildfires was observed in the watershed. On this basis, there have been no factors included in the peak flow estimates for wildfire effects. The potential for changes in the frequency and severity of forest fires related to the implications of climate change was accounted for within the hydrologic modelling.

3.1.2 Debris Flow/Flood Hazard

The field observations and data analysis, together with the historical air photo review of the Unnamed Creek watershed, indicate that there is a very low debris flow hazard for the subject property with no evidence for significant debris flood/flow events observed over timescales of several centuries. Therefore, the debris flood/flow hazard is assessed as being no greater than a probability of 0.002 in a given year, or less than once in 500 years.

As a result, the scaling or bulking of the clear flow rate to derive a design flow rate for the flood hazard assessment was considered unnecessary. It is Golder's opinion that only the clear flow rates are appropriate for the evaluation of flood hazards at the subject property.

3.2 Flooding Hazards

According to the Guidelines, *when a flood becomes a source of potential harm it becomes a hazardous flood* (EGBC 2012). Flooding hazards at the subject property can be generated from Unnamed Creek, which is the focus of this flood hazard assessment. No sources of flow data for Unnamed Creek were identified during this assessment. Therefore, to assess possible flooding hazards at the subject property, a hydrological analysis was completed. This analysis was based on review of climate conditions, rainfall, and snow.

The susceptibility of the subject property to flooding hazards from Nicola Lake was not included in the scope of work for this study. Nicola Lake has existing floodplain mapping available from the Province of BC (1989) but that this mapping is now dated. We understand that a dam safety review for the outlet of Nicola Lake is being carried out by others but it is not known if updated flood levels are being assessed.

3.2.1 Climate Overview

The *Merritt STP* climate station from ECCC (No. 1125079) has published Canadian Climate Normals data from the period between 1981 and 2010. This station is reasonably close to the subject property (22 km southwest) at an elevation of 609 masl. These data are summarized in Table 2. The average annual temperature at this station is 7.8°C. The warmest months are typically from May to September. The coldest months are from December to February. The average total annual precipitation is 321.1 mm. Rainfall can occur all year and the wettest rainfall month is typically June. Snowfall typically occurs between November and March, with small amounts falling in April, May, and October.

Table 2: 1981-2010 Canadian Climate Normals for Merritt STP Climate Station

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Average Temperature (°C)	-3.0	-0.5	4.1	8.1	12.3	15.9	18.8	18.6	13.9	7.6	1.2	-3.7
Rainfall (mm)	13.7	11.0	11.8	14.2	29.8	36.6	29.1	20.6	24.6	26.2	23.4	13.3
Snowfall (cm)	16.8	8.3	4.4	0.9	0.3	0	0	0	0	1.3	12	22.7
Total Precipitation (mm)	30.5	19.4	16.2	15.1	30.1	36.6	29.1	20.6	24.6	27.6	35.4	36.0

Based on review of climate conditions and Golder's knowledge of hydrology in this region, design flood conditions for a small watershed like the one for Unnamed Creek will be generated during an intense rainfall event when there is snow on the ground. The timing of this event will occur in the spring months in April or May. Based on the aspect and range of elevation in the watershed, it is estimated that there will only be snow on the ground in the upper watershed in April and May. Therefore, the critical design event for the hydrological analysis is an intense rainfall event that contributes to a rain-on-snow event in the upper watershed.

3.2.2 Hydrological Analysis

The hydrological analysis of the Unnamed Creek watershed was completed using a numerical model. In order to reconcile for the range of elevations within the watershed (approximately 700 m), precipitation within the watershed was separated into two zones:

1) A lower zone, with average elevations below approximately 1,200 masl
2) An upper zone, with average elevations higher than approximately 1,200 masl

For the lower zone, the precipitation input for the hydrological model includes rainfall only. For the upper zone, the precipitation input for the hydrological model includes rain-on-snow events.

3.2.2.1 Rainfall and Design Storm

Due to the small size of the watershed (2.7 km^2), and the generally steep terrain, it was assumed that the time-of-concentration for rainfall to report to the subject property from the upper areas of the watershed would be relatively short. Therefore, short duration events were analyzed (i.e., rainfall durations of 24 hours or less).

Based on ECCC data across Canada, the IDF_CC Tool can be used to estimate IDF data for ungauged locations. The IDF_CC Tool also provides rainfall estimates based on possible future climate change scenarios to the year 2100. There are three Representative Concentration Pathways (RCP) that are considered and RCP4.5 was selected for the watershed. RCP4.5 is an intermediate scenario when compared to RCP 2.6 (low) and RCP8.5 (high). This scenario would lead to moderate climate change severity. Further information on the climate change scenarios and Global Climate Models is provided in the IDF_CC Tool manuals (Western University 2018). Based on the data output available through the IDF_CC Tool, it was adopted to provide rainfall estimates for the watershed.

ECCC and the IDF-CC Tool provide short duration rainfall data up to a 100-year return period. Logarithmic extrapolation was completed to estimate 200-year return period rainfall depths. These estimated rainfall depths are listed in Table 3 for event duration between 1 hour and 24 hours.

Table 3: 200-Year Return Period Rainfall Depths for the Unnamed Creek Watershed

Duration (Hours)	Rainfall Depth (mm)	Duration (Hours)	Rainfall Depth (mm)
1	44.1	6	60.5
2	49.9	12	68.4
3	53.6	24	77.3

Design storms for these rainfall depths were developed using the alternating block method (Chow et al. 1988). For storm durations of 1, 2, or 3 hours a time step using 30 increments was applied. For storm durations of 6, 12, or 24 hours a time step using 24 increments was applied. These increments were selected such that the time steps were round numbers in the hydrological model (i.e., 2, 4, 6, 15, 30, and 60 minutes, respectively). The storm distribution for each synthetic design storm is shown in Figure 3.

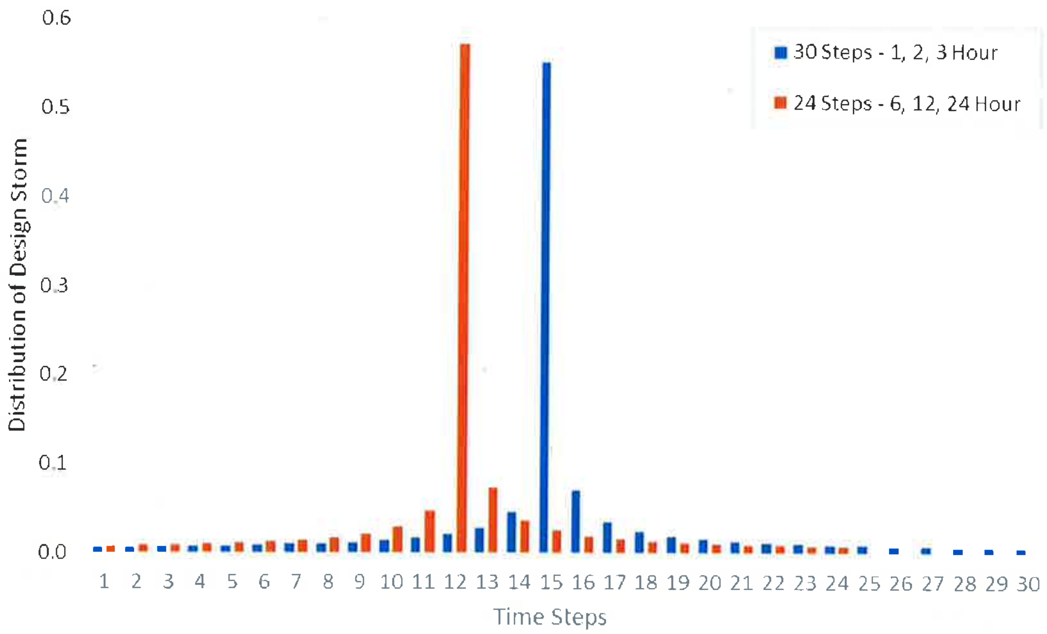

Figure 3: Design Storm Distributions (No Units)

3.2.2.2 Snowmelt

A temperature-index method (Coulson 1991) was applied to estimate snowmelt depths. Temperature data from the *Douglas Lake* climate station (No. 1122541) were used. This station is located at an elevation of 808 masl approximately 23 km east of the watershed.

Statistical analysis was completed on the daily temperature data in April and May. A May design temperature of 16.4 °C was selected, which corresponds to a 2-year return period temperature. The 24-hour duration rainfall depth (77.3 mm) was also applied in the calculation to estimate daily snowmelt. The daily snowmelt estimate from the temperature-index method is 74.1 mm. The hydrological model is described below and this was used to estimate runoff from snowmelt. Snowmelt was applied separately as baseflow in the upper zone of the watershed.

3.2.2.3 Hydrological Model

To estimate design flows in Unnamed Creek a precipitation runoff model was developed using HEC-HMS software. The model is an analytical representation of the watershed. It was built using the GIS add-in to Arc-GIS (HEC-GeoHMS) and the data was obtained from the provincial geodatabase (GeoBC). The model topography was based on a digital elevation model. The watershed was divided into four sub-watersheds, three reaches, and three junctions. Flows are estimated at the upstream boundary of the subject property. A description of the model elements is provided below, with comments on the sensitivity of the model parameters.

- Canopy and Surface Methods:
  - These two methods were applied to represent interception and minor storage of rainfall due to the presence of vegetation and ground surface depressions. The *Simple* options were selected for both methods. The total potential water storage was 30 mm (10 mm for *Canopy* and 20 mm for *Surface*).

- Loss Method:
  - The *Initial and Constant* option was selected for the loss method, which represents soil infiltration capacity in the watershed. A value of 20 mm per hour was selected for the infiltration rate, which is representative of a clay loam or loam soil (Coulson 1991).
- Transform Method:
  - The *Clark Unit Hydrograph* option was selected. This method uses the time of concentration (Tc) and a storage coefficient (R-value). The Tc was estimated based on the travel time calculations for each sub-watershed based on the DEM data (sheet flow, shallow concentrated flow, and channel flow characteristics [USDA 1986]). The estimated total Tc for the watershed is approximately 1.7 hours. The R-value has units of hours and was selected as two-times the Tc.
- Channel Routing Method:
  - Channel routing through the three reaches was completed using the *Musingum-Cunge* method. Data from the DEM determined the channel lengths and slopes. The channel geometry was defined as trapezoidal with a 1 m bottom width and 1:1 bank slopes based on the derived average of the field observations. A Manning's n value of 0.05 was selected for the channels.
- Precipitation Method:
  - The design storms (Section 3.3.2.1) were applied across the 2.7 km^2 watershed area (i.e., the design rainfall depths in Table 3 were distributed over the design storm distributions shown in Figure 3). There were no scaling or reductions considered for a watershed of this size. The model was run for a duration of 48 hours using a time interval of 15 minutes.
- Baseflow Method:
  - A constant baseflow was applied to the upper zone in the watershed to represent snowmelt runoff from two sub-watersheds. The constant baseflow is 0.54 m^3/s. This constant baseflow is the modelled result derived by applying the snowmelt temperature-index method from the above section (3.2.2.2). The hydrological model was analyzed separately to estimate this snowmelt runoff flow rate. The independent analysis of snowmelt was carried out to minimize the potential for over estimating flows that would occur by superimposing the snowmelt water depth on top of the design storm rainfall depth.
- Parameter Sensitivity:
  - Model calibration was not completed in the absence of detailed meteorological, hydrometric, and watershed data within the Unnamed Creek watershed. To check the validity of the numerical model, the key model parameters were checked for their sensitivity on the model results. The parameters were adjusted upwards and downwards, reviewed, and selected within a range that were considered to produce reasonable flow estimates for the watershed. To some extent all of the model parameters were sensitive to adjustment. It is noted that in most scenarios the 12-hour storm duration was determined to be the critical storm event.

3.2.2.4 Hydrological Results

The hydrological model results are listed in Table 4 and the hydrographs are shown in Figure 4. The 1-hour duration storm event was insignificant and was therefore excluded. The largest flow estimate was generated during the 12-hour design storm indicating that this was the critical event for Unnamed Creek at the subject property. The peak flow rate of the 12-hour design storm hydrograph was 4.7 m^3/s. The design storm event runoff volume was approximately 32,000 m^3.

Table 4: Hydrological Model Results

Design Storm Duration	Design Storm Runoff Volume (m^3)	Peak Flow from Hydrograph (m^3/s)
2-Hour	12,600	1.1
3-Hour	18,400	1.9
6-Hour	29,300	4.1
12-Hour (Critical Storm)	**32,000**	**4.7 (Peak Flow Rate)**
24-Hour	21,800	2.7

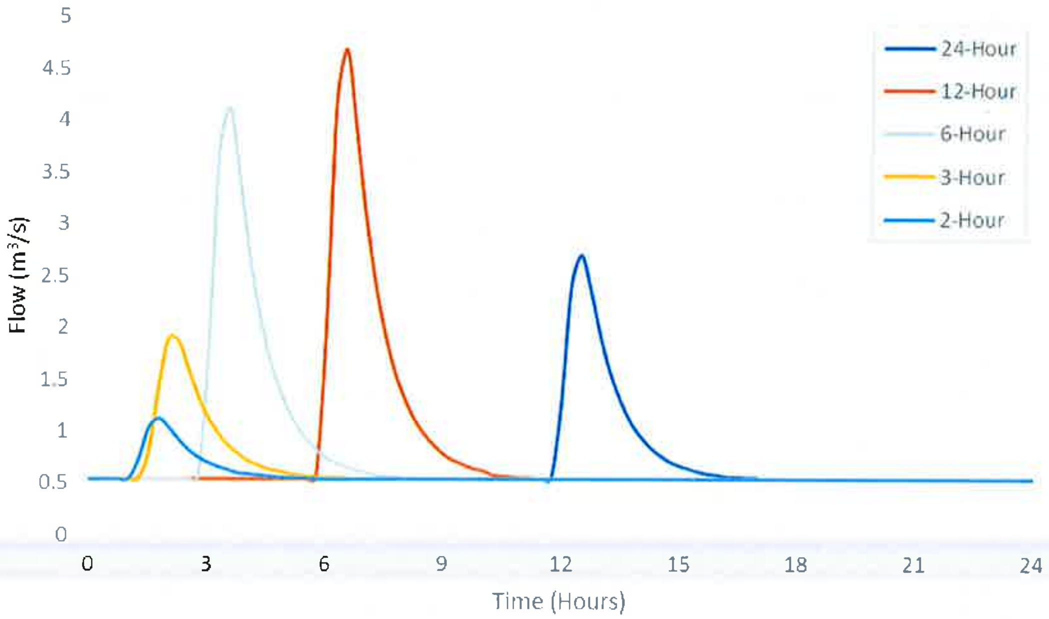

Figure 4: Hydrograph results from hydrological model for five design storms

4.0 MITIGATION OPTIONS FOR FLOOD HAZARD

The flood hazard posed by the presence of Unnamed Creek needs to be mitigated for the safe development of the subject property. The flood mitigation can be one of (or a combination of) the following options which are described further below. All of these flood hazard mitigation concepts would be infrastructure designed for protection of the subject property. As such, each would require periodic inspection and maintenance to ensure they are able to perform during a flood event. The proposed flood mitigation options should be considered for the current 'Phase 3' development and the future 'Phase 4' development.

1) Conveyance of the peak flow rate from Unnamed Creek around or through the subject property (open channel or pipe system conveyance).
2) Storage/detention of the design storm runoff volume, plus consideration for conveyance in the form of an open channel or pipe system with a reduced capacity relative to a conveyance system alone.
3) Designation of flood construction levels for all lots with consideration of the potential for overland flows.

4.1 Conveyance of Peak Flow Rate

The peak flow rate can be conveyed in an open channel or a piped system. Design measures to consider for each of these options is below. In preliminary discussion with Nicola Lakeshore Estates and Watson Engineering, the piped system concept was their preferred flood mitigation option.

Hydraulic analysis was completed to support the evaluation of conceptual flood mitigation options at the subject property. This included review of existing conditions, conceptual sizing of an open channel or pipe system that would be required to safely convey the peak flow rate from the gully of Unnamed Creek to Nicola Lake, and storage of the flood hydrograph volume. The existing conditions include the diversion of runoff from Unnamed Creek around the existing borrow pit and away from the subject property. However, this system is ill-defined and generally consists of roadside ditches which would not have the capacity for the design flood (Figure 2).

Detailed hydraulic models of the channel or piped system concepts were not developed as part of this study. A final grading and flood flow routing plan for the subject property and the adjacent borrow pit will need to be developed at the detailed design stage. Calculations have been provided for a range of hydraulic conditions to illustrate the viability of these concepts but these should not be considered as site-specific detailed designs.

4.1.1 Open Channel Design Measures

A flood hazard mitigation concept involving an open channel was identified. This concept would involve routing to collect flood flows upgradient from the subject property and an open channel floodway to safely convey these flows across the subject property. An engineered open channel needs to consider conveyance capacity, freeboard, and erosion protection for the peak flow rate.

Open channel geometry was analyzed using Manning's formula. An '*n*' value of 0.05 was conservatively assumed. The average slope through the subject property was noted to be approximately 15% (Section 2.3.3.3), however steeper and flatter portions are possible so a range of slopes were considered. A trapezoidal channel shape was assumed, with 1.5H:1V (horizontal to vertical) bank slopes, and a 2 m bottom width. Selected hydraulic results are listed in Table 5 for the peak design flow rate. It is noted that these calculations assume uniform flow conditions.

Table 5: Selected Open Channel Calculation Results (Peak Flow Rate of 4.7 m^3/s)

Parameter	Channel Slope		
	10%	15%	20%
Water Normal Depth (m)	0.52	0.46	0.43
Average Water Velocity (m/s)	3.27	3.77	4.17

Consideration was given to the TNRD floodplain regulations identified in Section 2.4. However, an engineered channel would not have a natural boundary, so the criteria requiring that the flood construction level be a minimum of 1.5 m above the natural boundary of a watercourse was not considered to be applicable at this site. The engineered channel would have an appropriate freeboard and the flood construction would be specified relative to the design flood profile.

4.1.2 Pipe System Design Measures

A flood hazard mitigation concept involving a piped system was also analyzed. This concept would also involve routing to collect flood flows upgradient from the subject property, collection of these flows at an inlet structure, and conveyance in a pipe across the subject property. A pipe system design needs to consider the inlet condition, vertical and horizontal alignment, and any appurtenant structures. In addition, regular inlet inspection and maintenance is required. There is a potential for inlets to become plugged with debris and/or waste material. Secondary conveyance such as emergency conveyance capacity on the roadways shall also be included as a redundant design feature for the subject property if a piped concept is implemented.

A pipe system would require an inlet structure(s) with adequate capacity such that the headwater depth at the inlet would not exceed the top of the pipe (headwater depth, HW / diameter, D ≤ 1). To meet these criteria under inlet control with the peak flow rate, the minimum inlet diameter for a single inlet would need to be approximately 1.7 m. If a double inlet was used (two parallel pipes at same elevation), the minimum diameter of the inlets would need to be approximately 1.3 m.

Once the peak flow rate has entered the inlet, there may be an opportunity to reduce the diameter of the pipe and safely convey the flow. The details of reducing the pipe diameter for conveyance would need to be evaluated at the detailed design stage as this evaluation would require consideration of slope, bends, and material for the pipe system.

4.2 Storage and Conveyance

A flood hazard mitigation concept involving a storage facility was considered. A storage facility would need to retain all or part of the design storm volume. This concept would allow for a reduction in the size or capacity of the open channel or piped conveyance system. The design storm water volume from rainfall and snowmelt over the peak of the hydrograph was approximately 32,000 m^3. If a storage facility is considered then flood routing analysis through the facility is required to check the performance with the design flood hydrograph. A storage facility will require at least one outlet structure that flows around or through the subject property for safe conveyance. The concepts described above for open channel and pipe system are applicable to this concept.

4.3 Flood Construction Levels

The flood construction level of each lot shall be a function of the highest of the following:

- Based on existing topography of the subject property and the lands upslope from the subject property, there is potential for shallow overland flows from ill-defined drainages to affect the property. The design and final grading of the subject property will influence the potential for overland flooding. It is recommended that the minimum flood construction levels for each lot shall be 0.3 m above the final grade surrounding the dwelling or above any structure that may cause flood waters to pond on the lot. An example of this may be a roadway running perpendicular to the slope on the downgradient side of a building lot.
- If an open channel is used to mitigate the potential flood hazard, the flood construction level for the lots adjacent to the channel shall be a minimum of 0.6 m above the design flood profile for the channel.
- If a piped system is used to mitigate the potential flood hazard, the intake shall be located such that it is located adjacent to a roadway or another engineered structure which has been designed to act as a redundant drainage path in the event of blockage of the inlet. Lots adjacent to this drainage path shall have a minimum flood construction level of 0.6 m above these works.

5.0 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

'Phase 3' on the subject property is proposed to be developed into 40 strata lots. 'Phase 4' on the subject property is proposed to be developed into less than 60 strata lots in the future. There are less than 100 total proposed lots on the subject property. The Unnamed Creek watershed drains the land above the subject property and presents a potential flood hazard to the development.

The susceptibility of the subject property to flooding hazards from Nicola Lake was not included in the scope of work for this study. It is noted that Nicola Lake has existing floodplain mapping available from the Province of BC (1989) but that this mapping is now dated. It is understood that a dam safety review for Nicola Lake Dam is being completed by others, but it is not known if updated flood levels are being assessed.

A debris flood/flow assessment was also carried out for Unnamed Creek. The absence of a well-defined alluvial fan along the lake and the presence of deadfall and standing timber in or near the stream channel indicate that debris floods/flows are unlikely on Unnamed Creek and have not occurred over the last 500 years. The probability of occurrence in a given year was assessed as no greater than 0.002 or less than once in 500 years. Therefore, the probability of debris flood/flow events are considered to be low enough at this site such that a flood hazard assessment using a clear flow event is suitable.

The estimated design flood peak flow rate was 4.7 m^3/s which includes consideration for potential future climate change (for a 200-year hydrological return period). In order to mitigate the identified flooding hazard to an acceptable level several mitigation measures were identified.

It is recommended that flood mitigation works for the subject property include at least one of the following three concepts. On lots where multiple flood construction levels overlap, the highest level shall govern.

1) A conveyance system to safely convey the peak design flow rate through the subject property. This system may include:
    a. An engineered channel that can safely convey the peak flow rate of 4.7 m^3/s. The channel requires adequate erosion protection and freeboard (appropriate freeboard shall be determined based on the detailed design of the channel). The minimum flood construction levels for lots adjacent to the channel shall be a minimum of 0.6 m higher than the flood profile generated from the peak flow rate in the engineered channel.
    b. A pipe system that can safely convey the peak flow rate of 4.7 m^3/s under inlet control. The inlet structure(s) shall have adequate capacity such that the headwater depth at the inlet does not exceed the top of the pipe.
        i. If a piped system is selected, the inlet shall be positioned such that a roadway or other engineered infrastructure which has been designed such that can act as a redundant drainage path in the event of a blockage of the inlet. The flood construction level for lots adjacent to this drainage path shall be 0.6 m above the elevation of the adjacent roadway.
        ii. Alternatively, the redundant drainage can be a secondary pipe system located adjacent to the same inlet. The secondary pipe system can be smaller compared to the primary pipe system and should be a minimum diameter of 600 mm. The inlet should be designed such that the invert elevation of the secondary pipe system is higher compared to the invert elevation of the primary pipe system.

    iii. A piped system will require the development and implementation of an inspection and maintenance plan such that any sediment and debris accumulating at the entrance to the system are removed. It is recommended that inspection of the inlet is completed at least once per month and after any significant runoff event in Unnamed Creek.

2) An engineered floodwater storage system combined with a conveyance system. The storage system shall be designed such that it can retain all or part of the design storm volume. An engineered channel or pipe conveyance system as described above would be required to accompany the storage system but the conveyance capacity could be designed with consideration for the reduced peak flow for that would result from the constructed storage.

3) In order to mitigate the potential for minor flooding, the minimum flood construction level for each lot shall be 0.3 m above the final grade surrounding the dwelling or above any downgradient structure that may cause flood waters to pond.

The mitigation options outlined in Section 4 are conceptual and need to be confirmed and refined when the land development design is advanced. It is recommended that prior to completion of the land development design, Golder is provided an opportunity to review the flood mitigation design elements. If one or a combination of the flood mitigation concepts identified above are adequately designed and implemented, it is concluded that the subject property will be safe for the use intended. Appendix B includes the *Flood Hazard and Risk Assurance Statement* from the Guidelines.

6.0 LIMITATIONS

This flood hazard and debris flood/flow hazard assessment is based on the results of the field reconnaissance work, air photo interpretation, hydrological analysis, and review of existing literature. Only flooding hazards from Unnamed Creek have been considered in this report. Flooding from Nicola Lake was not part of the scope of work. It is noted that other natural and geotechnical hazards are also not included.

The study is subjective in nature and relies on the professional judgement and experience of the writers and consideration of the existing and potential flood hazards. In addition, the study is probabilistic in nature. As a result, the assessed hazard limits and probabilities should be considered approximate. Only hazard occurrence probabilities at the subject property were estimated. Other components of risk such as vulnerability and exposure are not included. As such, the results are incomplete from a risk perspective. The estimated probabilities for the flood hazards are only expected average times between events at a particular location and there is no information about when the event could occur.

The results are based on information made available and site conditions observed at the time of the study. If probability estimates or limits change with future, more detailed hazard investigations or changed land use conditions, the hazard limits provided in this report should be updated to reflect the new information.

7.0 CLOSURE

A site-specific flood hazard and debris flood/flow hazard assessment has been completed for the proposed subdivision of Lots 75, 76, and 77 within DL 530; KYD, Plan KAP 79399, on Monck Park Road, near Merritt, BC (the subject property). We trust this flood hazard assessment meets your needs. Please contact the undersigned directly should have any questions regarding this report.

Golder Associates Ltd.

G. S. CAHILL
30248

12JULY2018

CT Coles

Geoffrey Cahill, PEng
Water Resources Engineer

Chris Coles, MASc, PEng
Associate, Senior Water Resources Engineer

R. J. ATKINS

12 July 2018

Rowland Atkins, MSc, PGeo
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GC/CC/RA/syd

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8. Where the *Approving Authority* has **not** adopted a level of *flood risk* or *flood hazard* tolerance I have:
   - [✓ 8.1] described the method of *flood hazard* analysis or *flood risk analysis* used
   - [✓ 8.2] referred to an appropriate and identified provincial or national guideline for level of *flood hazard* or *flood risk*
   - [✓ 8.3] compared this guideline with the findings of my investigation
   - [✓ 8.4] made a finding on the level of *flood hazard* of *flood risk* tolerance on the Property based on the comparison
   - [✓ 8.5] made recommendations to reduce *flood risks*

[✓ 9.] Reported on the requirements for future inspections of the Property and recommended who should conduct those inspections.

Based on my comparison between

Check one
- ☐ the findings from the investigation and the adopted level of *flood hazard* or *flood risk* tolerance (item 7.2 above)
- ☒ the appropriate and identified provincial or national guideline for level of *flood hazard* or *flood risk* tolerance (item 8.4 above)

I hereby give my assurance that, based on the conditions contained in the attached flood assessment report,

Check one
- ☒ for subdivision approval, as required by the *Land Title Act* (Section 86), "that the land may be used safely for the use intended".

  Check one
  - ☒ with one or more recommended registered *covenants*.
  - ☐ without any registered *covenant*.
- ☐ for a development permit, as required by the *Local Government Act* (Sections 919.1 and 920), my report will "assist the local government in determining what conditions or requirements under [Section 920] subsection (7.1) it will impose in the permit".
- ☐ for a building permit, as required by the Community Charter (Section 56), "the land may be used safely for the use intended".

  Check one
  - ☐ with one or more recommended registered *covenants*.
  - ☐ without any registered *covenant*.
- ☐ for flood plain bylaw variance, as required by the *Flood Hazard Area Land Use Management Guidelines* associated with the *Local Government Act* (Section 910), "the development may occur safely".
- ☐ for flood plain bylaw exemption, as required by the *Local Government Act* (Section 910), "the land may be used safely for the use intended".

GEOFFREY CAHILL
Name (print)

3 JULY - 2018
Date

Signature

300-590 MCKAY AVE.
Address
KELOWNA, BC, V1Y 5A8

(250) 860-8424
Telephone

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
G. S. CAHILL
38248

(Affix Professional seal here)

If the *Qualified Professional* is a member of a firm, complete the following.

I am a member of the firm GOLDER ASSOCIATES LTD.
(Print name of firm)
and I sign this letter on behalf of the firm.

APPENDIX J: *FLOOD HAZARD AND RISK* ASSURANCE STATEMENT

Note: This Statement is to be read and completed in conjunction with the "*APEGBC Professional Practice Guidelines - Legislated Flood Assessments in a Changing Climate*, March 2012 ("*APEGBC* Guidelines") and is to be provided for *flood assessments* for the purposes of the *Land Title Act*, Community Charter or the *Local Government Act*. Italicized words are defined in the *APEGBC* Guidelines.

To: The *Approving Authority*

Date: 3 - JULY - 2018

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
THOMPSON - NICOLA DISTRICT #127-447 COLUMBIA STREET
KAMLOOPS, BC, V2C 2T3
Jurisdiction and address

With reference to (check one):

☒ Land Title Act (Section 86) – Subdivision Approval
☐ Local Government Act (Sections 919.1 and 920) – Development Permit
☐ Community Charter (Section 56) – Building Permit
☐ Local Government Act (Section 910) – Flood Plain Bylaw Variance
☐ Local Government Act (Section 910) – Flood Plain Bylaw Exemption

For the Property:
LOTS 75,76,77, DL 530, KDYD, PLAN KAP79399 AND PORTIONS OF LOT 4 AND REM. DL 530
Legal description and civic address of the Property

The undersigned hereby gives assurance that he/she is a *Qualified Professional* and is a *Professional Engineer* or *Professional Geoscientist*.

I have signed, sealed and dated, and thereby certified, the attached flood assessment report on the Property in accordance with the APEGBC Guidelines. That report must be read in conjunction with this Statement. In preparing that report I have:

Check to the left of applicable items

✓ 1. Collected and reviewed appropriate background information
✓ 2. Reviewed the proposed *residential development* on the Property
✓ 3. Conducted field work on and, if required, beyond the Property
✓ 4. Reported on the results of the field work on and, if required, beyond the Property
✓ 5. Considered any changed conditions on and, if required, beyond the Property
6. For a *flood hazard* analysis or *flood risk* analysis I have:
   ✓ 6.1 reviewed and characterized, if appropriate, floods that may affect the Property
   ✓ 6.2 estimated the *flood hazard* or *flood risk* on the property
   ✓ 6.3 included (if appropriate) the effects of climate change and land use change
   ✓ 6.4 identified existing and anticipated future *elements at risk* on and, if required, beyond the Property
   ✓ 6.5 estimated the potential *consequences* to those *elements at risk*
7. Where the *Approving Authority* has adopted a specific level of *flood hazard* or *flood risk* tolerance or return period that is different from the standard 200-year return period design criteria⁽¹⁾, I have
   ___7.1 compared the level of *flood hazard* or *flood risk* tolerance adopted by the *Approving Authority* with the findings of my investigation
   ___7.2 made a finding on the level of *flood hazard* or *flood risk* tolerance on the Property based on the comparison
   ___7.3 made recommendations to reduce the *flood hazard* or *flood risk* on the Property

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(1) *Flood Hazard Area Land Use Management Guidelines* published by the BC Ministry of Forests, Lands , and Natural Resource Operations and the 2009 publication *Subdivision Preliminary Layout Review – Natural Hazard Risk* published by the Ministry of Transportation and Public Infrastructure. It should be noted that the 200-year return period is a standard used typically for rivers and purely fluvial processes. For small creeks subject to debris floods and debris flows return periods are commonly applied that exceed 200 years. For life-threatening events including debris flows, the Ministry of Transportation and Public Infrastructure stipulates in their 2009 publication *Subdivision Preliminary Layout Review – Natural Hazard Risk* that a 10,000-year return period needs to be considered.

APPENDIX B

Flood Hazard and Risk Assurance Statement

that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but 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 available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions

APPENDIX A

Important Information and Limitations of this Report

8.0 REFERENCES

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